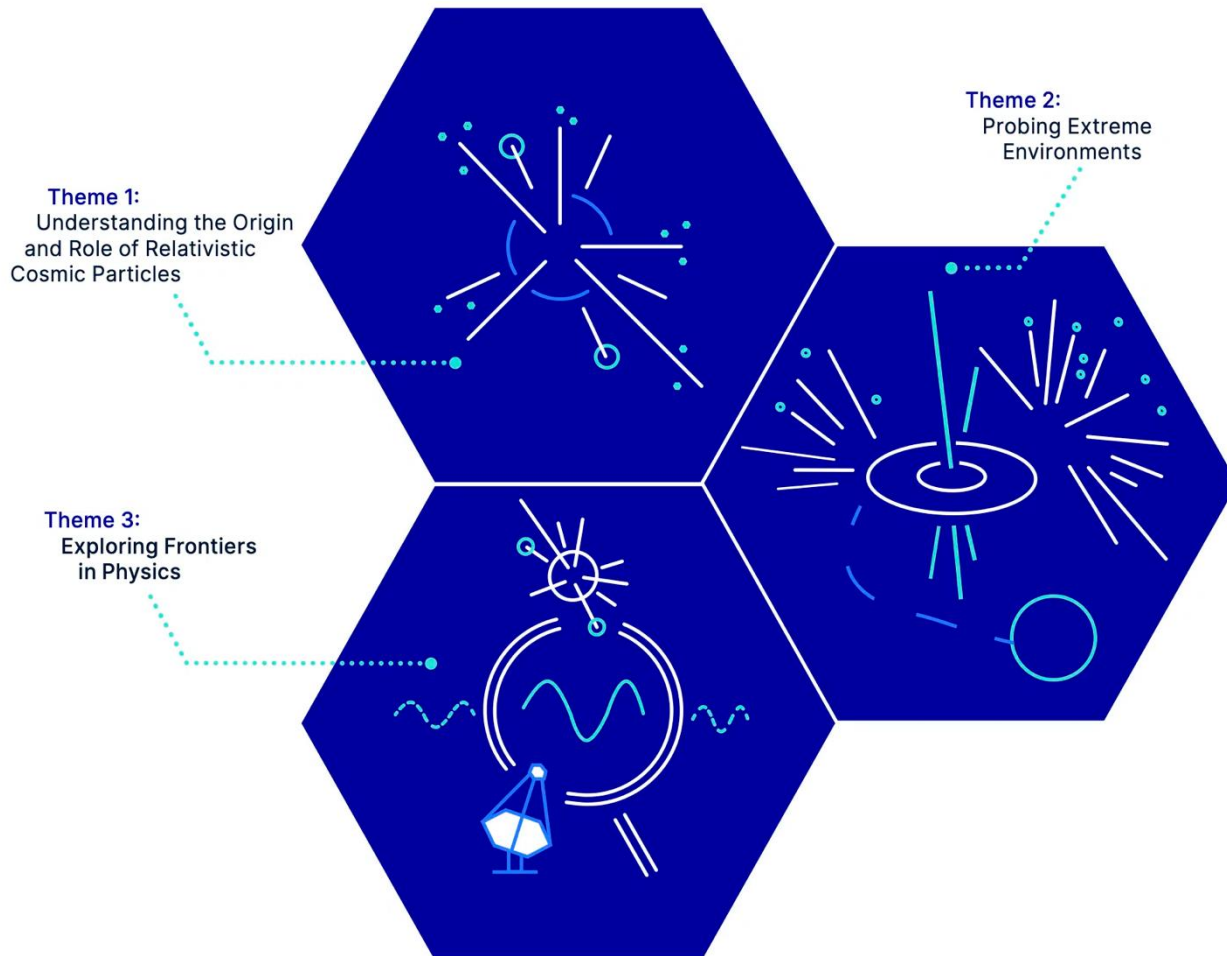# Cherenkov Telescope Array Observatory

May 6, 2025

Gareth Hughes (On-site ICT Coordinator), Stefan Schlenstedt (Computing Coordinator)

gareth.hughes@cta-observatory.org, stefan.schlenstedt@cta-observatory.org

Scientific Potential

Science Themes:

Theme 1:
Understanding the Origin and Role of Relativistic Cosmic Particles

Theme 2:
Probing Extreme Environments

Theme 3:
Exploring Frontiers in Physics

- Expanding the number of known gamma-ray objects by up to 1,000

  - In-depth understanding of known objects

  - Detection of new classes of gamma-ray emitters

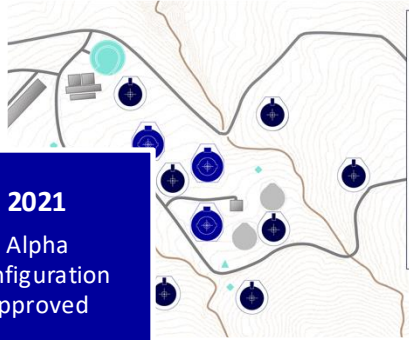 - Great potential for fundamentally new discoveries

- Addressing a wide range of questions in astrophysics and fundamental physics

https://arxiv.org/abs/1709.07997

How we got here

The path to building the CTAO…

2019
CTAO hosts first science symposium

2021
Alpha Configuration approved

2023
CTAO ranked highest priority by ASTRONET

2023
Governing bodies invest ~30M Euro

2024
CTAO hosts second science symposium

2024
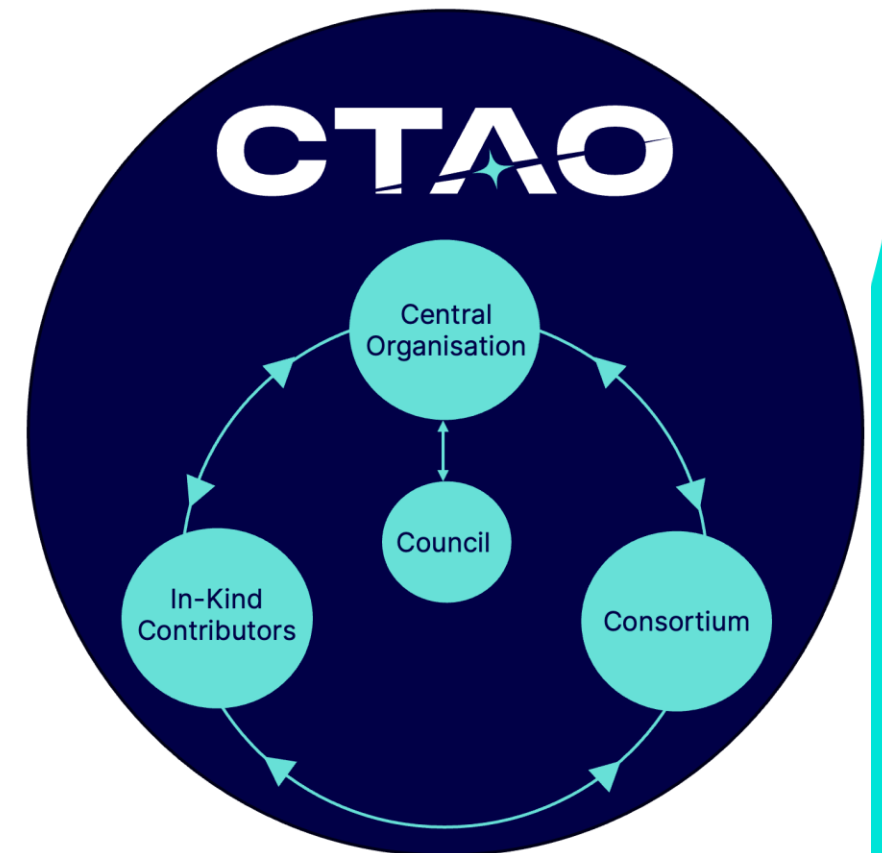The Science Data Management Centre is opened
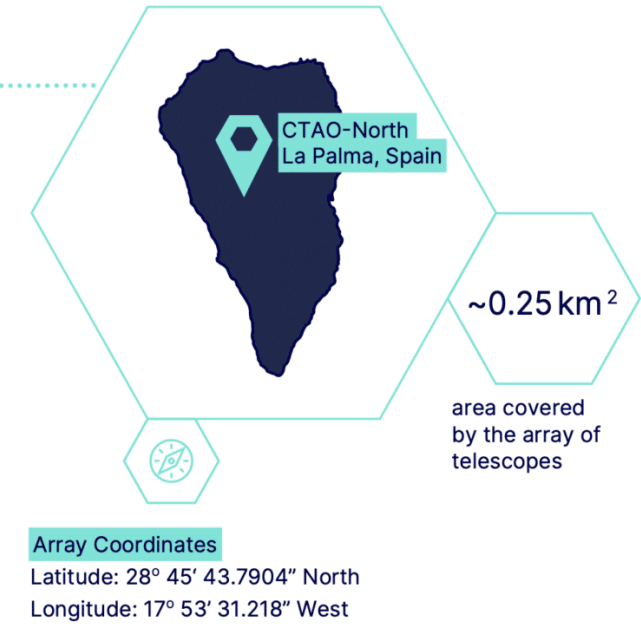
2025
The CTAO ERIC is established

