LSST Data and Computing

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Large – Synoptic – Survey – Telescope

LSST is an instrument designed to make high precision images of the whole accessible sky in 4-D (x, y, z, t) - 10 year time-lapse movie of the sky

Time domain science
- Novae – Supernovae – GRBs
- Source characterization
- Instantaneous discovery

Moving sources
- Asteroids and comets
- Proper motions of stars

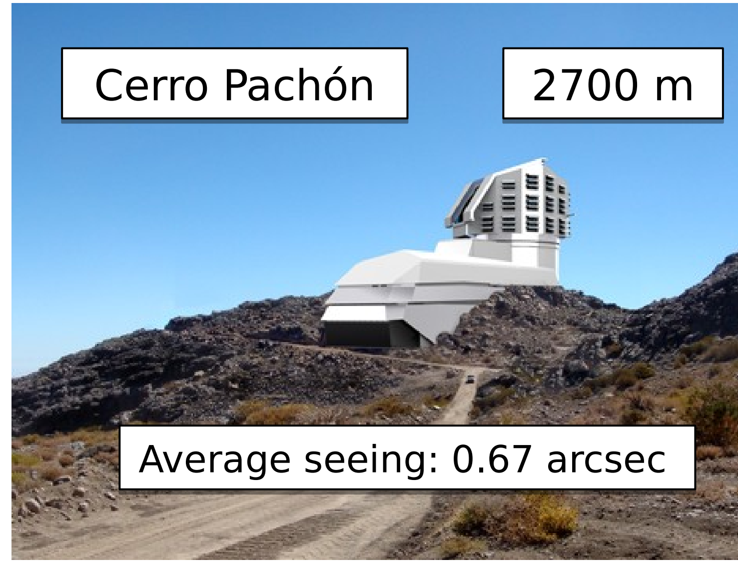
Mapping the Milky Way
- Tidal stream
- Galactic structure
- Complementary to GAIA

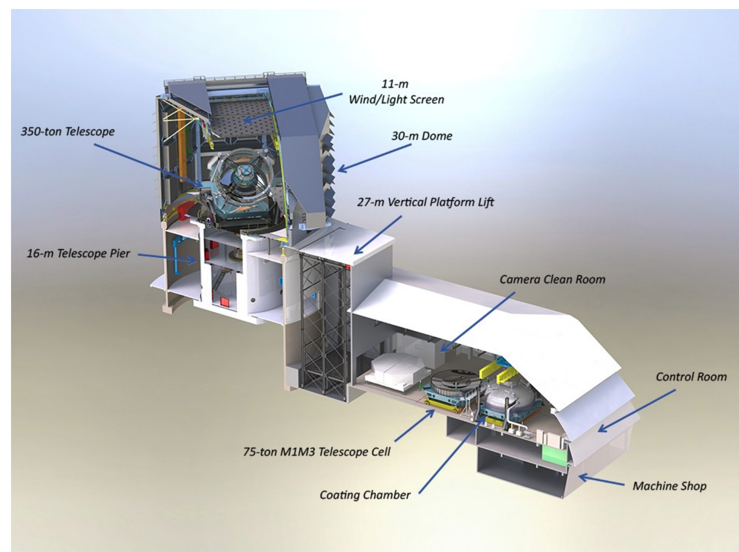
Dark energy and dark matter
- Gravitational lensing (strong and weak)
- Evolution of large scale galactic structures
- Trace the nature of dark energy

