

Digitising the Universe with the Large Synoptic Survey Telescope

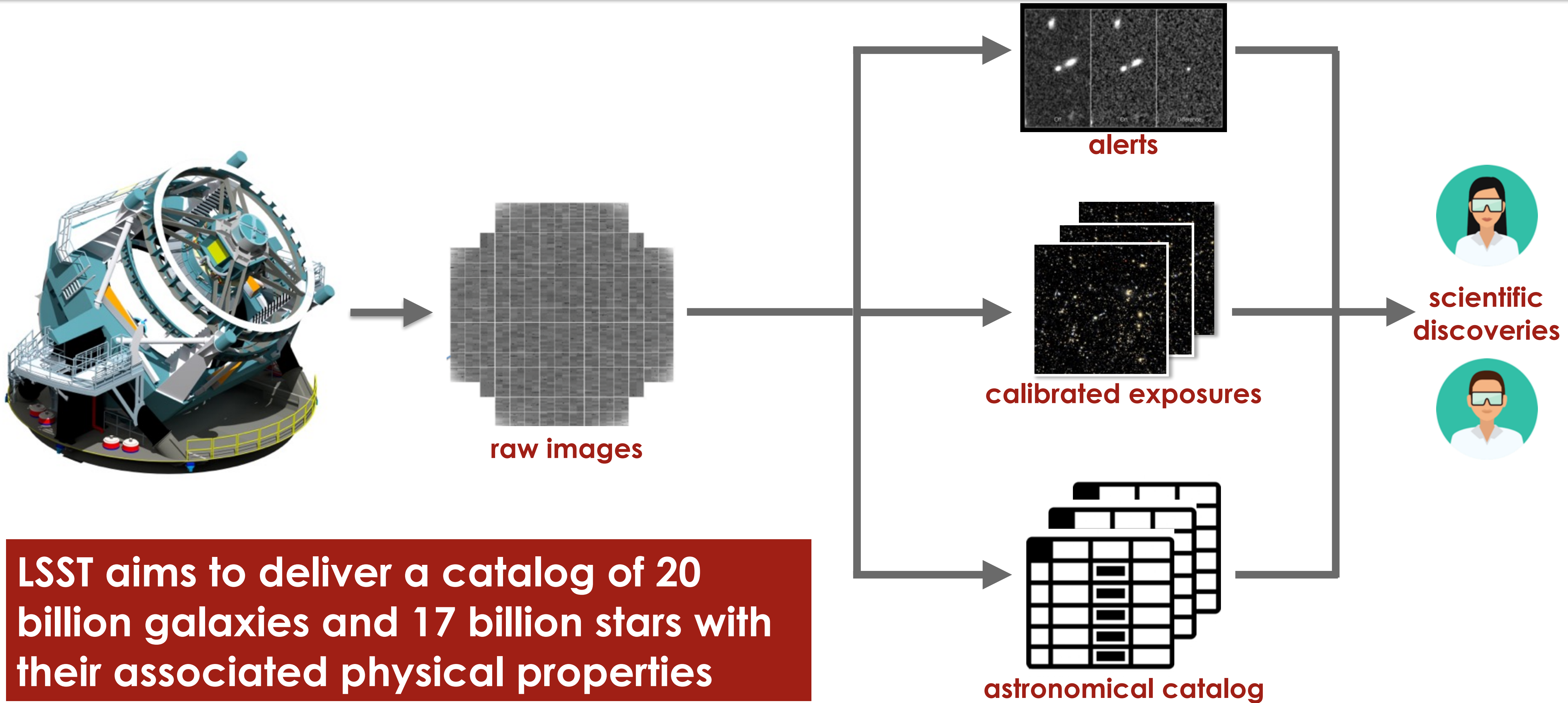
fabio hernandez

CONTENTS

- LSST overview
- IN2P3 contributions to LSST
- Science platform
- Summary

LSST OVERVIEW

LARGE SYNOPTIC SURVEY TELESCOPE



LSST aims to deliver a catalog of 20 billion galaxies and 17 billion stars with their associated physical properties

LSST OVERVIEW (CONT.)

- Principle of operations

*90% of the observing time of the telescope devoted to a **deep-wide-fast survey***

one complete visit of the southern hemisphere sky every 3-4 nights, from 2022 for 10 years

43% of the celestial sphere will be covered by this survey

each patch of the sky to be visited about 1000 times

- Science themes

*determining the nature of **dark energy** and **dark matter***

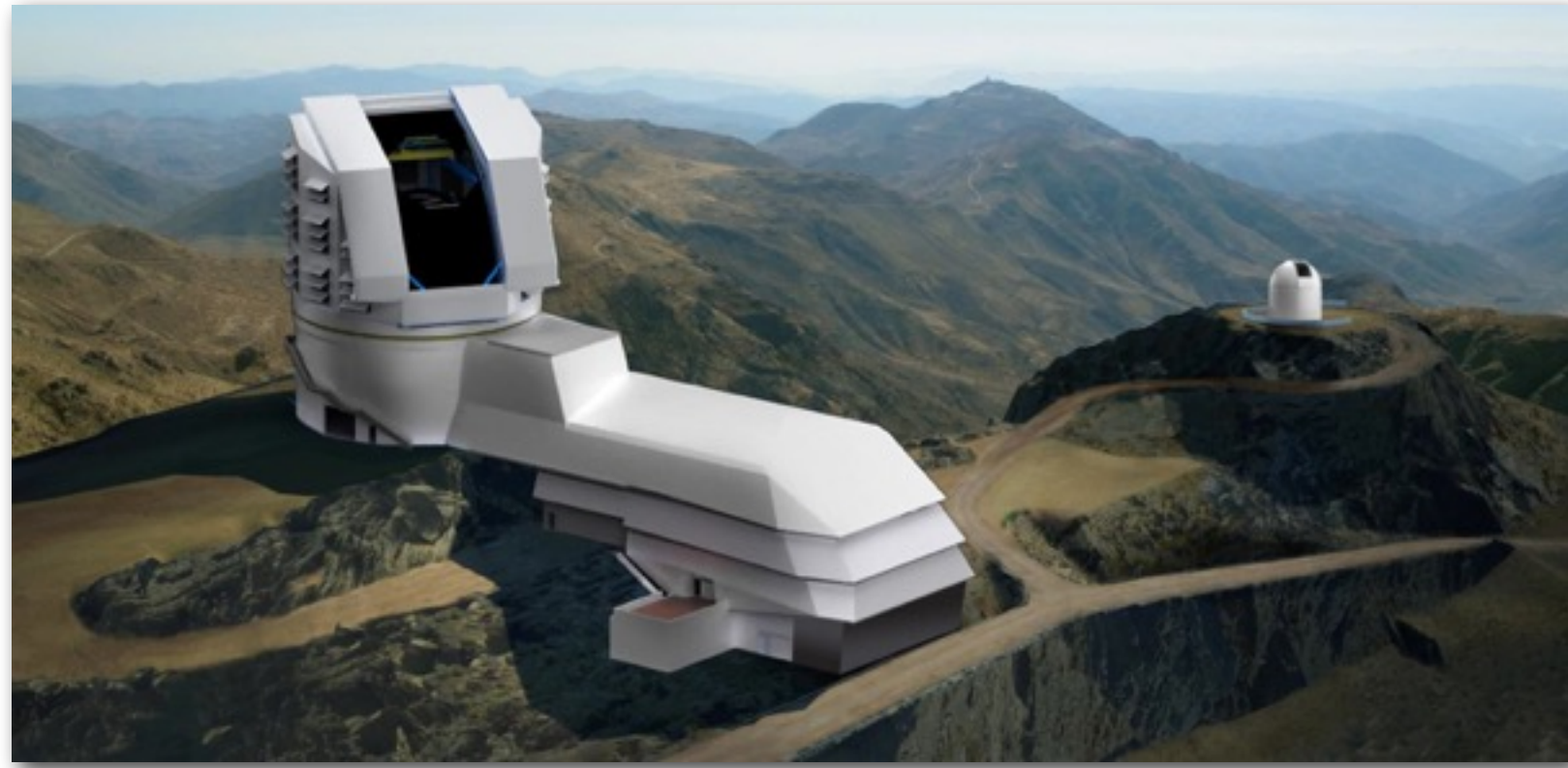
*taking an inventory of the **solar system***

*exploring the **transient** optical sky*

*mapping the structure and evolution of the **Milky Way***

LSST OVERVIEW

OBSERVATORY



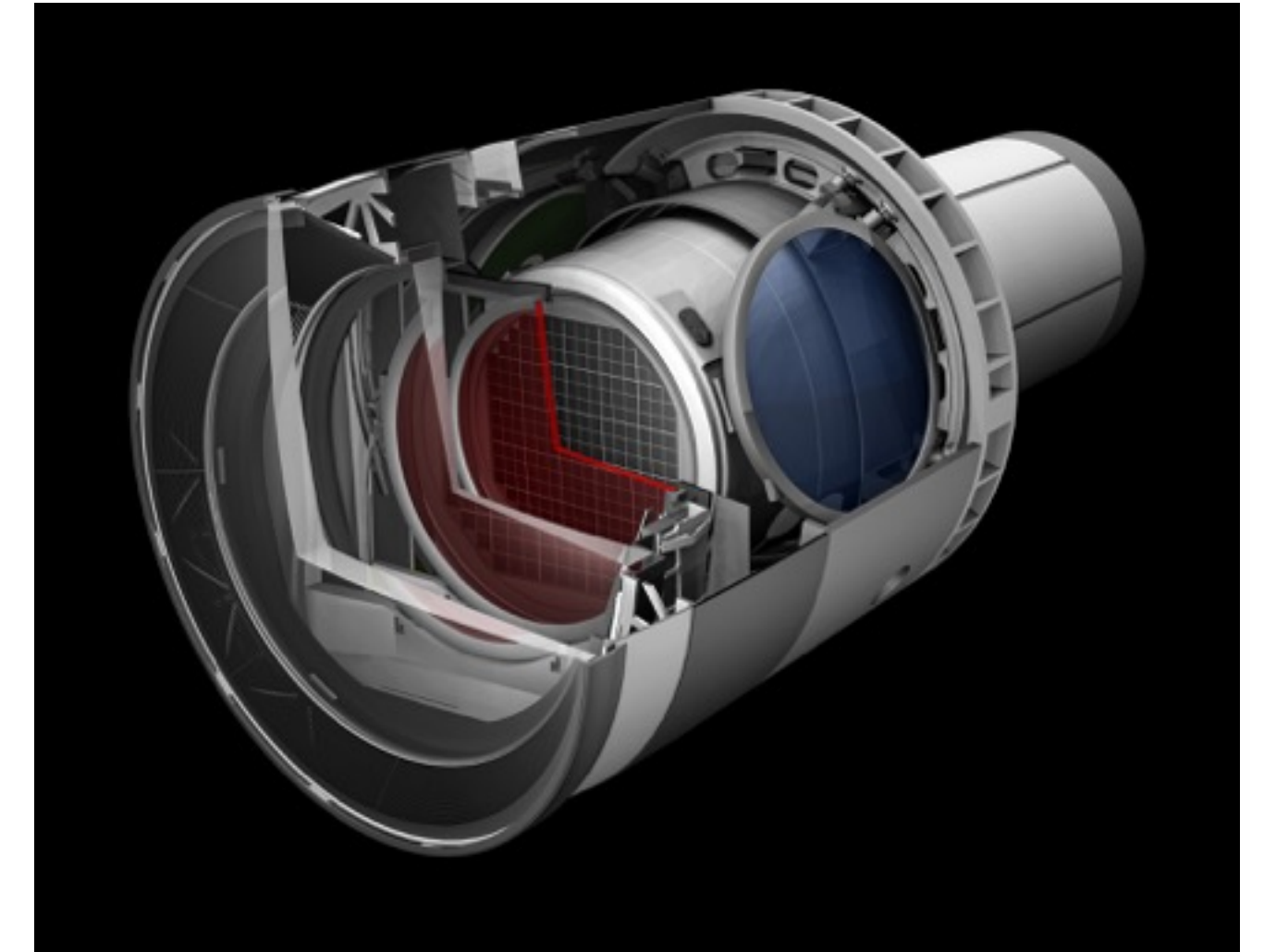
south hemisphere | 2647m a.s.l. |
stable air | clear sky | dark nights
| good infrastructure