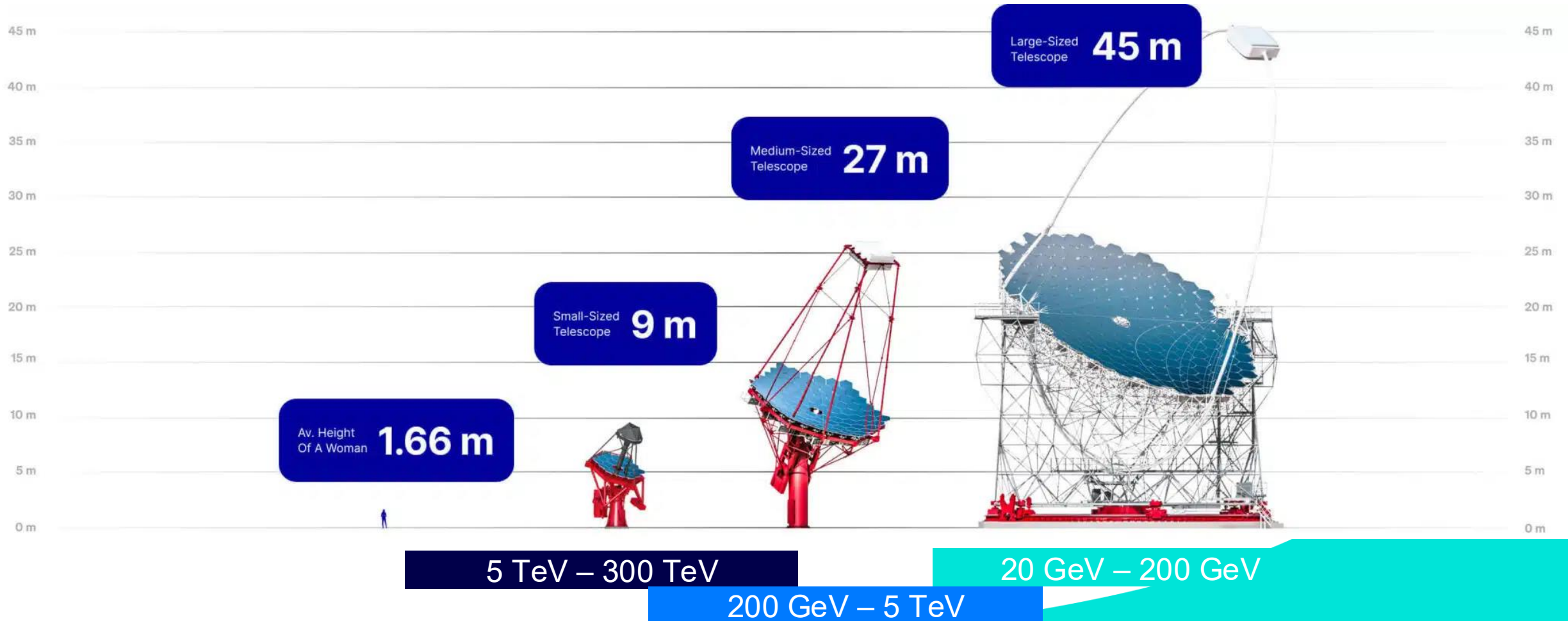**2025**
The CTAO ERIC Council is formed

CTAO Partnerships

- Consortium consists of >1500 scientists and engineers who devised the CTAO concept in the past decade (focusing now more on science exploitation of the Observatory)

- IKCs providing goods and services to the CTAO Central Organisation (e.g. hardware, software, or services)

The Array Sites

Array Coordinates
Latitude: 24° 41' 0.34" South
Longitude: 70° 18' 58.84" West

CTAO-South
Paranal, Chile

~3 km²

area covered by the array of telescopes

CTAO-North
La Palma, Spain

~0.25 km²

area covered by the array of telescopes

Array Coordinates
Latitude: 28° 45' 43.7904" North
Longitude: 17° 53' 31.218" West

The Telescopes

Large-Sized Telescope **45 m**

Medium-Sized Telescope **27 m**

Small-Sized Telescope **9 m**

Av. Height Of A Woman **1.66 m**

5 TeV – 300 TeV

200 GeV – 5 TeV

20 GeV – 200 GeV

CTAO

CTAO-N

Alpha Configuration

North
Observatorio del Roque de los Muchachos
Longitude: 17º 53' 31.218" West
Latitude: 28º 45' 43.7904" North

Spain
La Palma

LEGEND

Large-Sized Telescope (LST)

Medium-Sized Telescope (MST)