3 keywords : **Fast –Wide – Deep**

Site

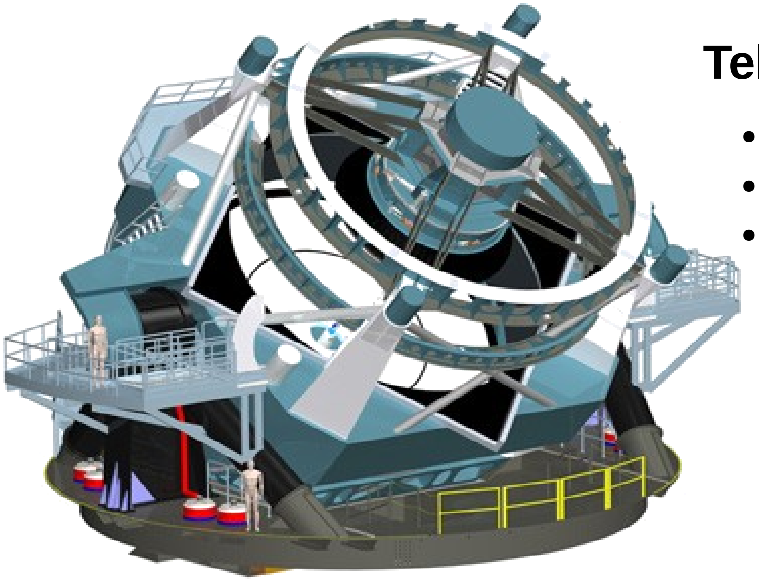

Chili
LSST Site
La Serena
Santiago


Cerro Pachón
2700 m
Average seeing: 0.67 arcsec


11-m Wind/Light Screen
350-ton Telescope
30-m Dome
27-m Vertical Platform Lift
16-m Telescope Pier
Camera Clean Room
Control Room
75-ton M1M3 Telescope Cell
Coating Chamber
Machine Shop

Site

September 9th

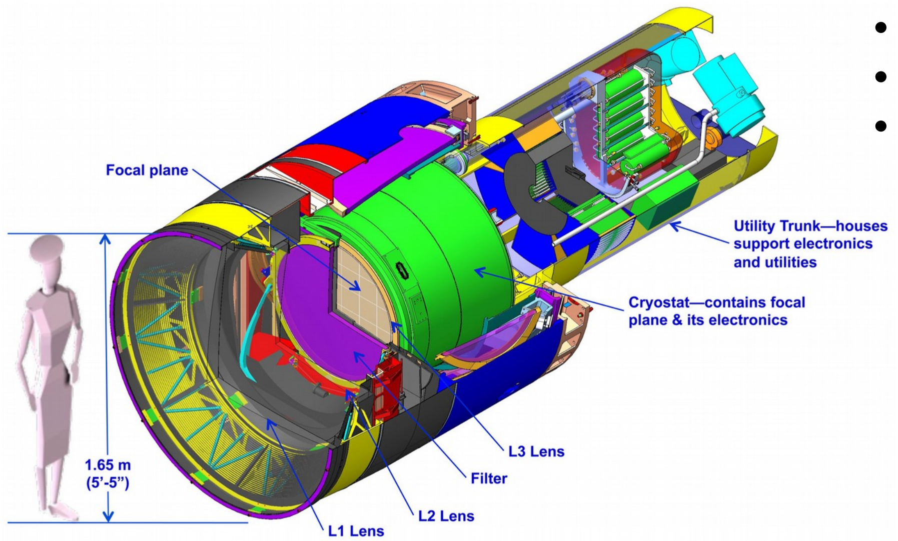


Telescope

- 8.4 m (6.7m effecif)
- Fully corrected (sphericity, coma, astigmatisme)
- A 350 tons mobile structure