TELESCOPE

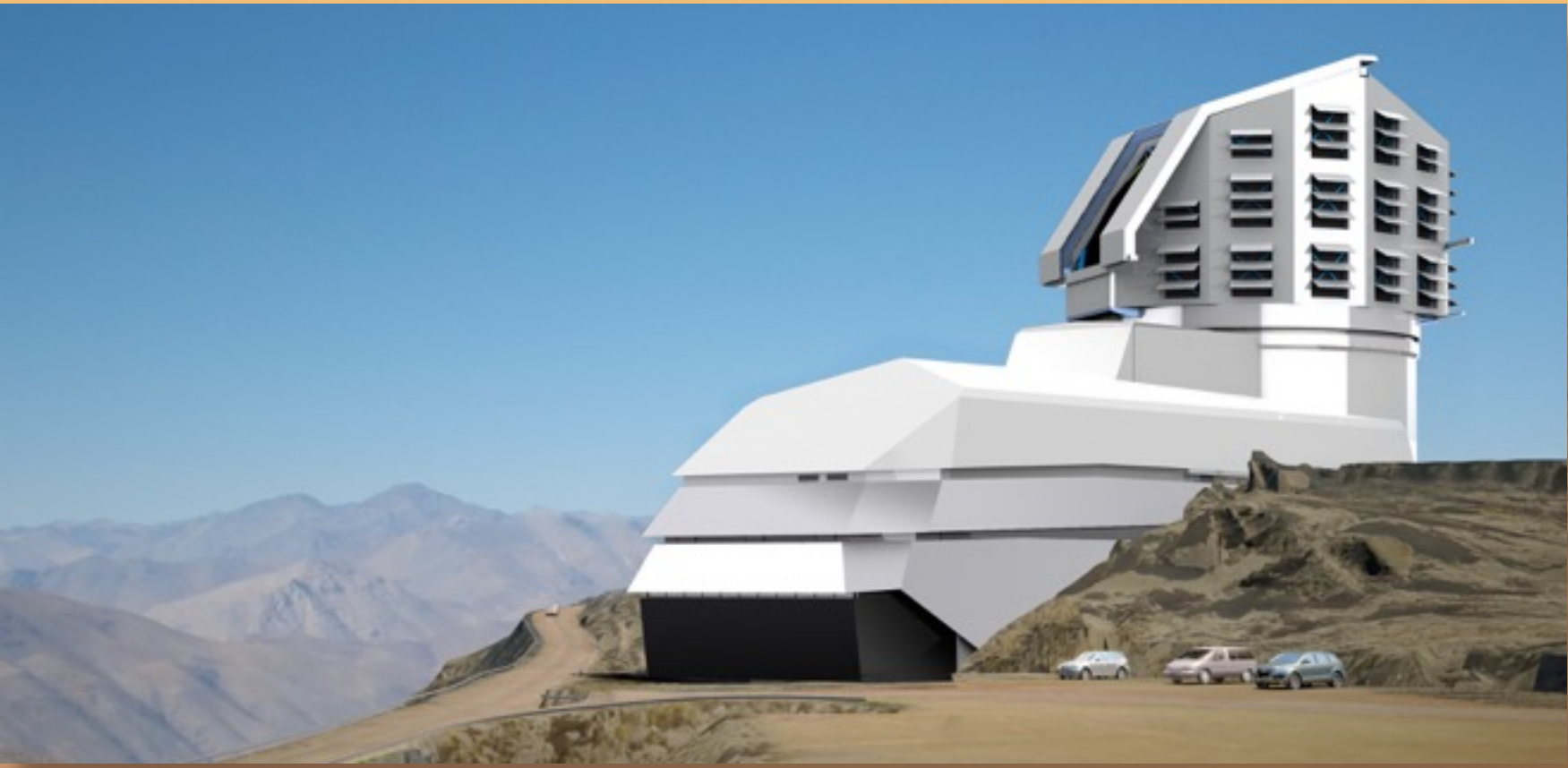


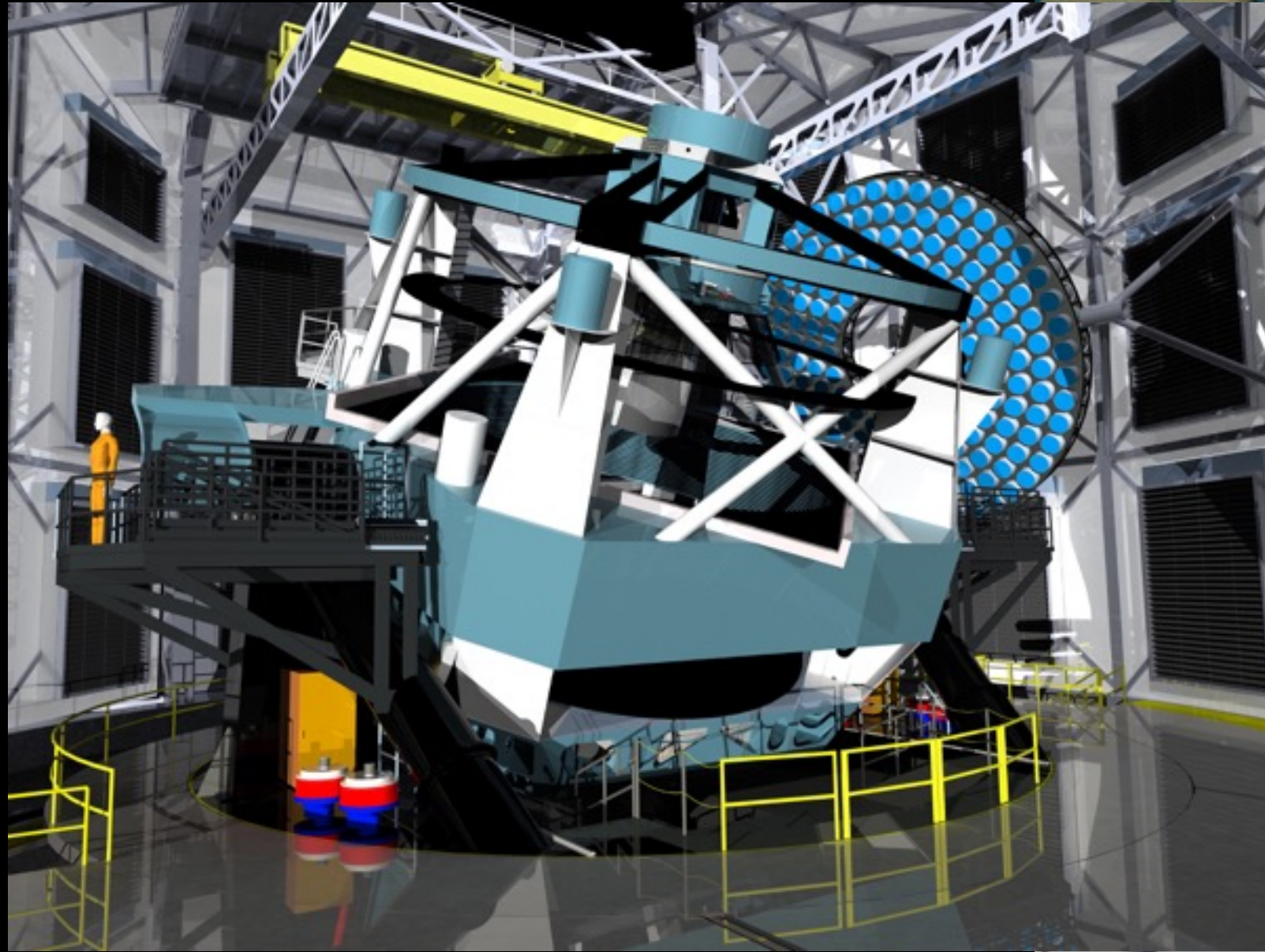
main mirror \varnothing 8.4 m (effective
aperture 6.5 m) | large
aperture: f/1.234 | wide field
of view | compact | 350 ton |
to be repositioned about 3M
times over 10 years of
operations

CAMERA



3.2 G pixels | \varnothing 1.65 m |
3.7 m long | 3 ton | 3
lenses | 3.5° field of view |
 9.6 deg^2 | 6 filters ugrizy |
focal plane and electronics
in cryostat at 173K