CTAO Operations Building & Other Calibration Devices

Weather Station

Stellar Photometer

Raman LIDAR

Road

Gradient

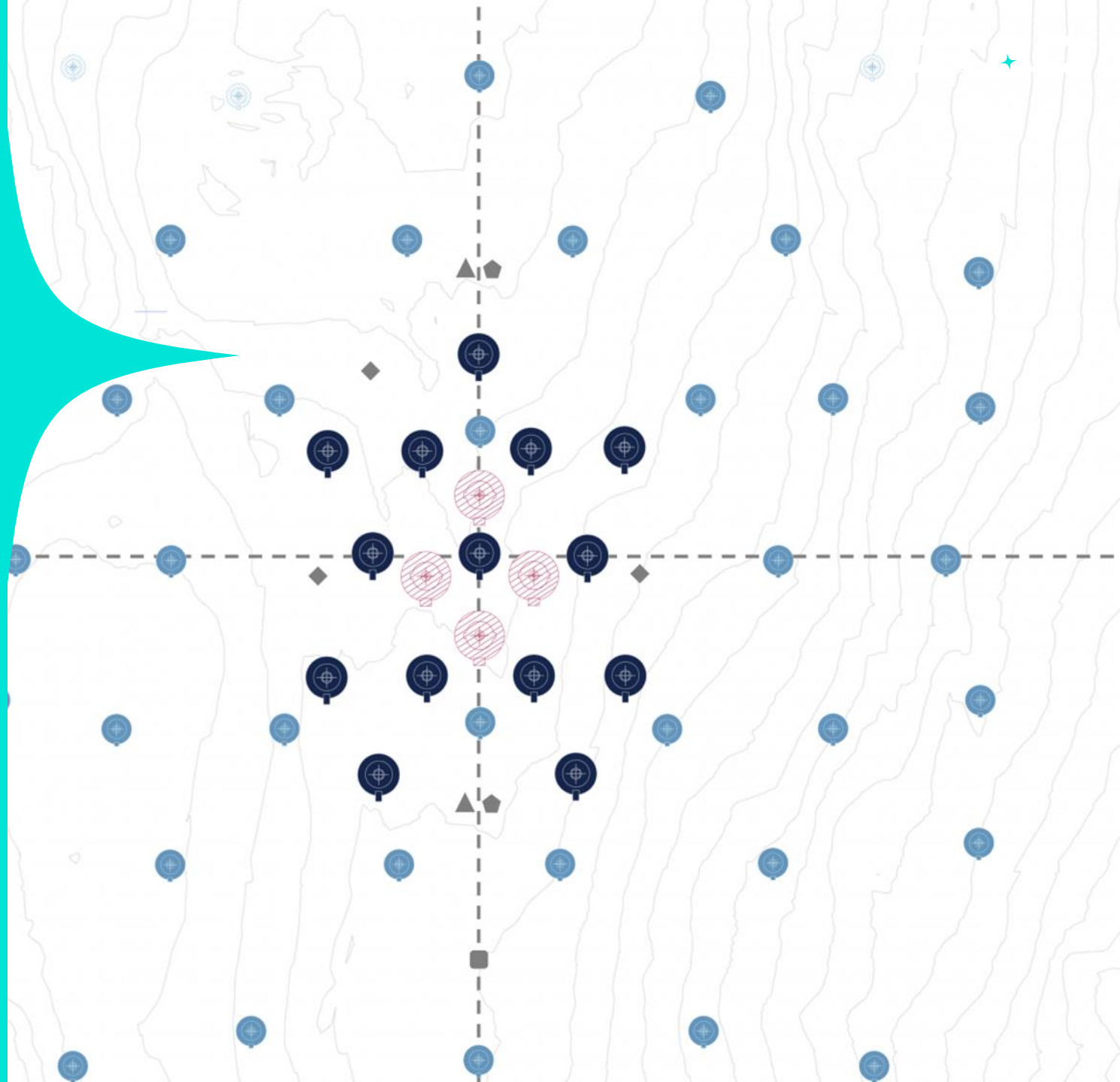MAGIC Telescopes

External Facilities
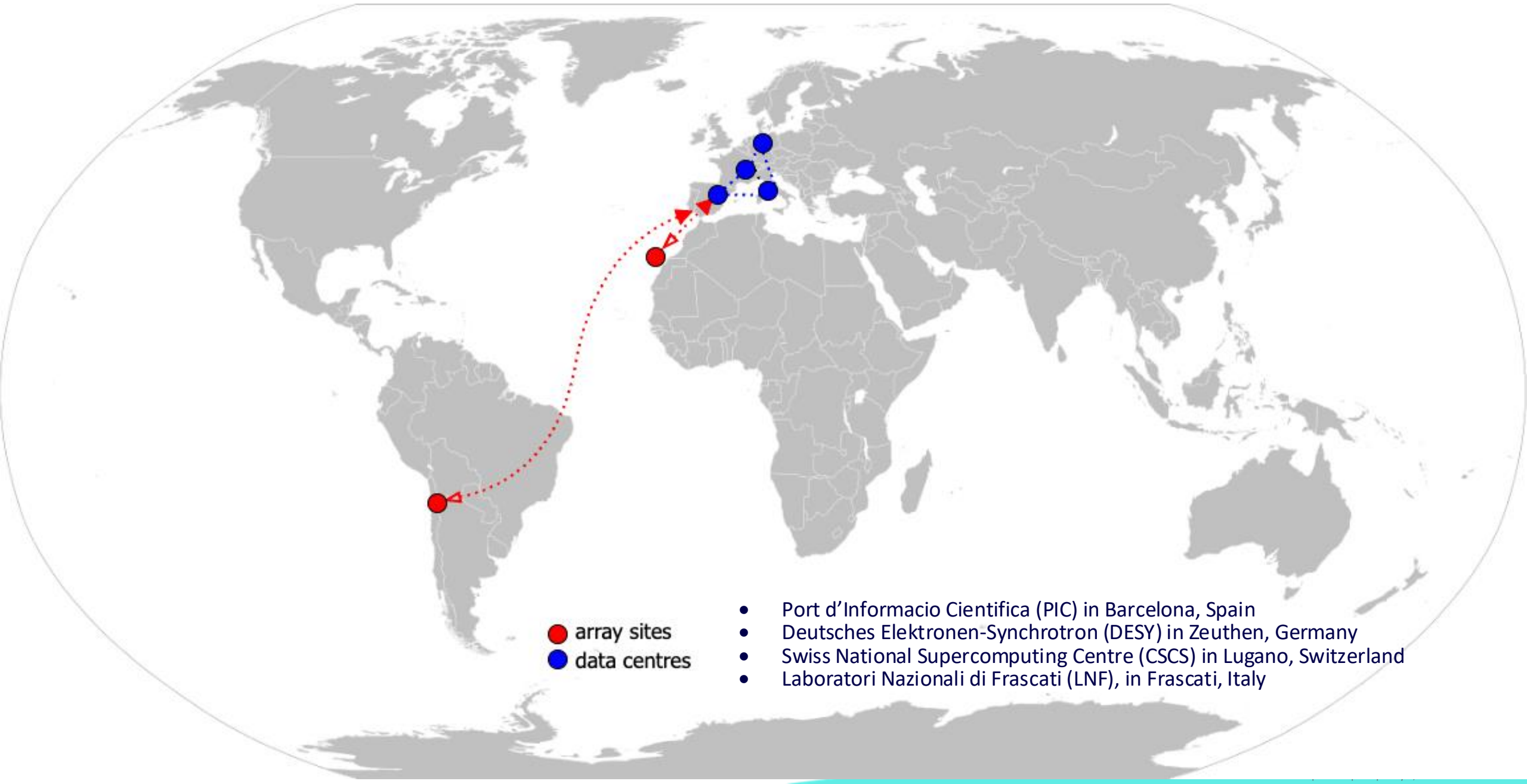
4 LSTs + 9 MSTs
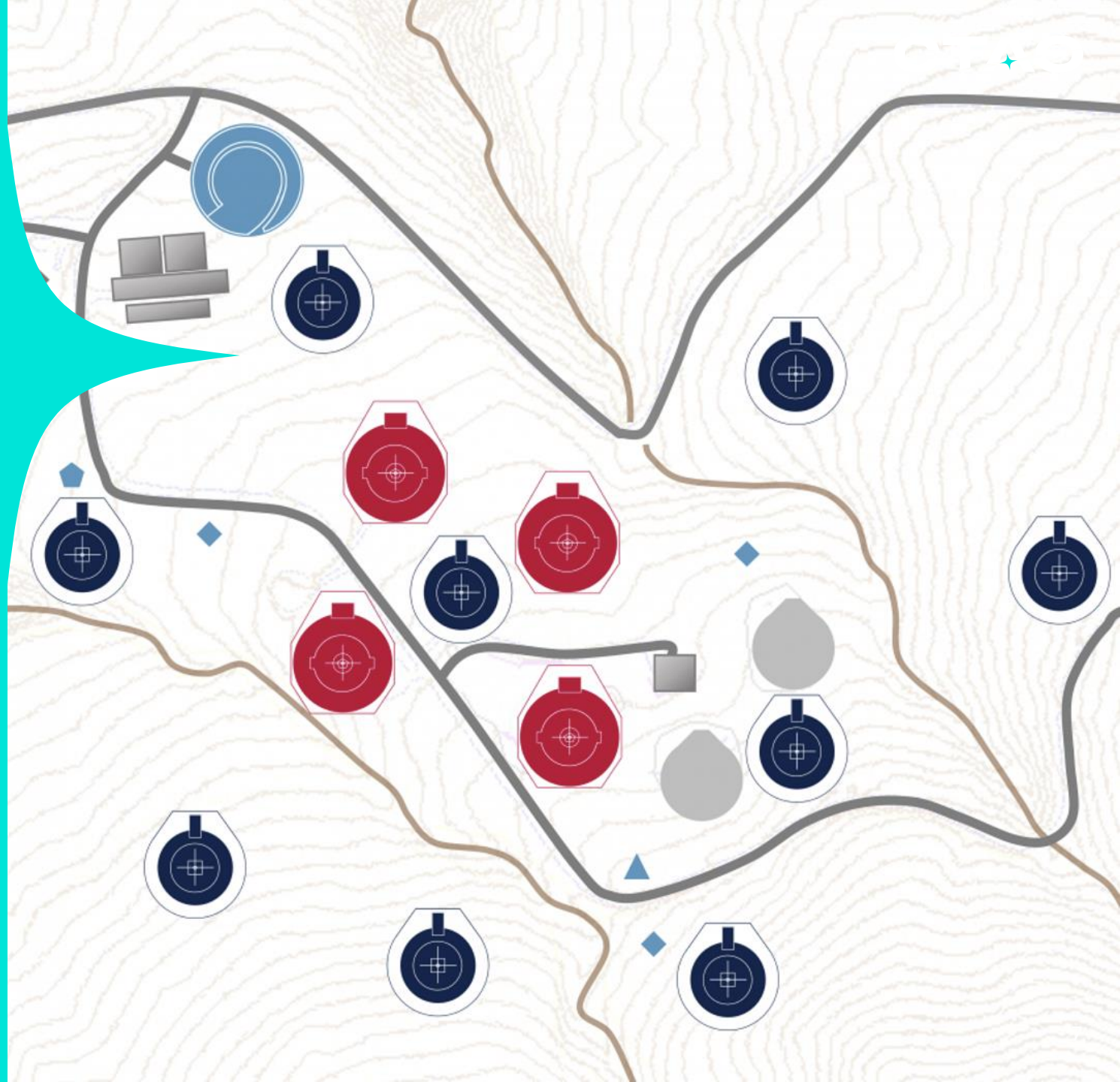
CTAO-S