Camera

- 3.2 billion pixels @ 0.2 arcsecond / pixel
- 21 rafts
- 9 CCD / raft



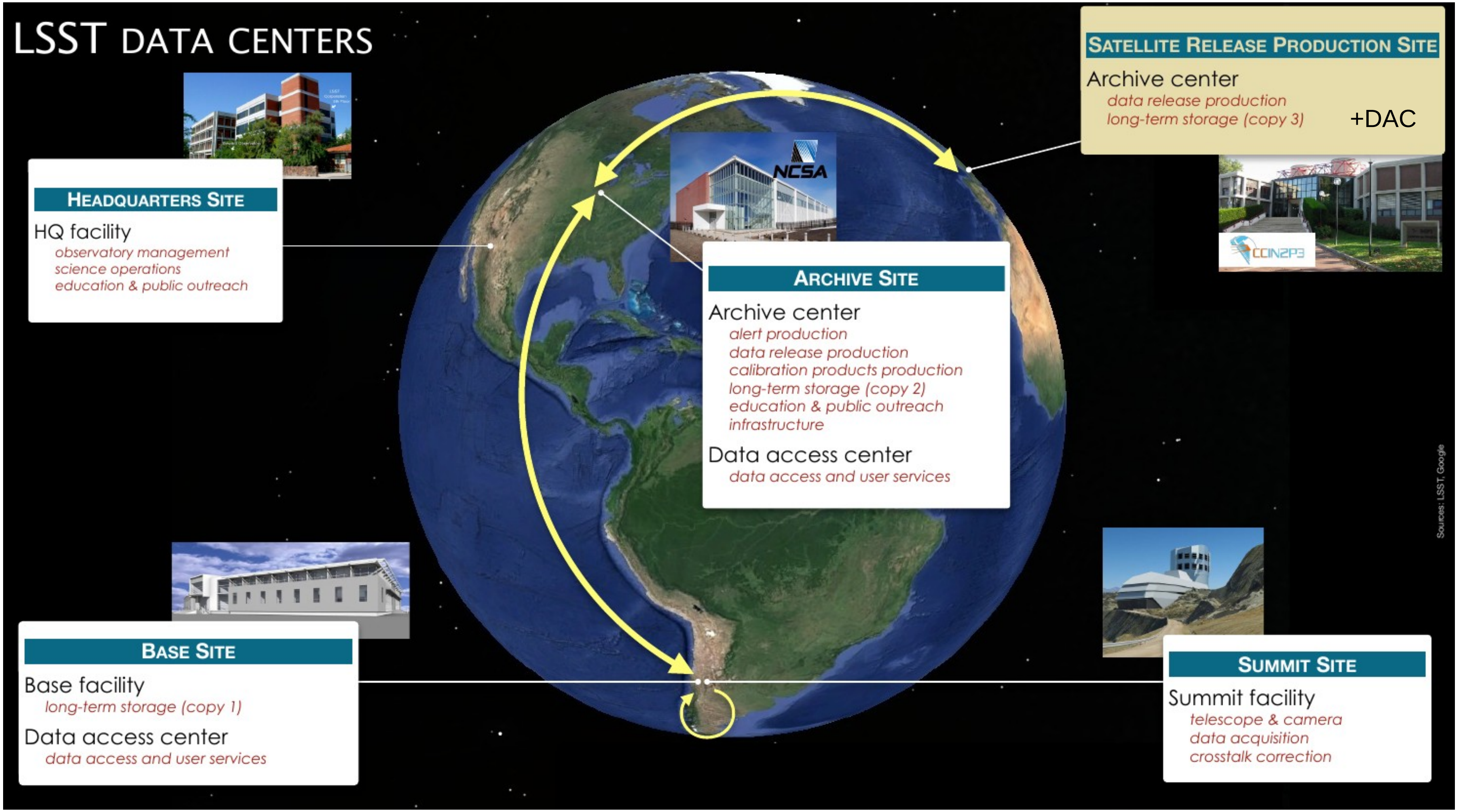
Camera ¾ Section

Surveys

- **Timing**
  - 1 visit = 2 successive exposures
    - CCD Exposure: 15 s
    - CCD readout: 2 s
    - Shutter positioning : 1 + 1 s
    - Telescope slewing : 5 s (median)
  - Total / visit: 39 s (median) – 44 s (mean)
  - The whole visible sky is imaged every 3 days
  - Alerts on transient events will be available world-wide within 60 sec
    - ~10 millions / night

- **Size**
  - ~15 TB of raw data / night
  - Repeat this during 10 years starting in 2022
  - Final image collection : 0.5 Exabytes

- **Field**
  - Deep Wide Survey: 18,000 deg^2
  - Deep Drilling Survey: ~30 selected fields – 300 deg^2 : ~1 hour /night
  - Mos t of the sky will be covered over 800 times with 2 × 15 sec visits
  - Exposure of the same field are stacked together (co-addition)
    - reach magnitude 27.5



Summit (Pachón) to Base (La Serena) = 2 x 100 Gbps
Base(La Serena) to Archive (NCSA) = 2 x 40 Gbps

Data centers

- Collaboration between IN2P3 and LSST / NCSA
  - 50 % of the data processing → annual catalogs production
  - Integral copy of all data at CC-IN2P3
  - A 20 Gb/s dedicated link already deployed
- Explore standard transport protocols for bulk file transfer over high-latency network links
  - Goal: understand what will be possible to use for transferring data between CC-IN2P3 and NCSA for the 2020-2030 era
  - Test HTTP2 as an underlying transport protocol
- Test Object Store technologies to determine if they are suitable for LSST use cases
  - OpenStack Swift and CEPH

LSST Software Stack

- Goal: develop a full modular, efficient and versatile image analysis framework

- LSST software stack is largely written from scratch, in Python, unless computational demands require the use of C++
  - **C++**:
    - Computationally intensive code
    - Made available to Python via SWIG
  - **Python**:
    - All high-level code
    - Prefer Python to C++ unless performance demands otherwise
  - All the code is, and will stay open source