ROTATION: 10 deg/s
3.5° SLEW-SETTLE: 5 s

DATA ACQUISITION

- **Raw data**

7.2 GB per image

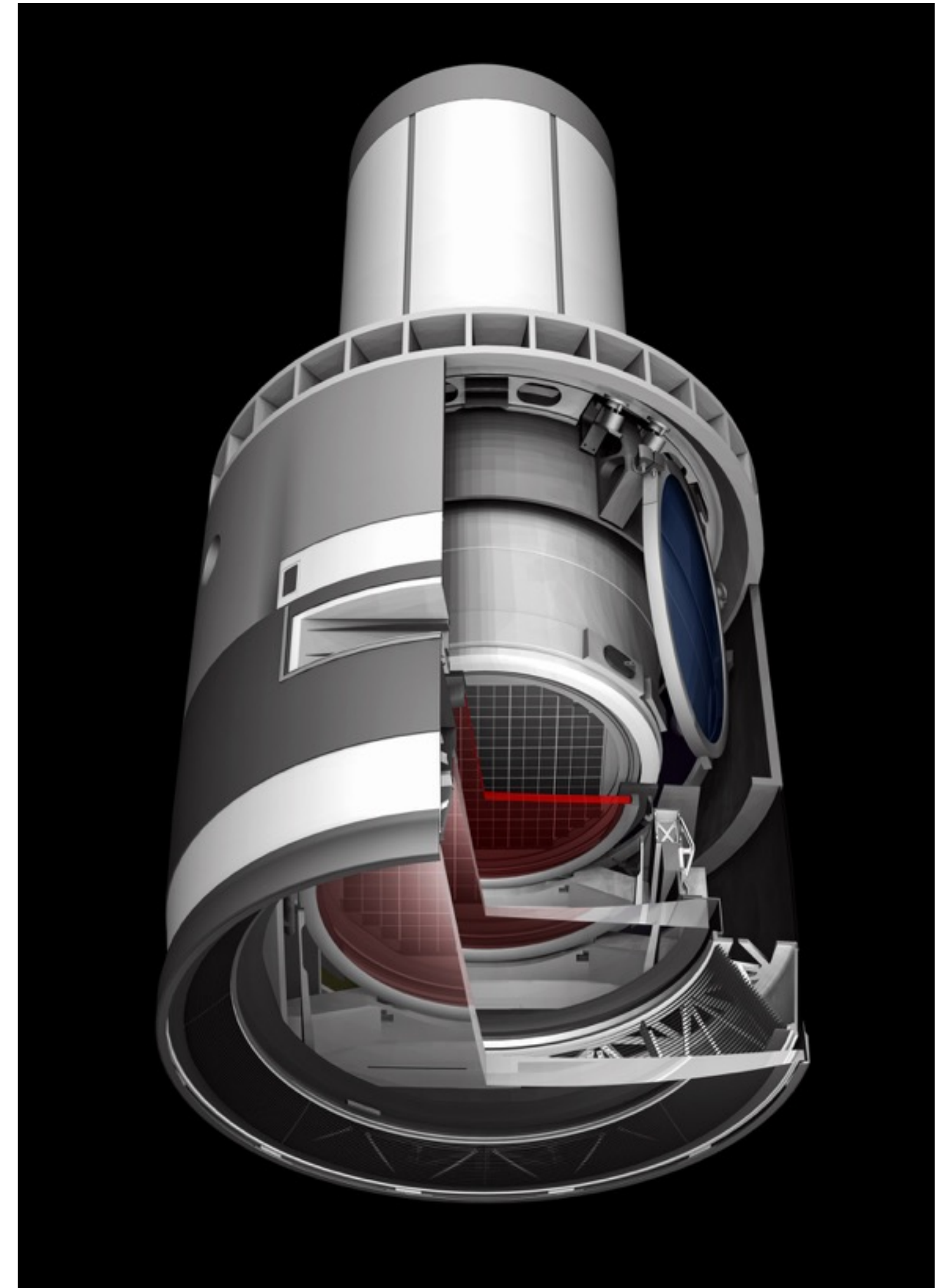
*2000 science images + 450 calibration images per night,
300 nights per year*

20 TB per night, 4.5 PB per year

- **Aggregated data over 10 years of operations, including derived data**

images: ~6M exposures, 515 PB

catalog database: 80 PB



Source: LSST

LSST OVERVIEW: DELIVERABLES

- Deliverable

*the science-enabling, **ultimate deliverable** of the project will be the **fully reduced data***

the scientific exploitation of the processed data will be performed by the scientific community

- Open data

*complete **cumulative data set** (images and catalogs), open to the scientific community of the participating countries, once per year, with no proprietary period*

***alerts** of detected variable sources (transients) made available for world-wide distribution **within 60 seconds of observation**, published via standard protocols*

- Open source software: github.com/lstst

LSST OVERVIEW: FUNDING AND BUDGET

1

2014-2022 — Construction phase budget: US\$ 671M



About 20% of the construction budget devoted to the DATA MANAGEMENT subsystem

2019-2034 — Operations phase budget: US\$ 41M/year

International collaboration: 25 countries, 39 research institutions

IN2P3

IN2P3

A DISTRIBUTED LABORATORY

2500 researchers, engineers and technicians

700 post-docs and PhD students

25 laboratories and research platforms in France, 16 international laboratories

COMPUTING CENTER



IN2P3 COMPUTING CENTER

- **CC-IN2P3**

 - 84 people, 80 FTE, 80% permanent positions*

 - ~15 M€ overall annual budget*

 - scientific data center, high throughput computing*

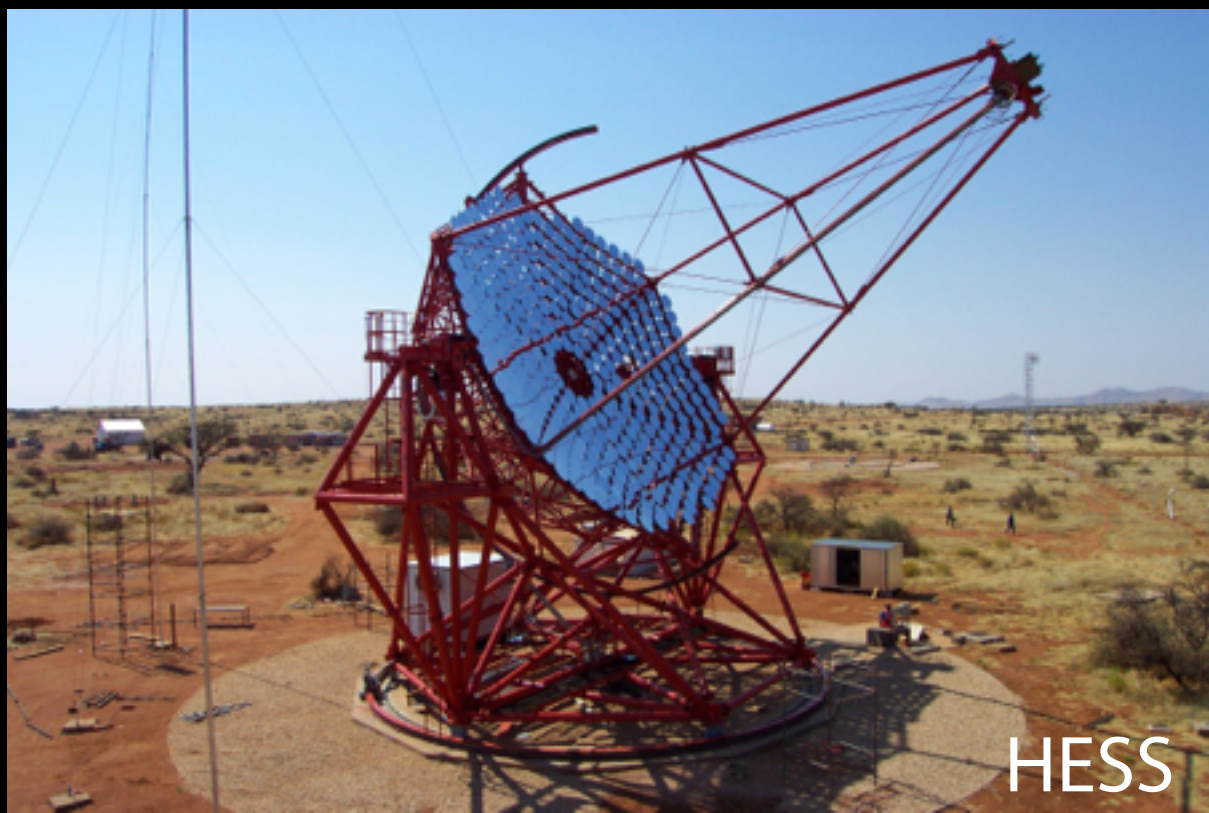
 - well connected to national and international networks*

- **Shared computing facility supporting the institute's research program**

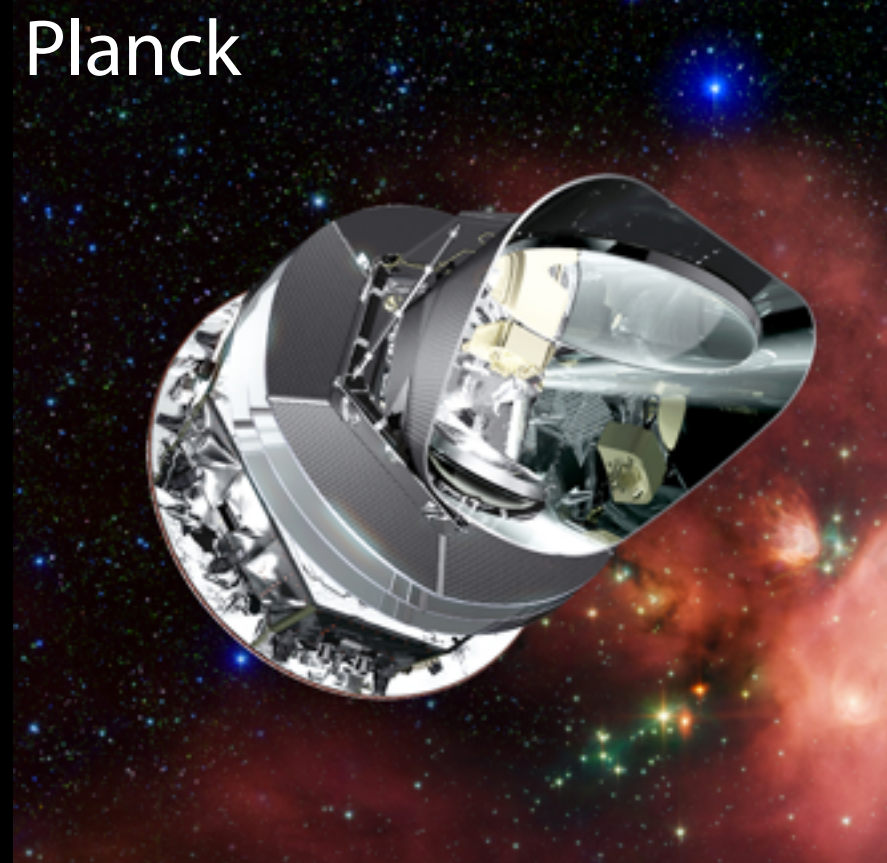
 - ~70 projects in high energy physics, nuclear physics and astroparticle physics*