Alpha Configuration

South
Paranal Observatory
Latitude: 24º 41′ 0.34″ South
Longitude: 70º 18′ 58.84″ West

14 MSTs + 37 SSTs
(+ 2 LSTs)

Chile
Paranal

LEGEND

Medium-Sized Telescope (MST)	Weather Station
Small-Sized Telescope (SST)	Stellar Photometer
Large-Sized Telescope (LST) Foundation	Raman LIDAR
SST Foundation	Other Calibration Devices

- Port d'Informacio Cientifica (PIC) in Barcelona, Spain
- Deutsches Elektronen-Synchrotron (DESY) in Zeuthen, Germany
- Swiss National Supercomputing Centre (CSCS) in Lugano, Switzerland
- Laboratori Nazionali di Frascati (LNF), in Frascati, Italy

array sites
data centres

Data and Computing

The CTAO is a data-driven project.

- Generates hundreds of petabytes (PB) of data in a year (~6 PB after compression)
- Computing team + IKC teams develop hardware and software products to deal with the data flow (from proposal handling to data dissemination)
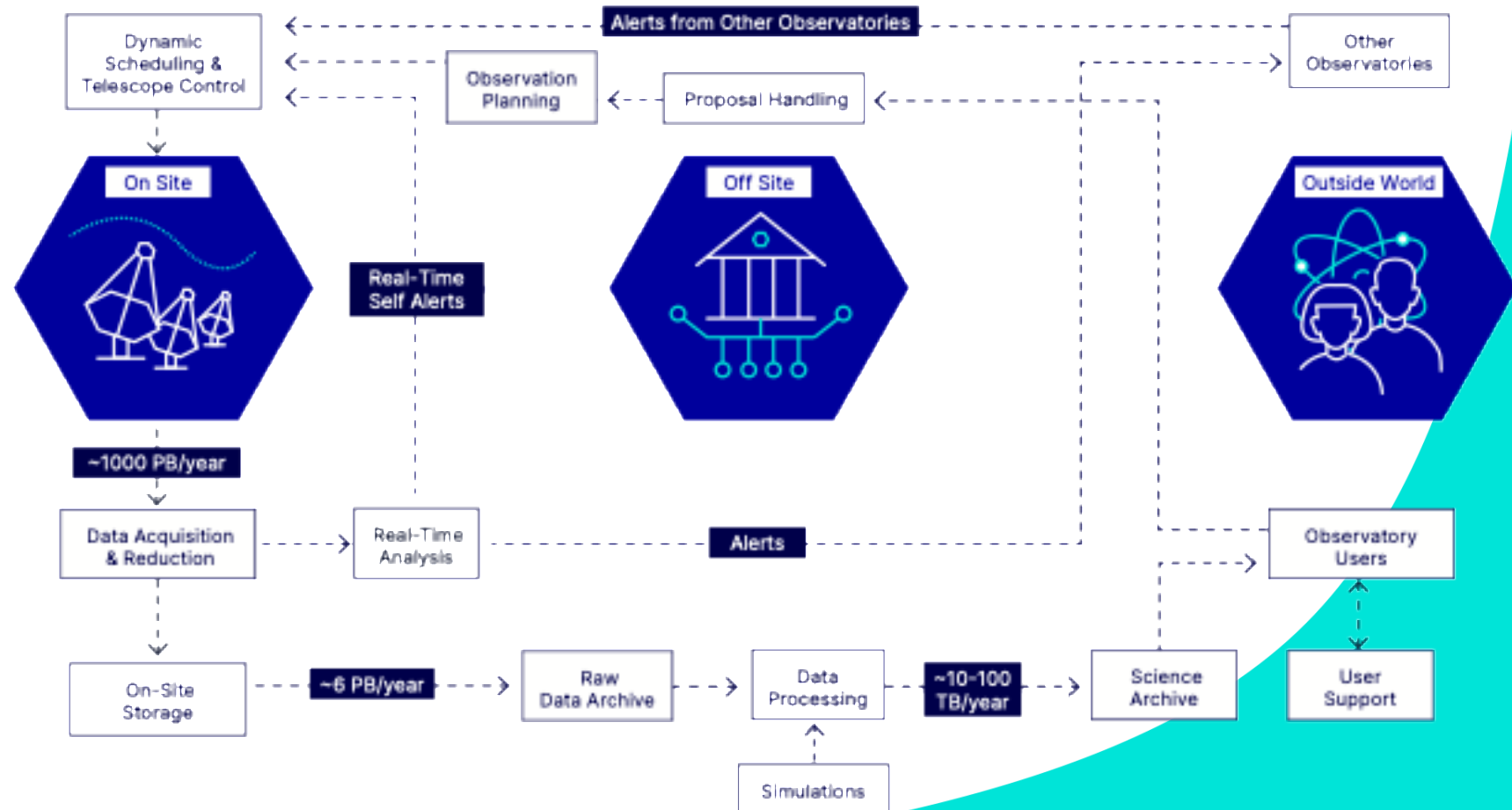
Data and Computir