- But we do not re-invent the wheel
  - Use of standards (fits,…)
  - Implantation of algorithms developed by others (SDSS,…)
  - Interfaced with existin software (psfex, GalSim,…)

- Modularity
  - Virtually everything is a Python module
  - ~60 packages (git repositories, ~corresponding to python packages)

- Designed to support several instruments: LSST - SDSS – HSC – CFHT – DES

Data from the user's perspective

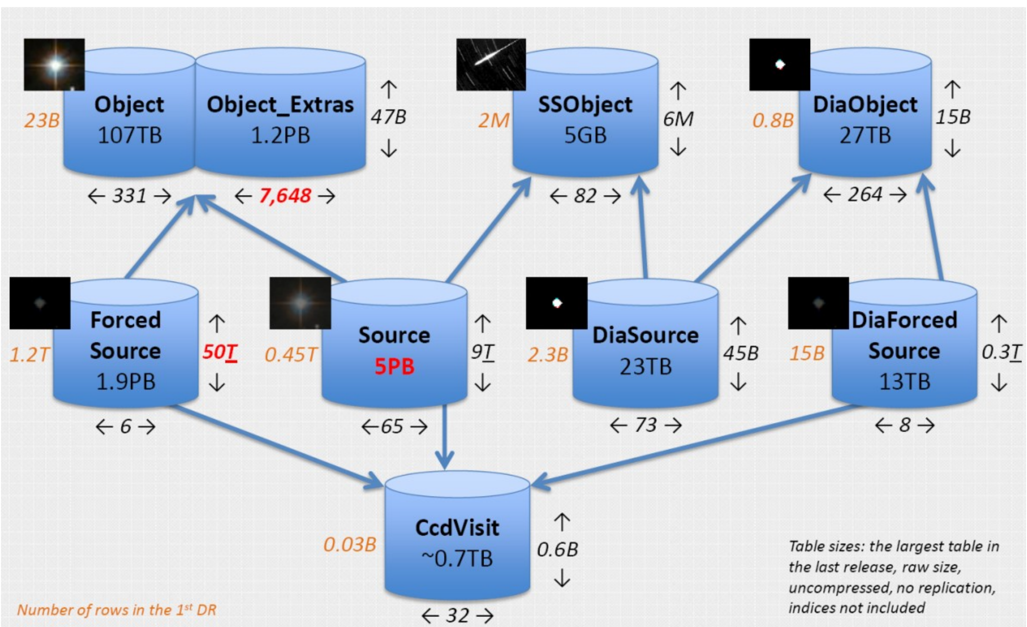
Three data product levels

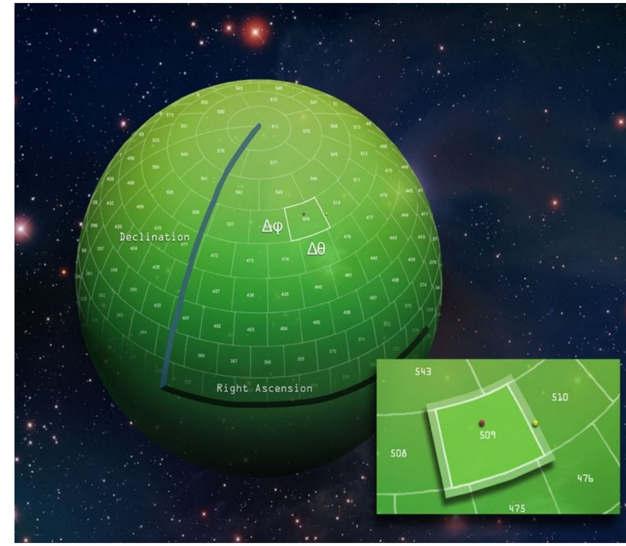
	Level	
– A stream of ~10 million time-domain events per night, detected and transmitted to event distribution networks within 60 seconds of observation. – A catalog of orbits for ~6 million bodies in the Solar System.	Level 1	Nightly data product
– A catalog of ~37 billion objects (20B galaxies, 17B stars), ~7 trillion observations ("sources"), and ~30 trillion measurements ("forced sources"), produced annually, accessible through online databases. – Deep co-added images.	Level 2	Annual data product
– Services and computing resources at the Data Access Centers to enable user-specified custom processing and analysis. – Software and APIs enabling development of analysis codes.	Level 3	User-created data product