- Operations: 24x7
unattended during nights and weekends
engineer on duty during off-hours



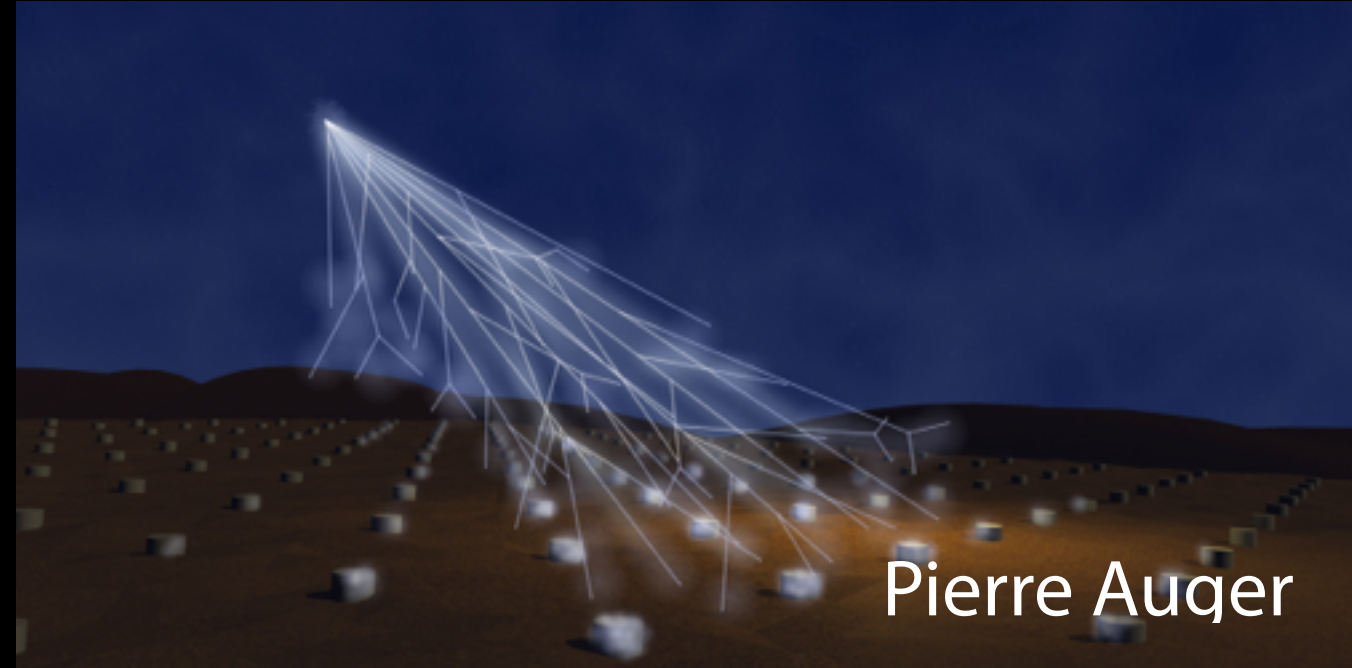
HESS



Planck



Fermi



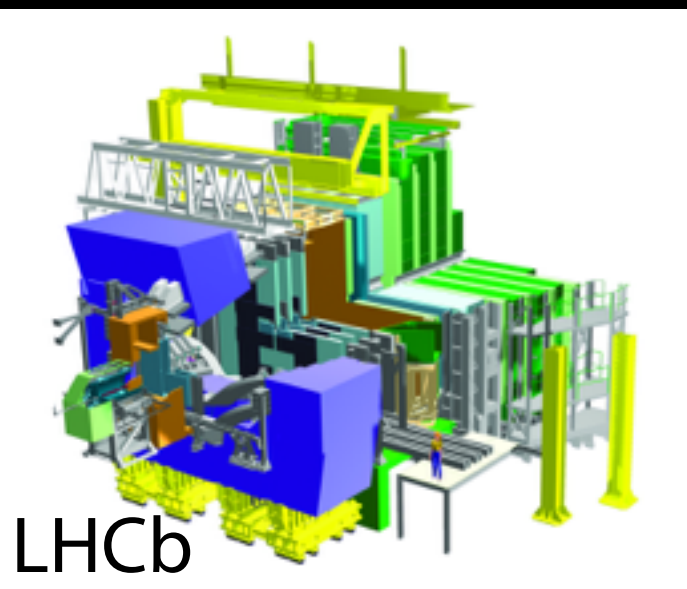
Pierre Auger



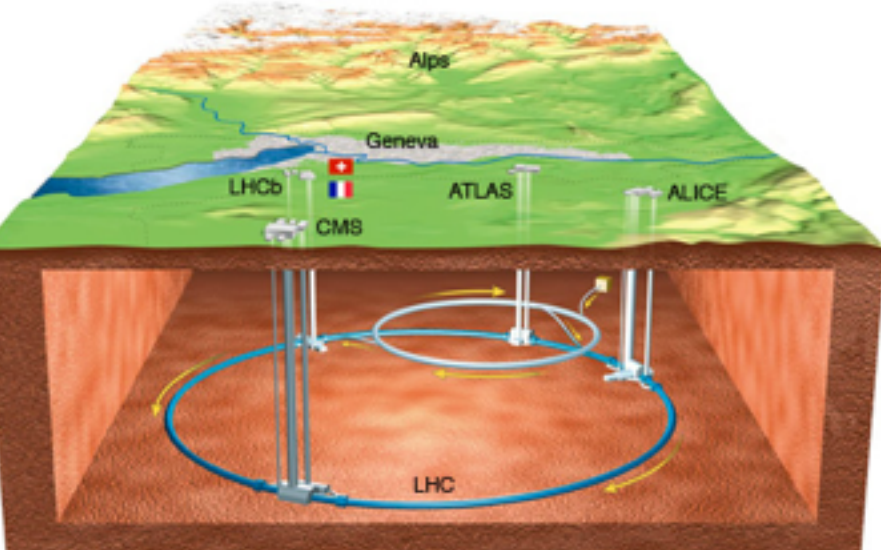
AMS



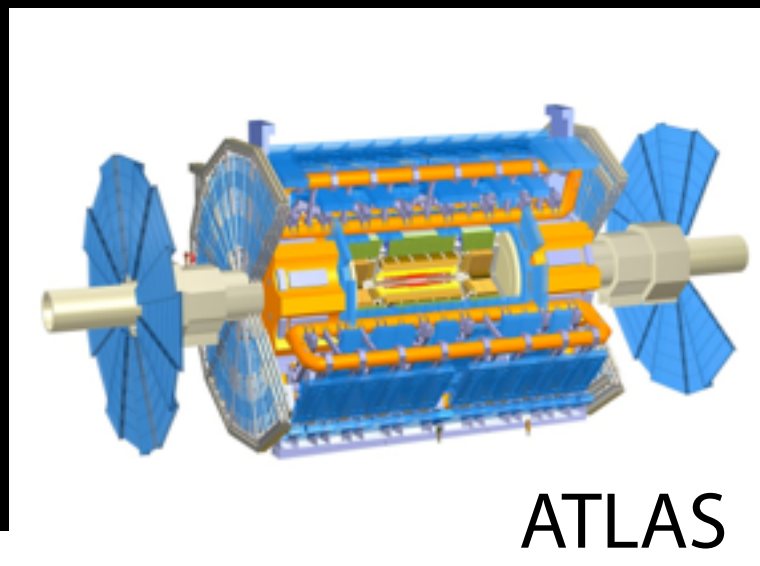
SuperNova Legacy Survey



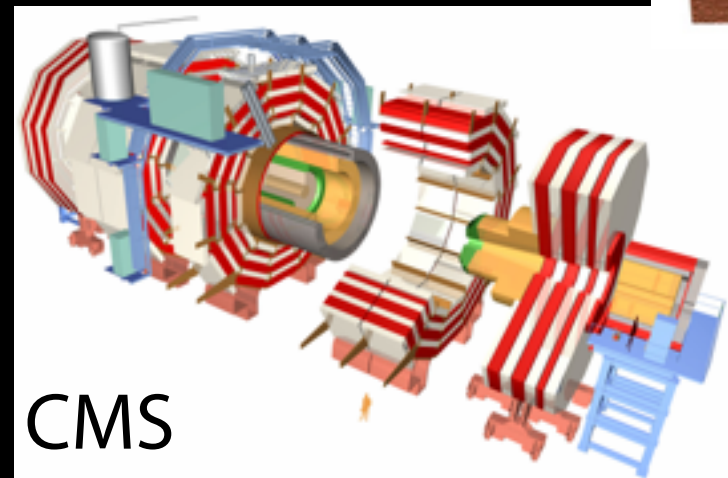
LHCb



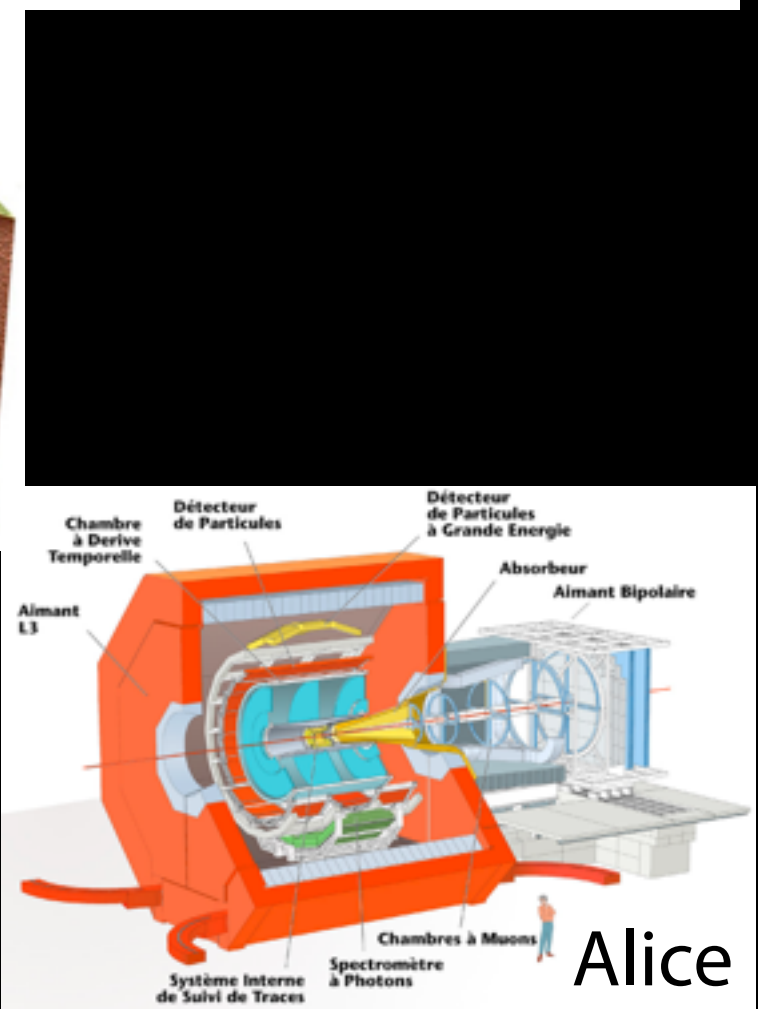
LHC @ CERN



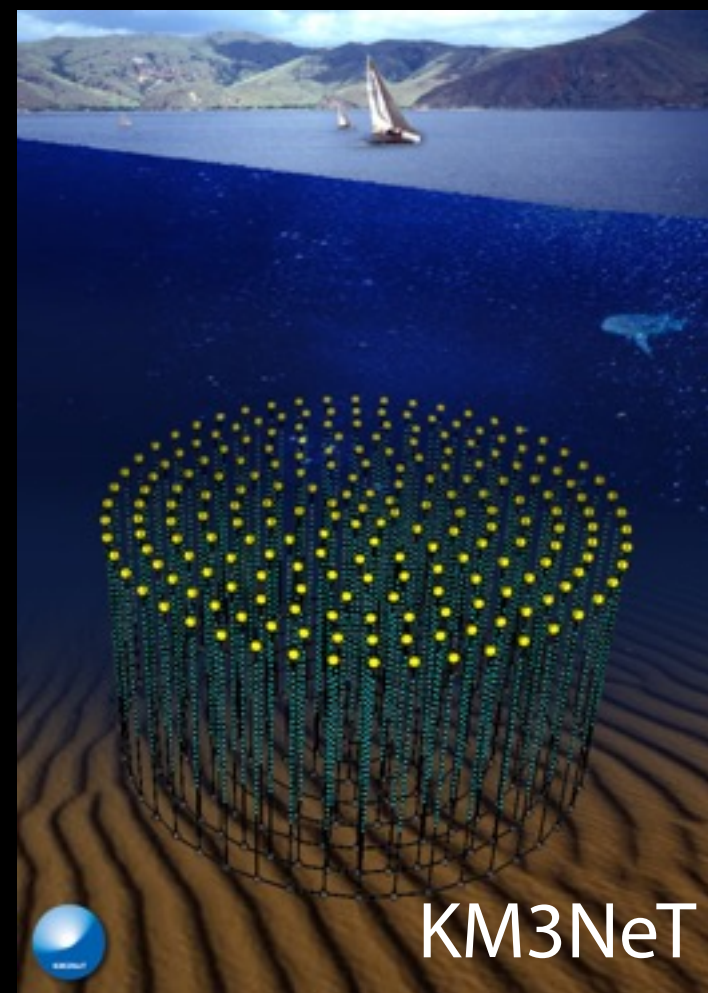
ATLAS



CMS



Alice



KM3NeT



Virgo

LSST AT IN2P3

- IN2P3 contributes to the construction of the LSST camera

CCD electronics, filter carousel, filter autochanger and manual loader (design, construction, command and control software)

- IN2P3 is preparing its contribution to **offline data processing** during both the commissioning and operations phases

LSST DATA PROCESSING

LSST DATA MANAGEMENT SUBSYSTEM

- Archival

to record, transport and permanently store raw data issued by camera

- Processing

to detect transients and emit alerts within 60 seconds after observation

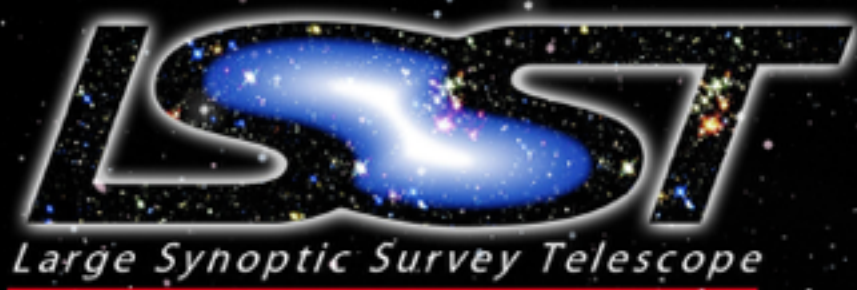
*once per year, to **produce a data release**: a self-consistent, immutable dataset, composed of processed data since the beginning of the survey*