Deliver the **central software** and **computing infrastructure** required to operate the CTAO

- Involving In-kind contributors (IKCs) and industrial partners
- Deliver products versions with incremental capabilities to support the Observatory deployment
- Set up agreements Central Organization – contributing partners (MoUs, LoIs, SLAs, etc.)
- Provide standards, guidelines, and procedures that impact other software products within the CTAO, such as software elements of telescopes and other array elements.
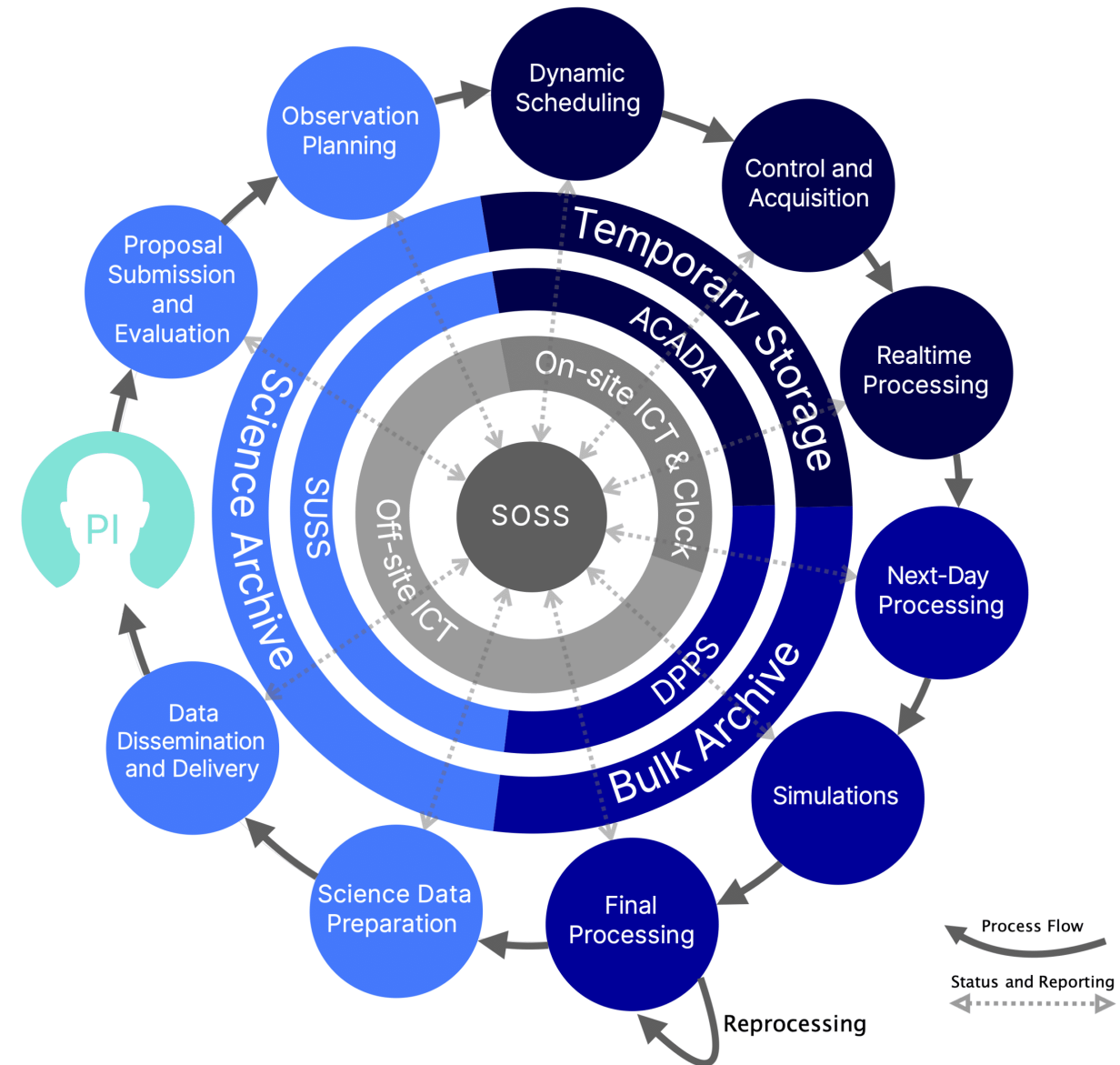
CTAO
Computing View

- Telescopes and other array elements on Chile and La Palma site

- Operate array elements

- Collect and process data in two on-site data centres (DCs)

- Data transfer → Europe → off-site DCs → data processing and preservation

- Data processed, preserved in science archive in one(two) off-site DCs

- Monitoring and oversight in Science Data Management Centre

- Science users get access through a portal for observation proposals,   and high-level data and software and status messages…

South site
access road

South site (today)