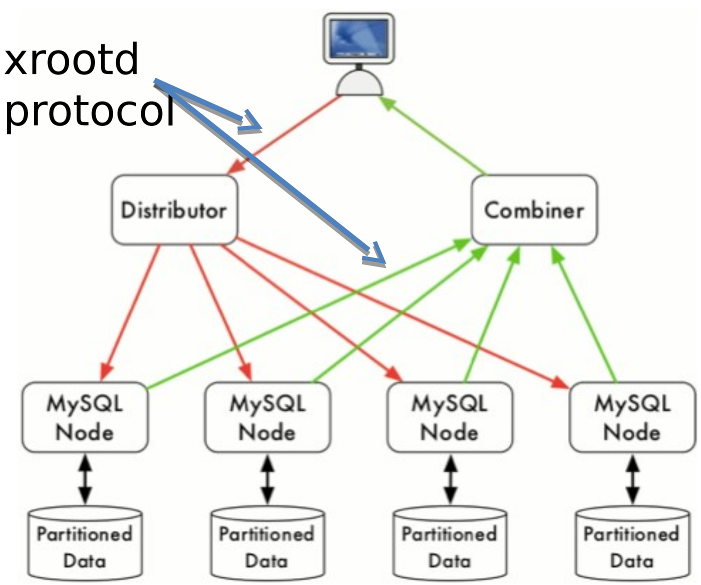
The database: a key component

The challenge is to design an SQL database system able to store trillions of objects while keeping a reasonable access time

Qserv : developed at SLAC + IPAC
Design optimized for astronomical queries







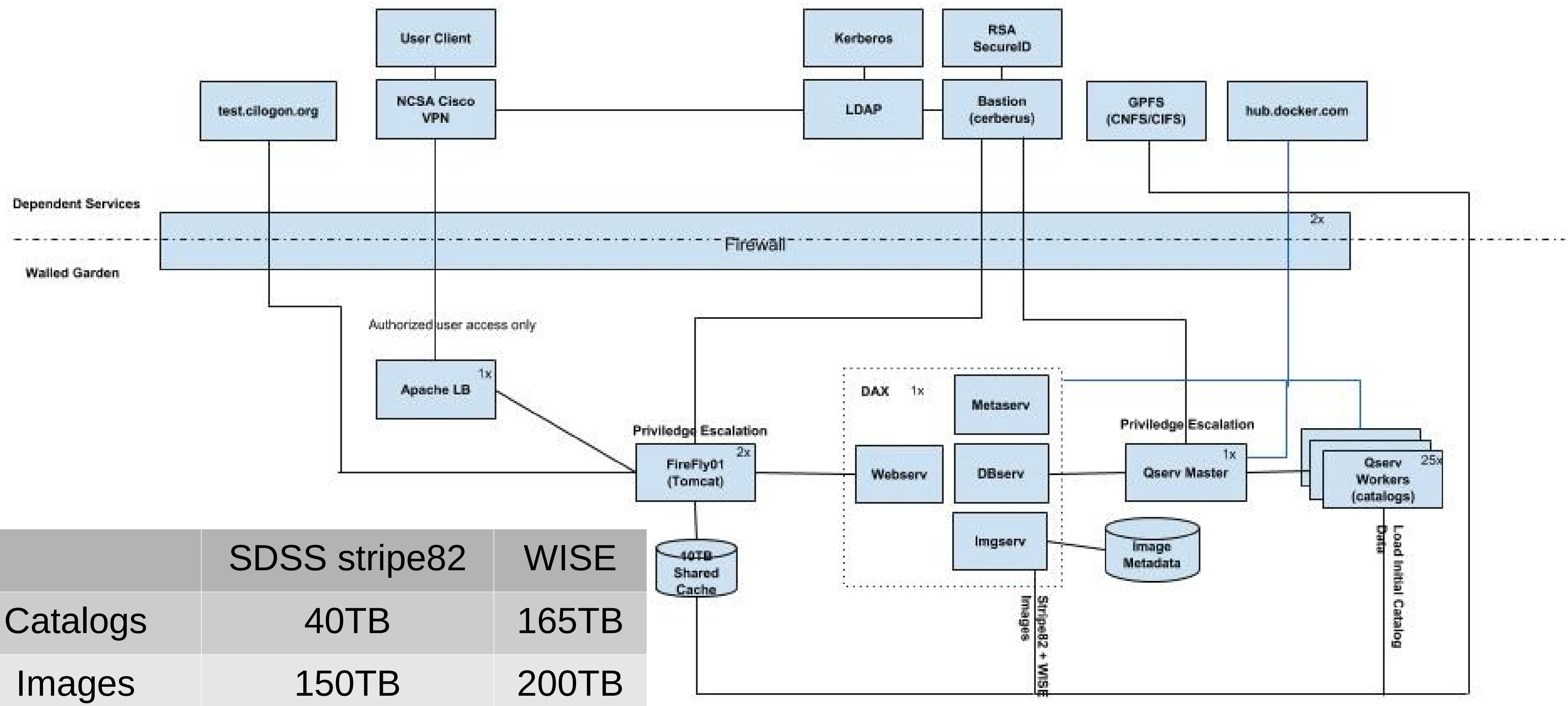
Massively parallel – distributed – fault tolerant **relational database**