to develop the software necessary for processing the data: image processing algorithms (calibration, point spread function, co-addition of images, characterization of objects, processing pipelines, ...), catalogue database, middleware (workload management, orchestration, ...), data transfer, etc.

- Publication

to deliver the reduced data (images + catalogs)

to facilitate custom data reduction and individual data analysis



LSST Operations: Sites & Data Flows



HQ Site
Science Operations
Observatory Management
Education & Public Outreach

Base Site
Base Center
Long-term storage (copy 1)
Data Access Center
Data Access & User Services

French Site
Satellite Processing Center
Data Release Production
Long-term Storage (copy 3)

Archive Site
Archive Center
Alert Production
Data Release Production
Calibration Products Production
EPO Infrastructure
Long-term Storage (copy 2)
Data Access Center
Data Access and User Services

Summit Site
Telescope & Camera
Data Acquisition
Crosstalk Correction

LSST DATA MANAGEMENT CONTRIBUTORS



Princeton University



National Optical
Astronomy Observatory



SLAC National Accelerator
Laboratory
Stanford University



Infrared Processing and
Analysis Center
California Institute of
Technology



National Center for
Supercomputing Applications
University of Illinois at Urbana-
Champaign

DATA RELEASE PROCESSING CENTRES



CNRS / IN2P3 computing center

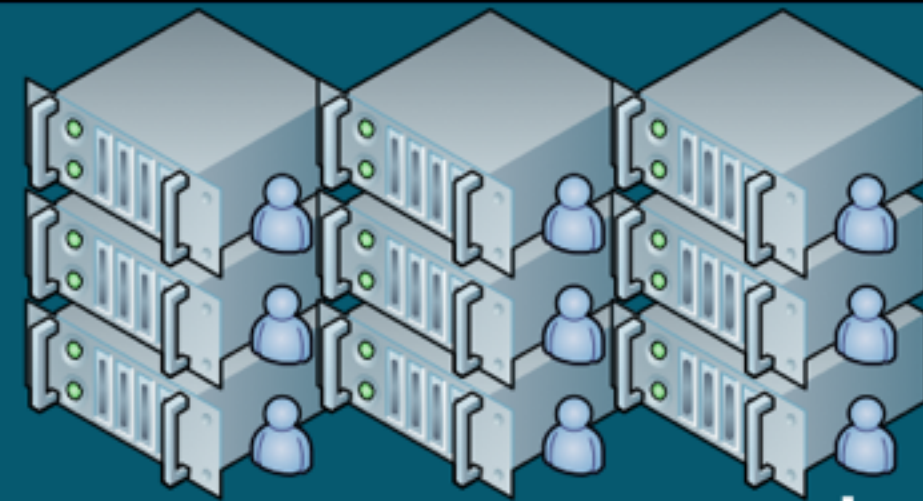
ENVISIONED ARCHITECTURE

(preliminary figures)