Start building roads and foundations in 2025

Start deploying telescopes in 2026
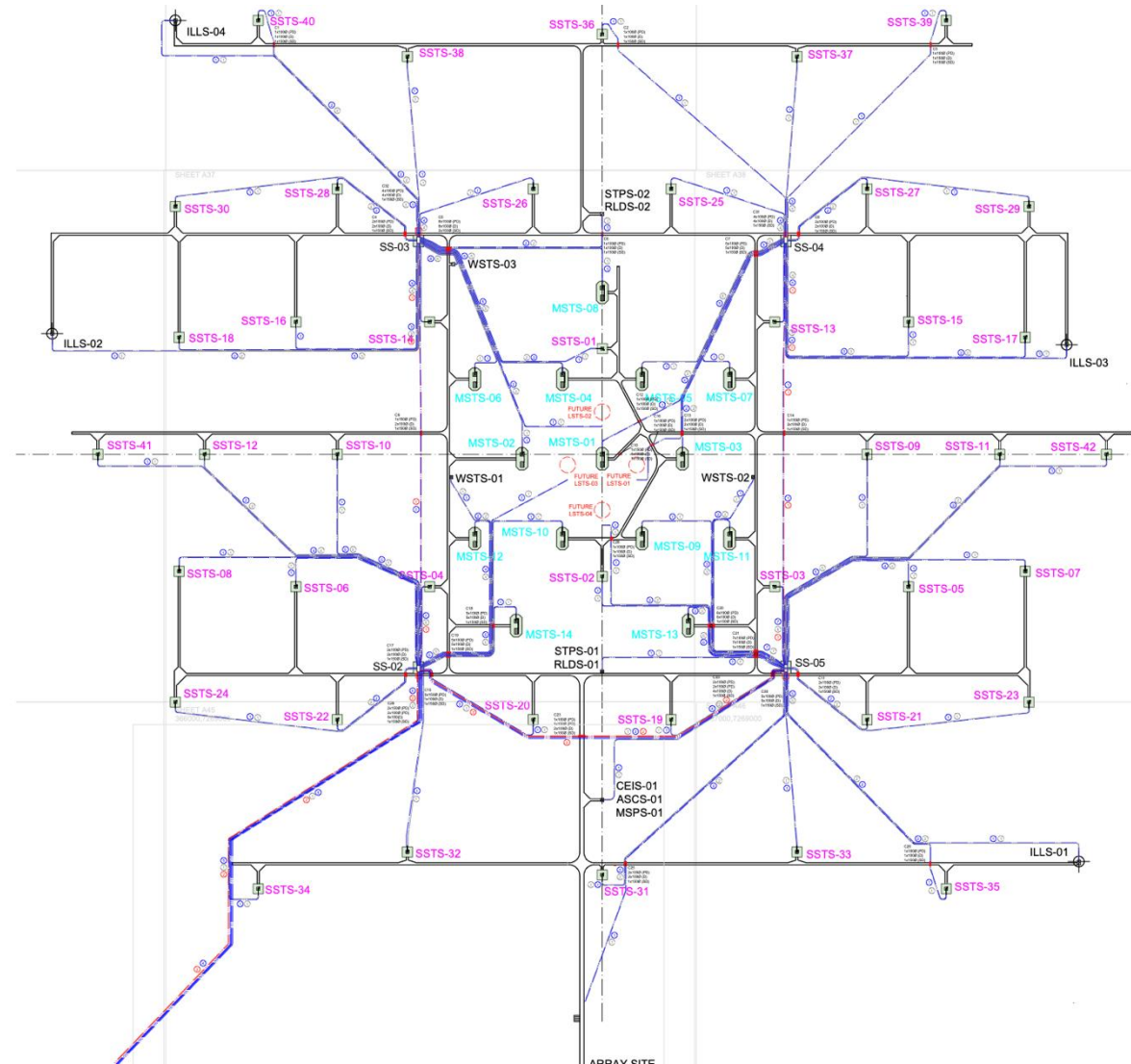
Data Distribution Network South

Multiple Star-like network

Support Site

   Data Centre located in the Operation Building

Array Site

    Array Elements

    Sub-stations / Splice Points

CTAO South Site
Start Building in the Northern Half

- Infrastructure
- Power
- Computing

- Telescopes
- Calibration devices

Computing Model

- Defines the data and processing workflows from
  - the data acquisition sites at CTAO-North and CTAO-South to
  - the different CTAO off-site Data Centres
- It specifies
  - number of versions of the data products per data type
  - number of replicas for each
  - storage Quality of Service (performance, access latency, reliability…)
- It uses
  - simulation and measurements of telescopes
  - data models and formats
  - data volume reduction of site

Data Rates

- Maximum Rates
  - LST: 12 Gbps
  - MST: 6 Gbps
  - SST : 2 Gbps

- Expected Rates
  - LST: 5.7 Gbps
  - MST: 1.6 Gbps
  - SST: 0.6 Gbps

- Alpha Configuration (South): **2** LSTs **14** MSTs **37** SSTs -> **53 Gbps**

- **Data Volume Reduction**
  Online removal of camera pixels that do not take part in events
  Without losing performance
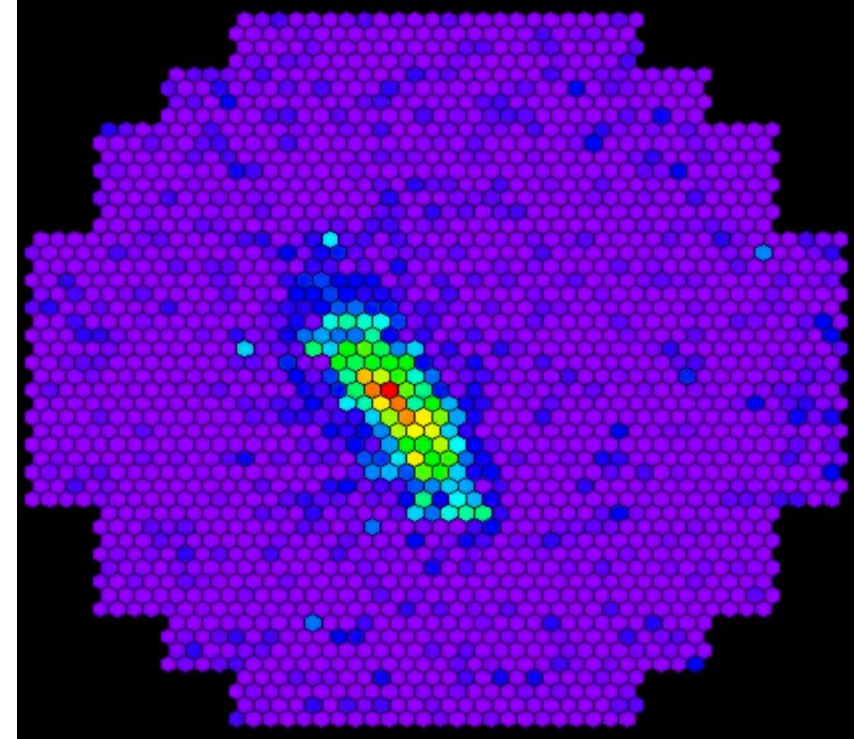
Assumptions

⚙️ Alpha Configuration: 14 MSTs + 37 SSTs + 2 LSTs

➕ Addition of 25 TB /year /Tel data for monitoring and service data

📍 Total Observation Hours 2000 North and **2100 South** per year
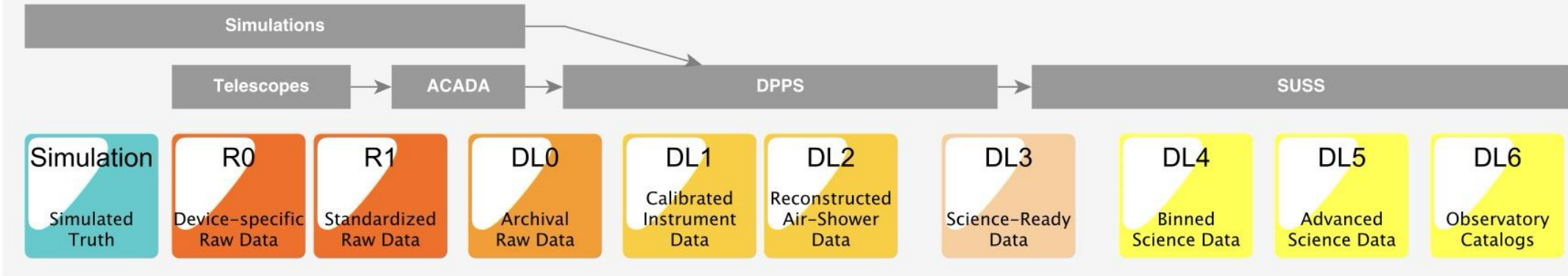
⏱️ Max 12 hours of data acquisition per day

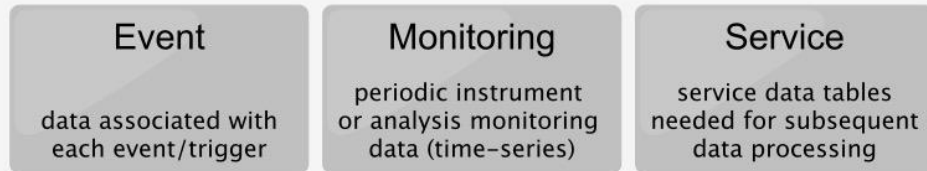🎛️ 2 Gbps link operating for 24 hours per day at 75% efficiency