Qserv test platform

- Thanks to a partnership with Dell we have deployed a Qserv test bench
- The only test bench currently available in LSST for large scale tests
  - 50 nodes - 400 cores
  - 800 GB memory
  - 500 TB disk storage
  - Non volatile memory devices to front end machines
  - Currently include 35TB or real data
  - Next step: 120TB from the Wide-field Infrared Survey Explorer (WISE)
- Test bench currently replicated at NCSA
- An other computer is lend by DELL for local Qserv tests at CC-IN2P3
  - CPU: 2 x Intel Xeon E5-2680 v4 (2.4 GHz, 35 MB cache, 14 cores, 28 threads)
  - RAM: 512 GB
  - Persistent storage
    - Data: NVMe (2 TB); SSD (3.2 TB): HDD (10 TB)
    - System: 0.6 TB)
  - Network: 10 Gbps
  - Operating system: CentOS 7, /sps/lsst, etc.

Prototype data access center

- Currently under preparation at NCSA
- Will be duplicated at CC-IN2P3 in a few month
- Also used to test the DB replication between the two distant sites



	SDSS stripe82	WISE
Catalogs	40TB	165TB
Images	150TB	200TB
Metaserv DB	< 1TB	< 1TB

Main technical implications

- Tests of the LSST stack
- Validation on real data
- Integration of new algorithms
- Scientific validation of the data base (Qserv) functionality

→ bridge between software and science
→ all these activities have been started quite recently

Summary

- LSST is going to push astronomical data to an unprecedented scale
- Project is approved and will operate in 2022 – 2031
  - Site, camera, mirror, filters all under construction
- LSST is building a new open source, multi-instrument, software stack
  - C++ and Python
  - Currently under development and tested against real data
- A highly distributed / fault tolerant SQL database system to store and give access to the catalogs is being developed: **Qserv**
  - Test on real data (clusters in CFHT images) will start soon
- Yearly Data Release Processing will be split between NCSA and CC-IN2P3
- **Still need to precise how to articulate the LSST use case within OBELICS work packages**

Key numbers

Observation Properties:

The standard visit = 2 x 15 sec. exposures
Exposure sequence = 1 s open shutter + 14 s dwell + 1 s close shutter = 16 s
Visit sequence = 16 s exp + 2 s readout + 16 sec exp = 34 s
(second readout concurrent with slew)
Median slew time between visits = 5 s
Average slew time between visits = 12 s
Visits per night = "about a 1000"
Calibration exposures = 450/day
Data collected per 24 hr period = "about 15 TB"

Network bandwidths:

Summit (Pachón) to Base (La Serena) = 2 x 100 Gbps
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Alert Production:

Real-time alert latency = 60 seconds
Average number of alerts per night= "about 10 million"

Data and compute sizes:

Final image collection (DR11) = 0.5 Exabytes
Final database size (DR11) = 15 PB
Final disk storage = 0.4 Exabytes
Peak number of nodes = 1750 nodes
Peak compute power in LSST data centers = 1.8 PFLOPS

Data Releases:

Number of Data Releases = 11
DR1 release = Date of Operations Start+ 12 months
Estimated numbers for DR-1 release
- Objects = 18 billion
- Sources = 350 billion (single epoch)
- Forced Sources = 0.75 trillion

Estimated numbers for DR-11
- Objects = 37 billion
- Sources = 7 trillion (single epoch)
- Forced Sources = 30 trillion
- Visits observed = 2.75 million
- Images collected = 5.5 million

More on the LSST webpage