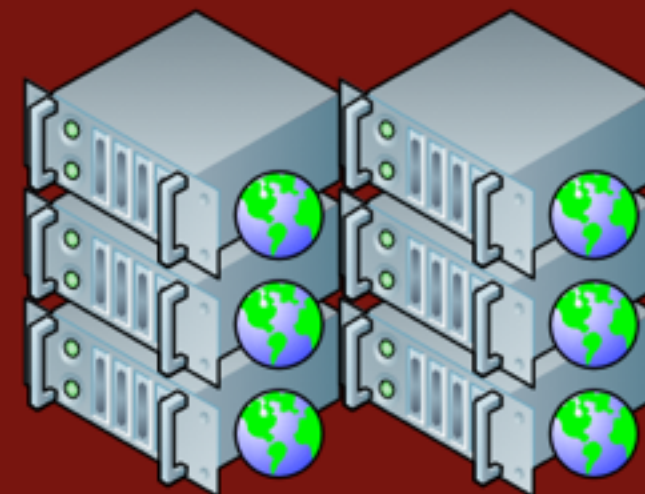
22k → 122k CPU cores



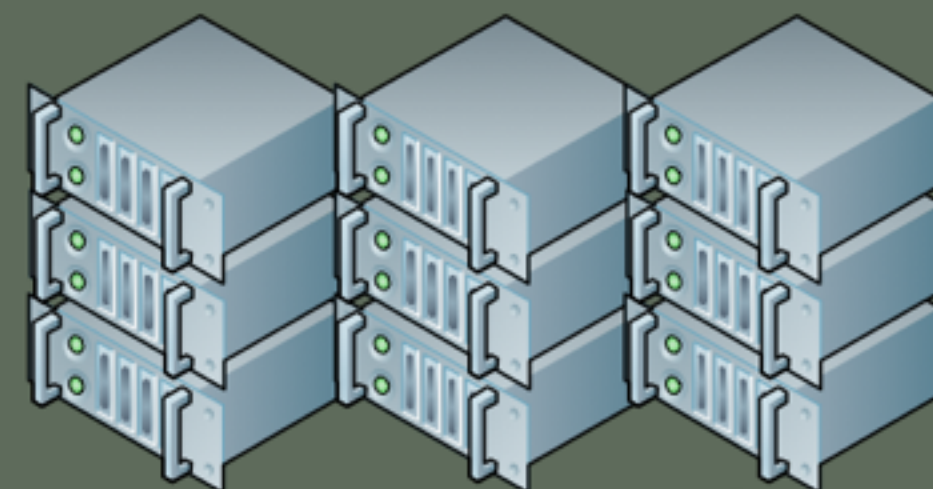
Batch farm



Login farm



Data transfer nodes

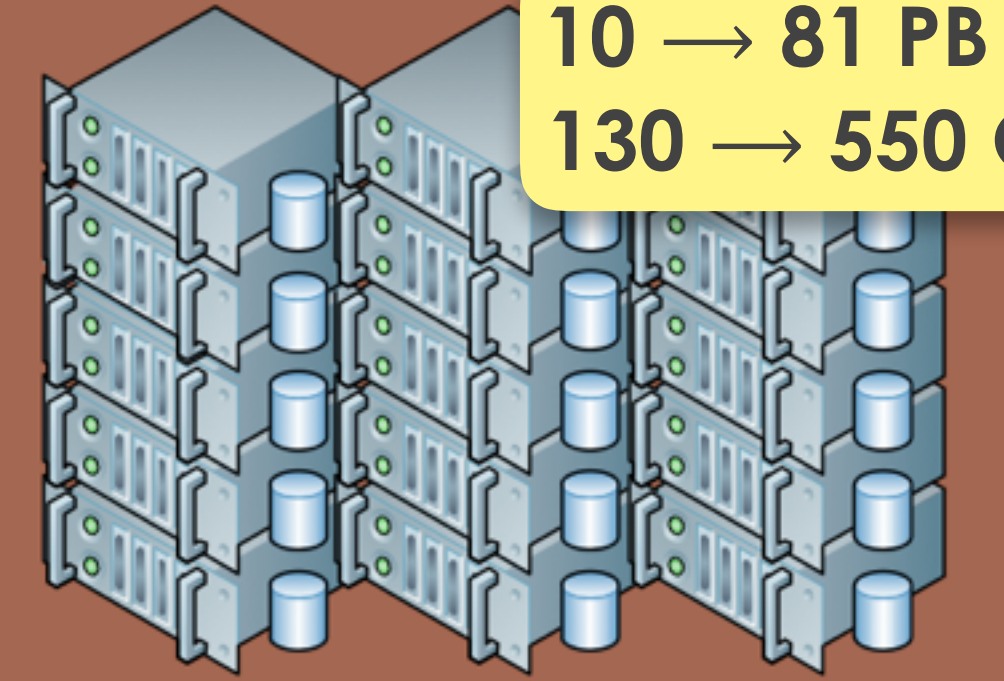


Application servers



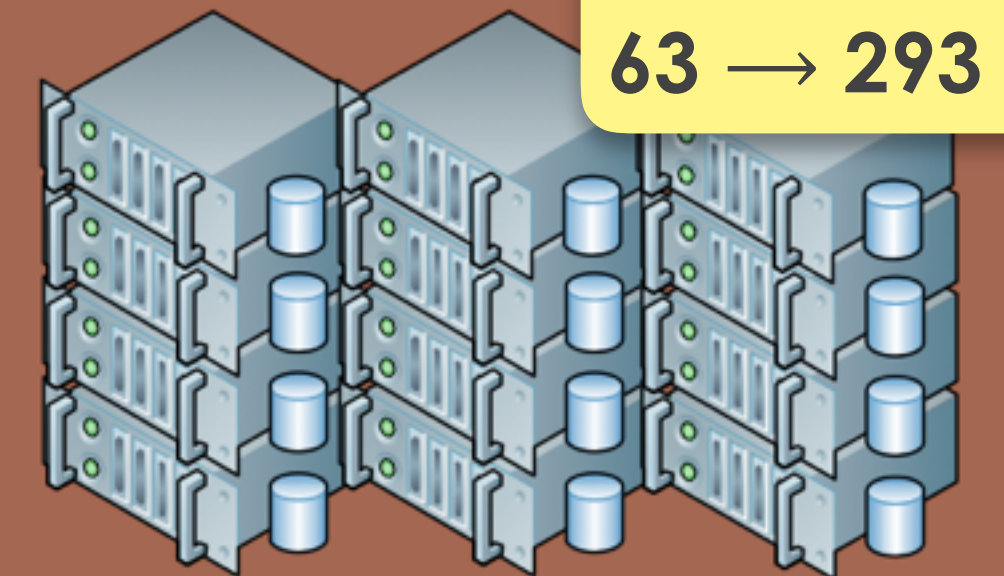
WAN

LAN



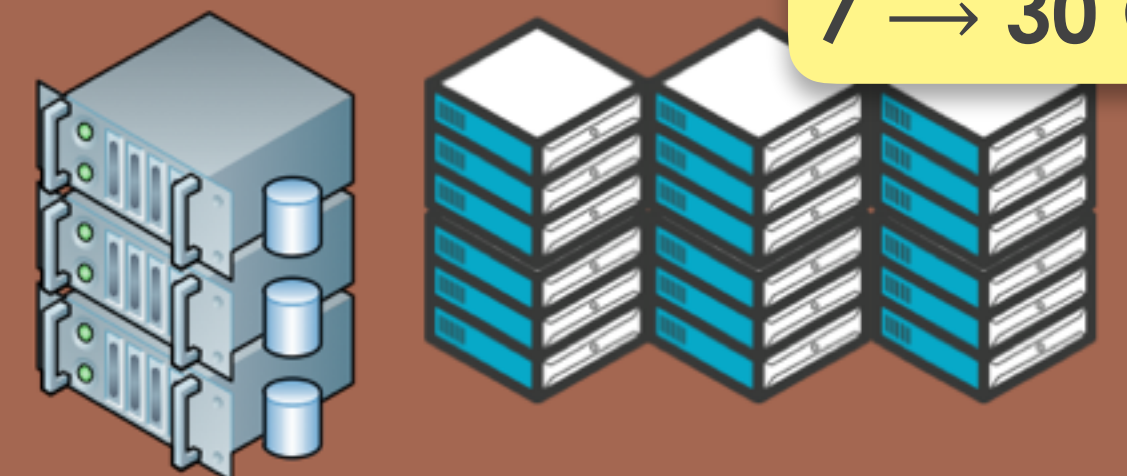
10 → 81 PB
130 → 550 GB/s

Catalog database



10 → 55 PB
63 → 293 GB/s

Disk storage



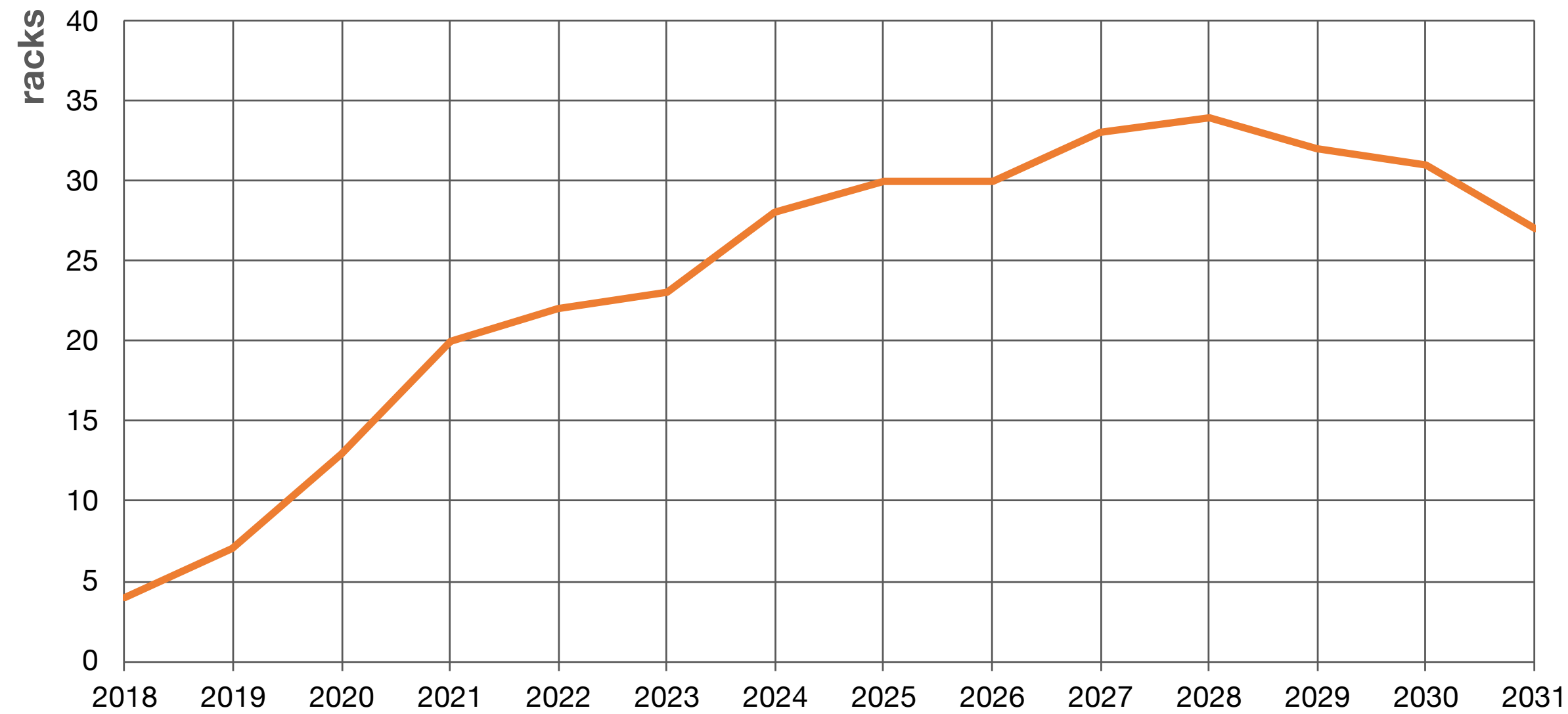
9 → 121 PB
7 → 30 GB/s

Mass storage

2022 → 2032

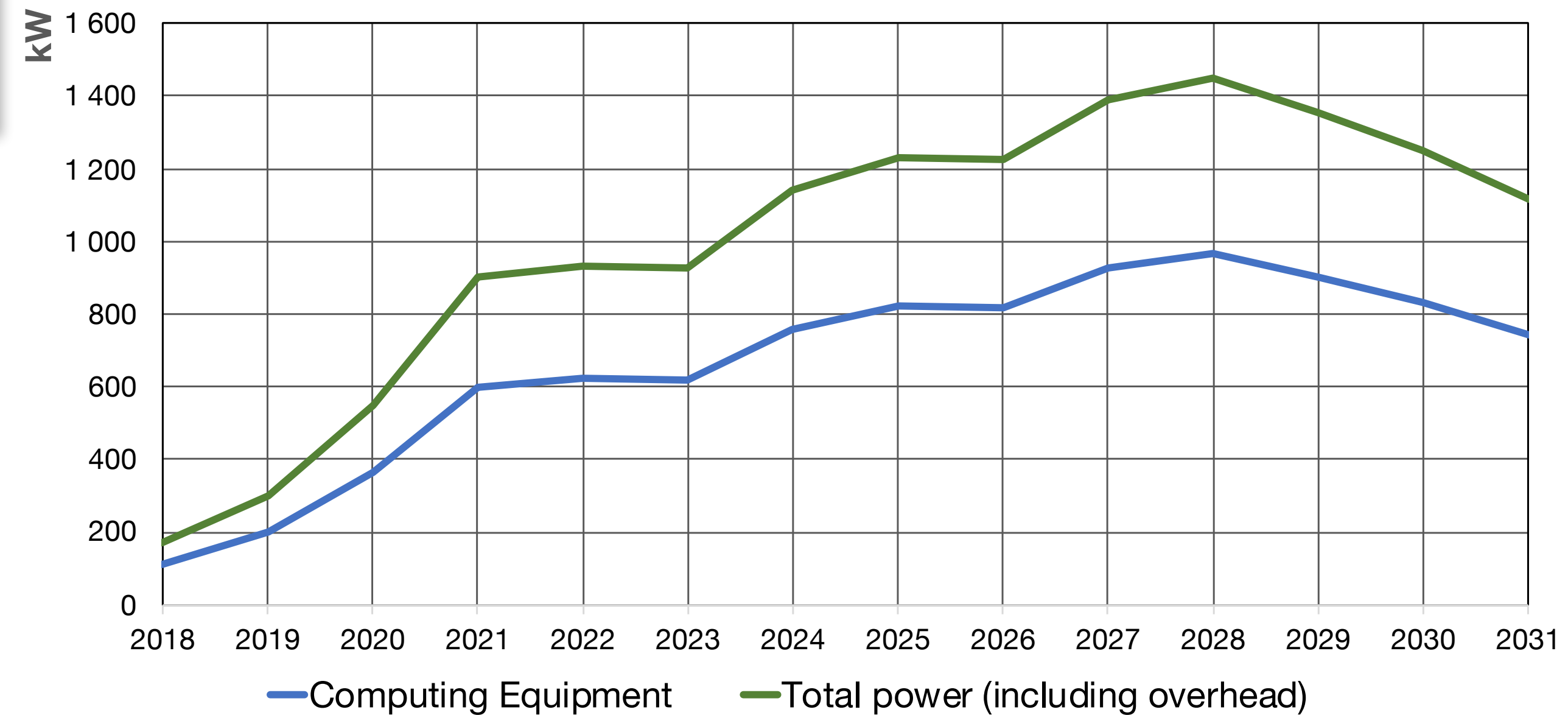
MACHINE ROOM INFRASTRUCTURE

Number of racks on the floor
LSST data release processing at CC-IN2P3



Racks
peak 34 racks

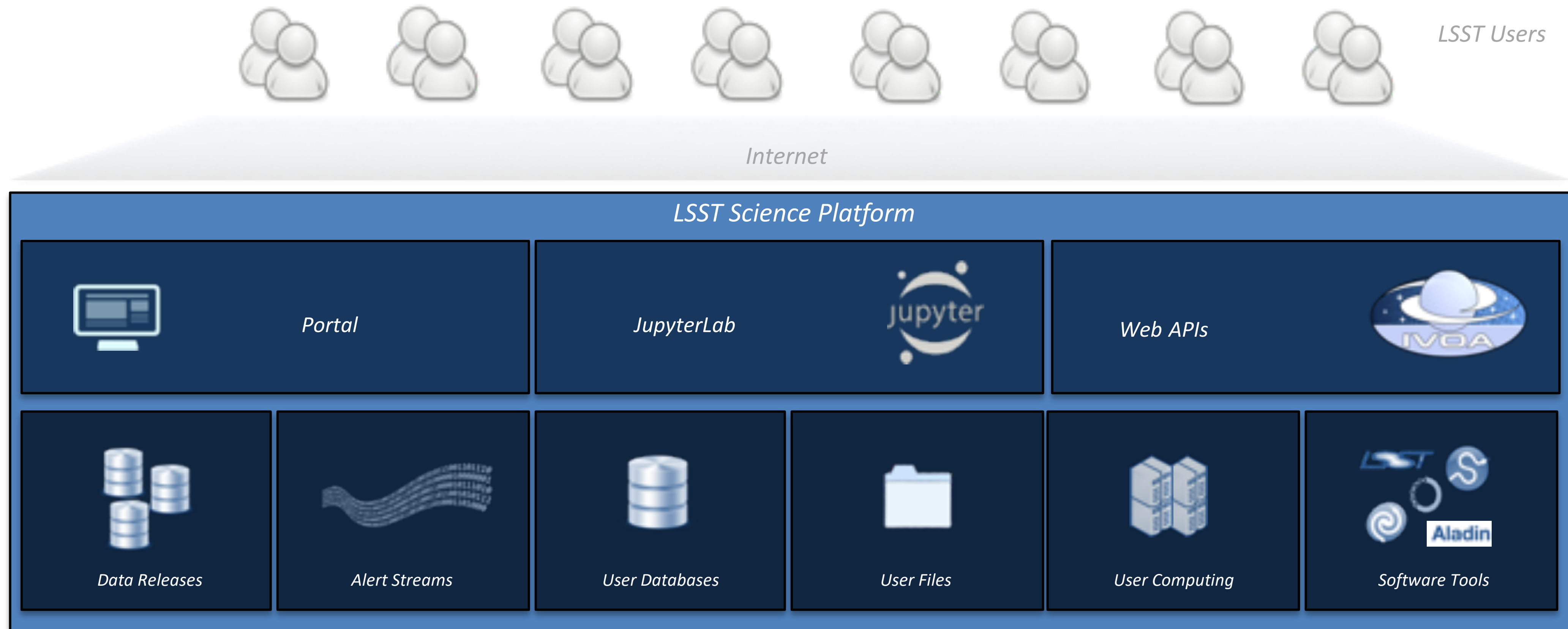
Required Power
LSST data release processing at CC-IN2P3



Power
peak 1.4 MW

SCIENCE PLATFORM

LSST SCIENCE PLATFORM



Set of integrated web applications and services, through which the scientific community will access, **visualize**, subset and perform **next-to-the-data analysis** of the data

LSST SCIENCE PLATFORM PROTOTYPE

doc.lsst.eu

Interactive computing based on Python notebooks and web-based visualisation tools

Prototype components deployed at CC-IN2P3 and being routinely used by scientists

```
exposures = {}
for bandpass in bandpass_color_map.values():
    dataId['filter'] = bandpass
    # refs[bandpass] = butler.get('deepCoadd_ref', dataId=dataId)
    exposures[bandpass] = butler.get('deepCoadd', dataId=dataId)

rgb_im = rgb.makeRGB(*(exposures[bandpass_color_map[color]].getMaskedImage().getImage()
                       for color in ('red', 'green', 'blue')), Q=8, minimum = -0.1, dataRange=1.5,
                       saturatedPixelValue=100,
                       xSize=None, ySize=None)

fig = plt.figure(figsize=(12,12))