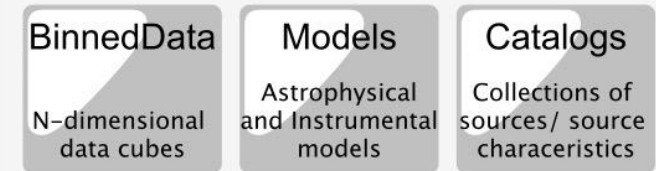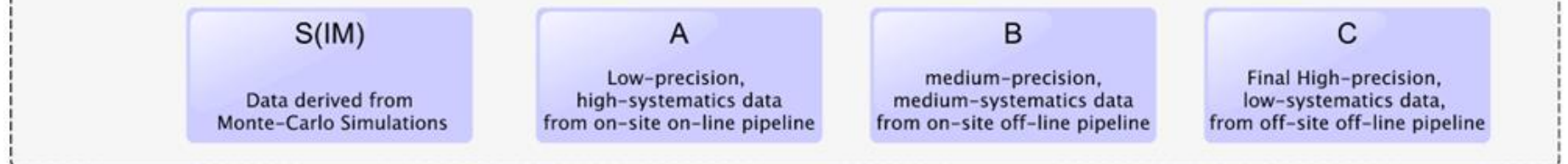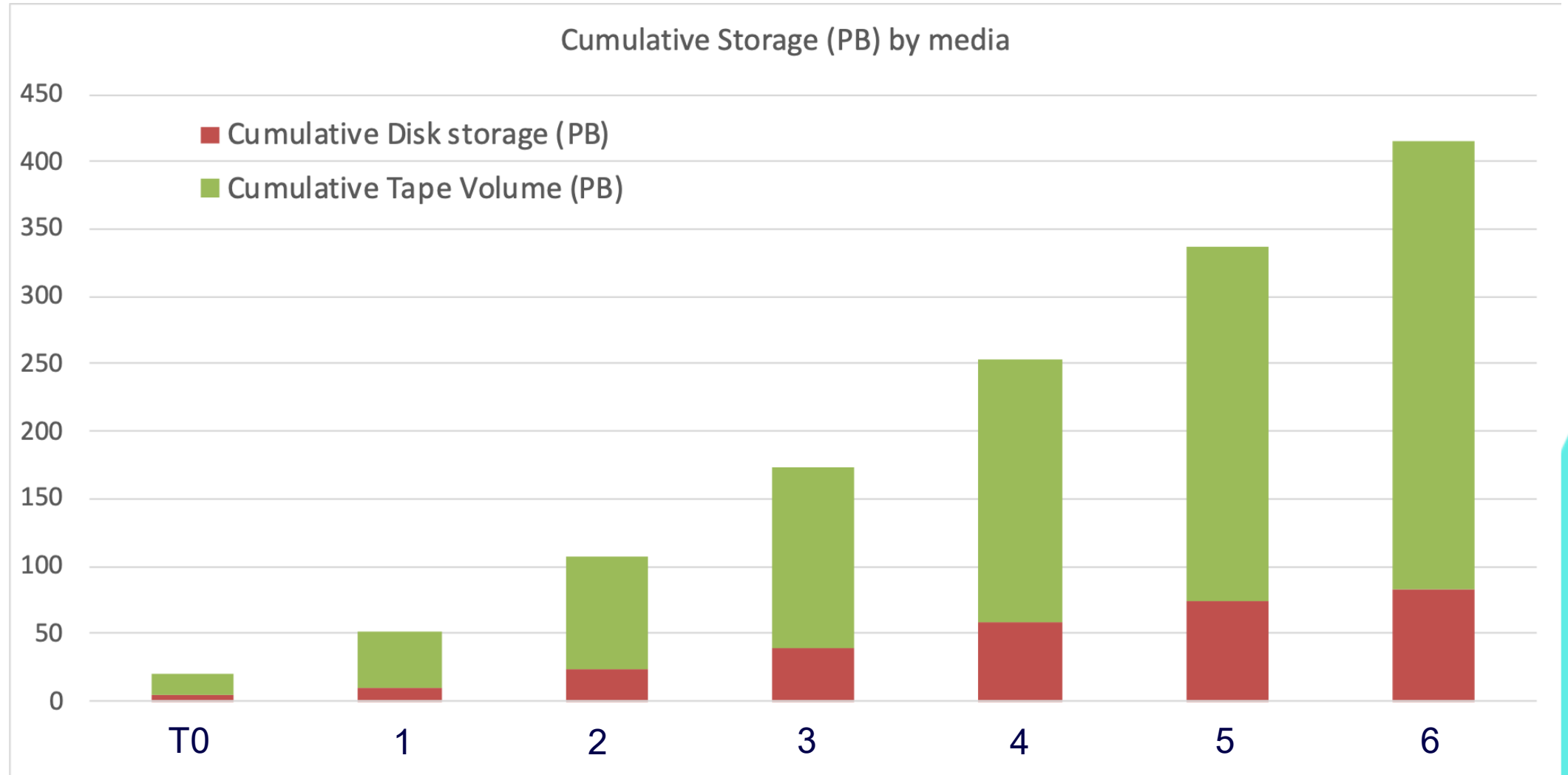➜ Integrated 53 Gbps on South site ➜ 6 PB/yr to Europe

Data Levels

Storage Model

- Raw Data will be storage twice before removal on-site
- Data will be processed during the night, the next day and to final science data products
- Large volumes of simulations are required to provide instrument response to scientists (45 PB)
- We expect to reprocess the data once per year
- Each data level will have its own retention policy

Storage
In Europe

Cumulative Storage (PB) by media

- ■ Cumulative Disk storage (PB)
- ■ Cumulative Tape Volume (PB)

Network Topology

- CTAO-S Connectivity: 12km fibre from on-site data centre
  - → Connection to ESO Paranal
  - → use ESO Network connectivity using REUNA to Santiago
  - → continental (RedCLARA for Latin America) and intercontinental Network Service Provider (BELLA) for Chile

- Pan-European Network Service Provider: GEANT (≥ 10 Gbps bandwidth)

- CTAO coordination, control and monitoring at a CTAO site: the Science Data Management Centre (Zeuthen, Germany)