#rgb.displayRGB(rgb_im)

In [3]: fig = plt.figure(figsize=(10,10))
rgb_im = rgb.makeRGB(*(exposures[bandpass_color_map[color]].getMaskedImage().getImage()
                      for color in ('red', 'green', 'blue')), Q=8, dataRange=1.0,
                      xSize=None, ySize=None)
#saturatedPixelValue=130,
rgb.displayRGB(rgb_im)
```

Firefly

File Data

designation	ra	dec	...
2132921.58+471401.9	202.339939	47.235842	...
2132920.87+471407.8	202.337408	47.236236	...
2132921.28+471422.6	202.338805	47.236294	...
2132922.12+471455.8	202.3422015	47.2488407	19-29m22.13s 47d14m05.83s 0.2122 0.2
2132920.47+471215.0	202.3398703	47.2143745	19-29m30.47s 47d12m01.03s 0.0626 0.3
2132920.31+471315.4	202.3721563	47.2206642	19-29m29.32s 47d13m01.47s 0.1319 0.1
2132920.43+471336.4	202.3726478	47.222424	19-29m29.44s 47d13m06.43s 0.0564 0.1
2132921.56+471311.3	202.3815205	47.2206205	19-29m31.56s 47d13m01.37s 0.1202 0.1
2132920.23+471329.0	202.3718143	47.2247399	19-29m29.24s 47d13m29.56s 0.5 0.6
2132924.48+471337.4	202.3921149	47.2267922	19-29m34.44s 47d15m07.41s 0.2052 0.2
2132920.98+471338.4	202.3707661	47.2268819	19-29m28.86s 47d13m08.45s 0.6195 0.6
2132923.26+471441.4	202.3886222	47.2448358	19-29m33.27s 47d14m41.41s 0.4373 0.4
2132922.56+471500.7	202.3807011	47.2502071	19-29m32.57s 47d15m00.75s 0.6843 0.7
2132920.82+471498.5	202.3796732	47.2488806	19-29m29.82s 47d14m08.57s 0.4766 0.4
2132920.31+471492.7	202.3763233	47.247423	19-29m30.32s 47d14m05.72s 0.5096 0.5
2132923.43+471525.1	202.3883316	47.2568794	19-29m33.44s 47d15m25.12s 0.278 0.3
2132921.51+471413.3	202.381295	47.2370368	19-29m31.51s 47d14m13.33s 0.4267 0.4
2132921.58+471418.2	202.3815304	47.2383973	19-29m31.57s 47d14m18.23s 0.3404 0.3

Sources: D. Boutigny, X. Wu et al.

SOFTWARE DISTRIBUTION

- LSST science pipelines automatically delivered

*both **stable** and **weekly** releases appear as if they were locally installed under `/cvmfs/sw.lsst.eu`*

*mechanism used for delivering the software to computers in both the CC-IN2P3 **login** and **batch farms** as well as to the **scientists' personal computers***

lower the barriers for end users to use the LSST software

useful for reproducibility

alternative mechanisms: Docker images, sources

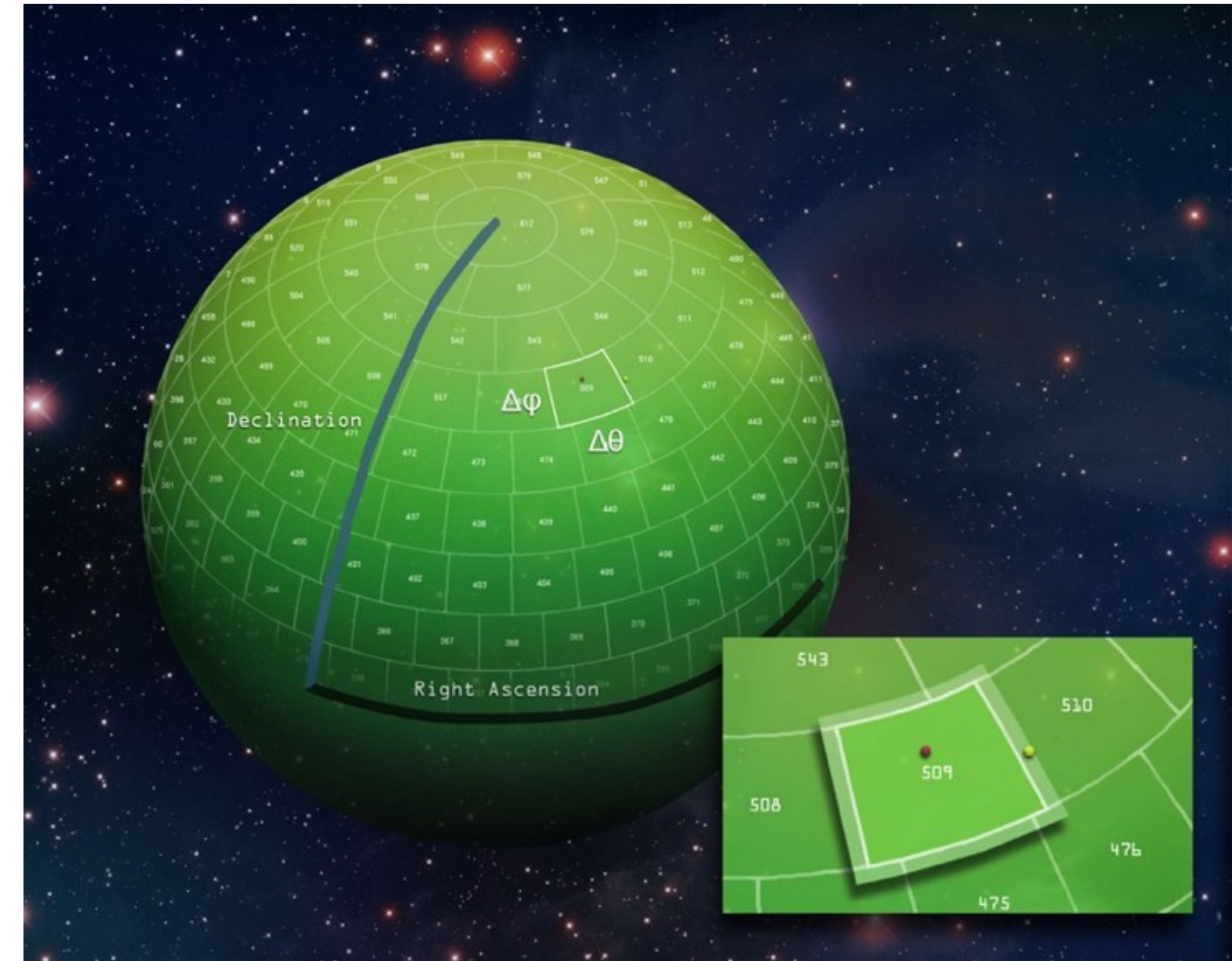


sw.lsst.eu

The screenshot shows a web browser window with the URL `https://sw.lsst.eu`. The page title is "Get the LSST science pipelines delivered to your computer". The main content area includes a search bar, a navigation menu on the left, and a main text area. The navigation menu lists sections: OVERVIEW, USAGE, INSTALLATION, HELP & FEEDBACK, FAQ, and CREDITS. The main text area contains the following sections: OVERVIEW, USAGE, INSTALLATION, HELP & FEEDBACK, FAQ, and CREDITS. The text describes how to get a binary distribution of the LSST science pipelines to use on a personal computer without installing the software. It mentions that both stable and weekly releases of the LSST software appear as if they were locally installed on the computer. The text also mentions that new releases just appear under the local path `/cvmfs/sw.lsst.eu` without any action from the user. The text also mentions that the service is brought to the LSST community by LSST-France and CNRS / IN2P3 computing center (CC-IN2P3).

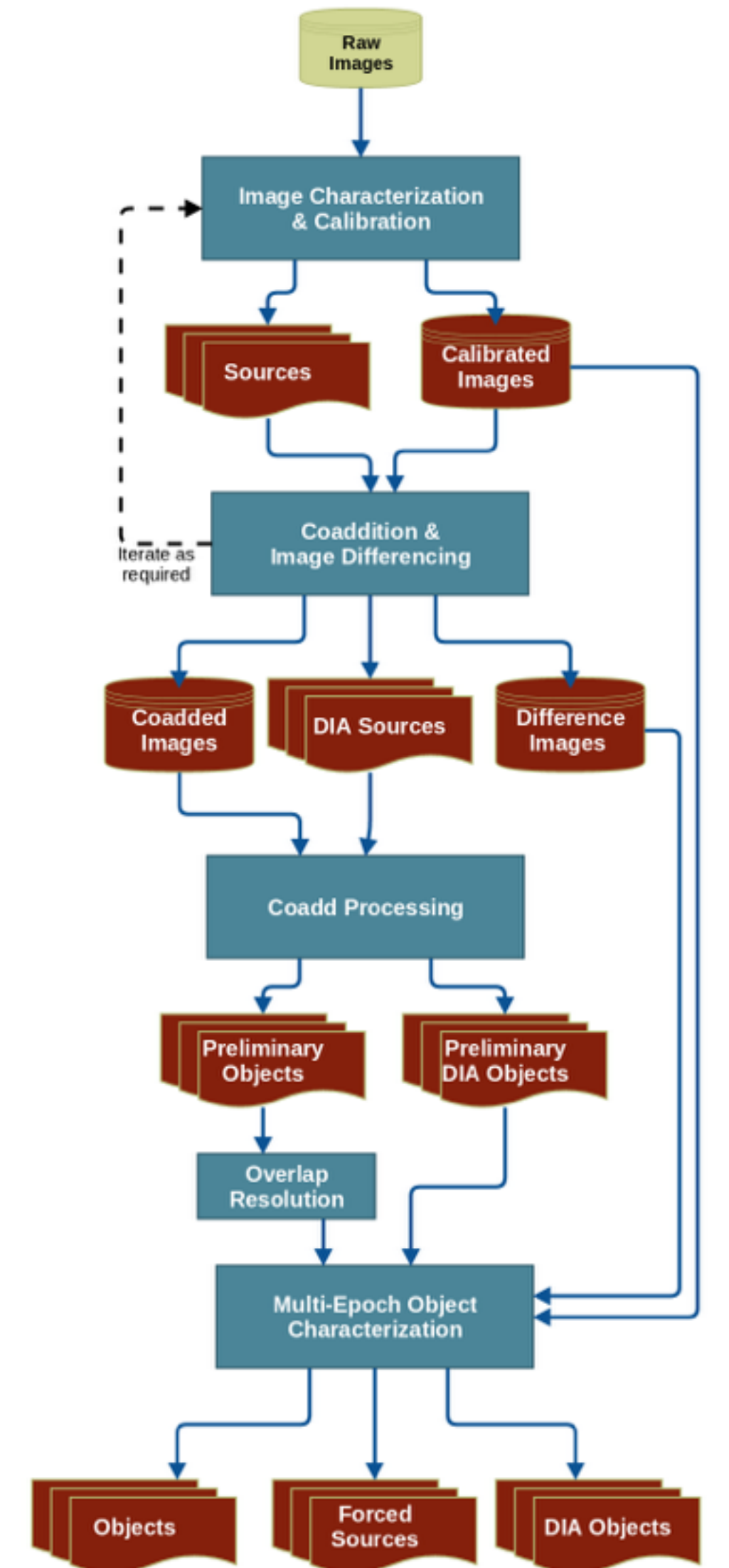
CATALOG DATABASE

- **Qserv**: custom, distributed relational database
 - spatial partitioning by sky coordinates, with overlaps*
 - map-reduce model*
 - very high number of rows: **~37 trillions***
- **CC-IN2P3** hosts and operates one of the development clusters
 - development effort lead by SLAC, with contribution by IN2P3 LPC Clermont*
- Currently using hardware lent by Dell in the framework of an institutional partnership



DATA RELEASE PROCESSING

- Bulk data processing for building the annual data release
*every year, the **entire dataset since the beginning of the survey** is reprocessed to produce an immutable set of calibrated images and catalogs and to update the references for nightly alert production*
- Currently exercising the LSST software for processing simulated data
Dark Energy Science Collaboration



CONNECTIVITY & DATA EXCHANGE

- Allocated bandwidth between CC-IN2P3 and NCSA: 20 Gbps
bottleneck link is currently 10 Gbps: expected upgrade to full 20 Gbps before end 2018
- We need to demonstrate capacity to import 20 TB of raw data per night from NCSA (RTT: 110 ms)
in addition to capacity to exchange data products with NCSA
- Currently exercising regular data exchanges with NERSC (RTT: 150 ms)

CONNECTIVITY & DATA EXCHANGE (CONT.)

Data flow: **NERSC (GPFS) → CC-IN2P3 (GPFS)** [3 servers, 4 clients]



Aggregated application-level network throughput: **1.5 GB/s (12 Gbps)**

*secure HTTP ⇒ integrity, confidentiality
pull model, disk-to-disk transfer, wide area network, 150ms RTT*

Connectivity provided by



SUMMARY

SUMMARY

- LSST is a world-class, high-profile project in optical astronomy
high expectations from the scientific community and from the funding agencies about what LSST will bring over the next decade
- IN2P3 is preparing to contribute to the annual production of the LSST data releases
integral copy of the data (both images and catalogs) to be available at CC-IN2P3 for French scientists members of the project
- Significant investment being made to realise the science discovery potential
quantified roadmap established, R&D activities ongoing and now entering the deployment phase

We are made of stellar ash. Our origin and evolution have been tied to distant cosmic events. The exploration of the Cosmos is a voyage of self-discovery.

CARL SAGAN, COSMOS

QUESTIONS & COMMENTS