- The four data centres provide high-performance LAN and high-bandwidth connectivity to their NREN:
  - RedIRIS for Spain, DFN for Germany, SWITCH for Switzerland and GARR for Italy
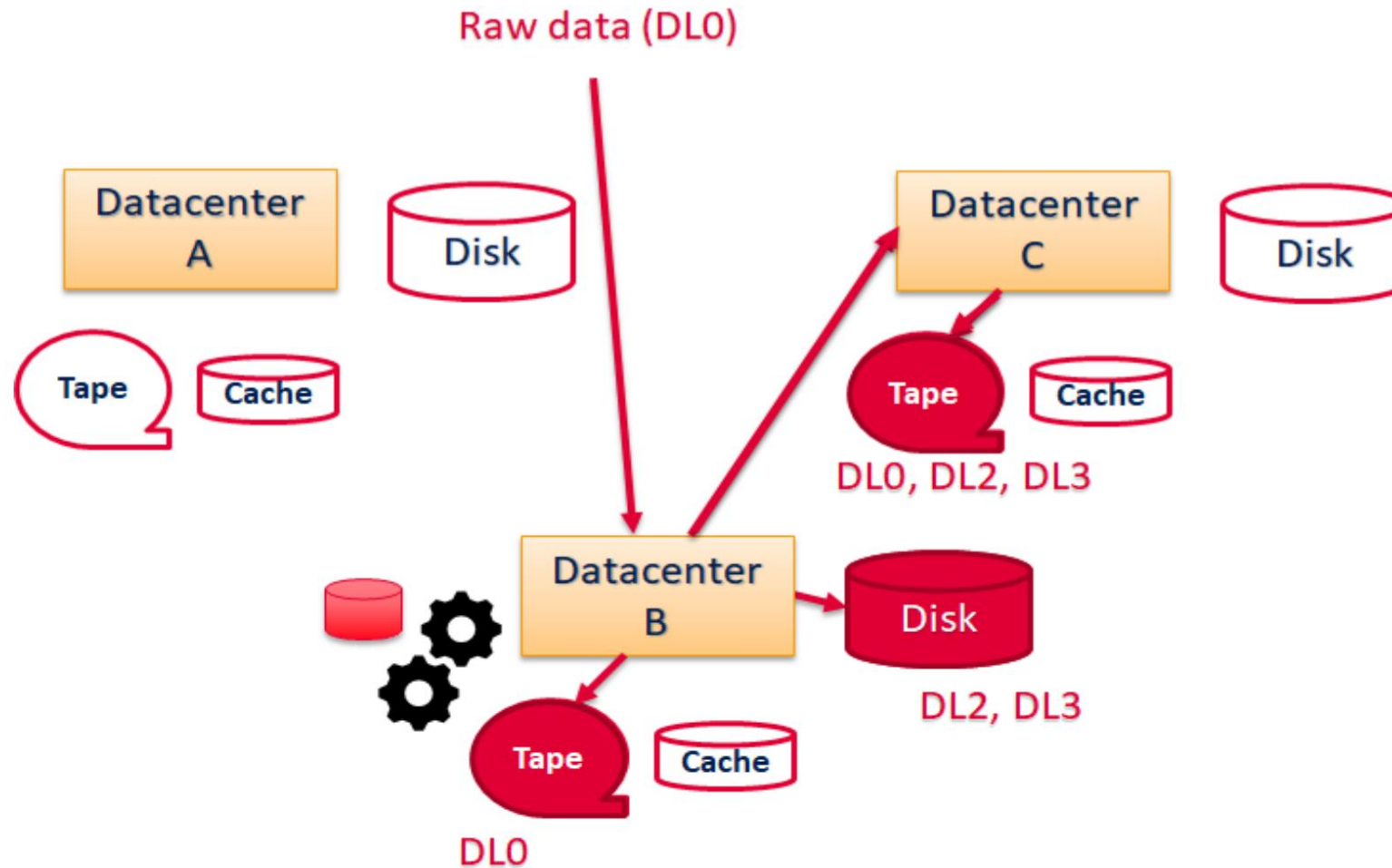
Data Links to Europe
One Option

Data Flow for Raw Data Processing
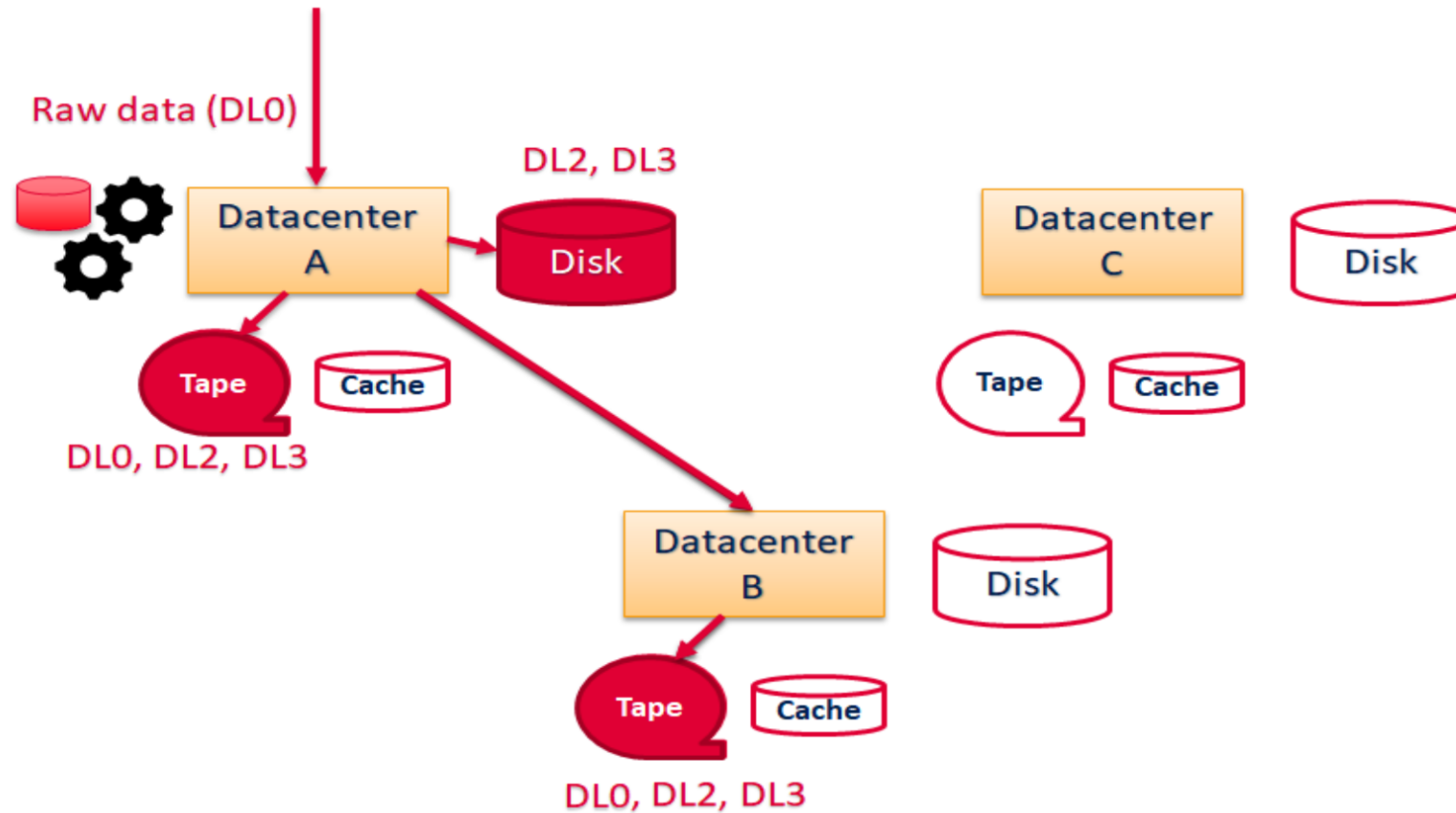
Off-site ICT
Data Flow for Raw Data Processing

Status and Next Steps

- Construction in South will begin next year (2026)

- Initial ~7 early Telescopes

- Build on-site data centre and site network within the next year

- Small number of telescopes can produce large amounts of data

- Replication polcies adds to this

- Expect to transfer ~6 PB/year/site

- IKC agreements with off-site data centres
  - schedule aligned with CTAO integrated project schedule

- Data link agreements (including agreement with GEANT)
  - CTAO-S: ESO, REUNA and possibly other NRENs

- Begin to take data ...