LSST Data Processing : A Customer's View

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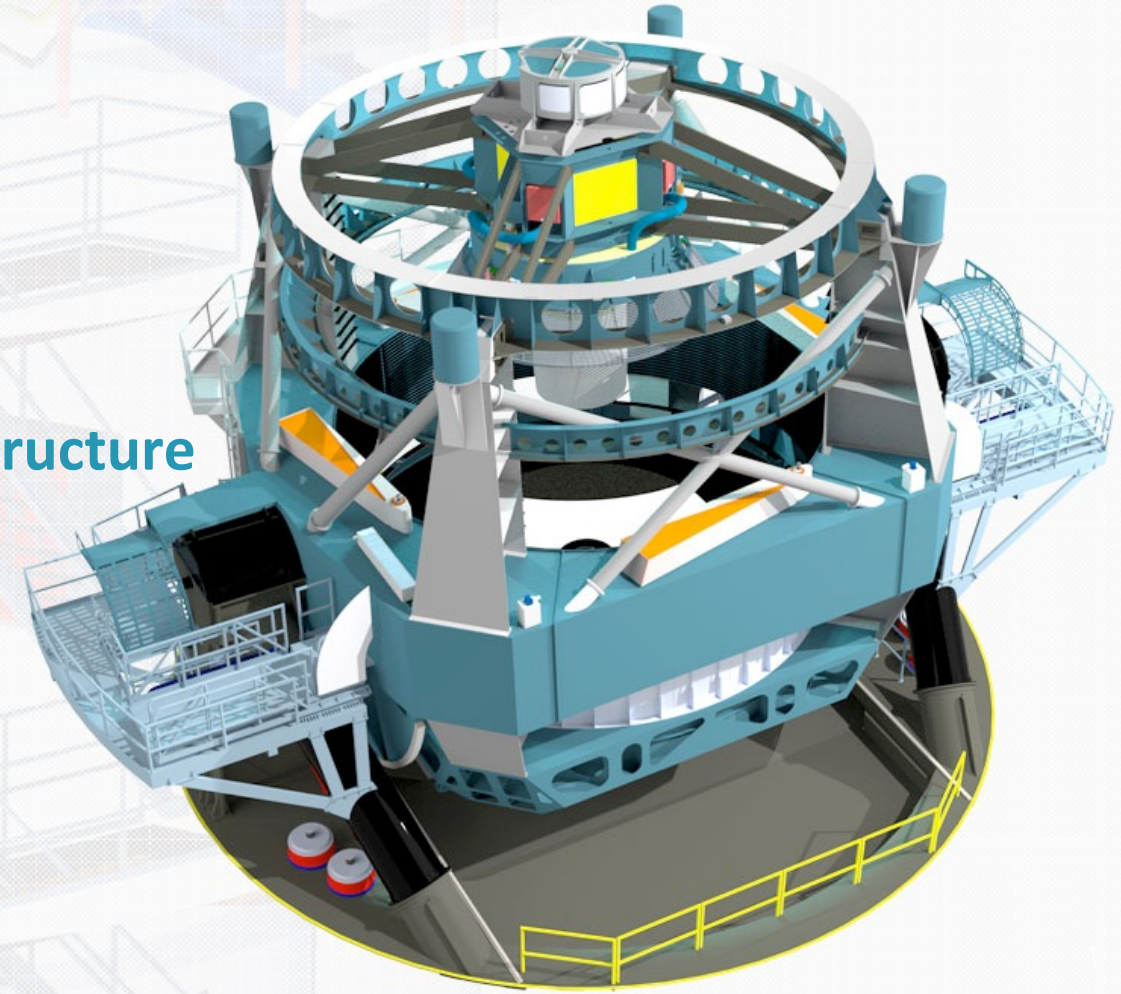
DESC Computing Infrastructure co-lead



LSST DESC Dark Energy Science Collaboration

What is LSST?

- A telescope:
  - 8.4 m primary mirror, 3.2 Gpix camera, 6 filter bands
  - 2x15 sec exposures per visit, 2 sec readout
- Science themes:
  - Dark Energy and Dark Matter
  - Inventory of the Solar System
  - Transient Optical Sky
  - Mapping the Milky Way
- A survey:
  - 10 year survey
  - > 18K sq deg sky coverage (up to 25K with special programs)
  - > 825 visits per point, > 2.75 million visits total

LSST Data Volume and Expected Yields

- Two 6.4-gigabyte images (one visit) every 39 seconds
- ~1000 visits each night, ~300 nights a year
- Up to 450 calibration exposures per day
- ~15 terabytes of raw data in each 24 hour period

- Will detect ~10 million real time events per night, for 10 years
- Changes detected, transmitted, within 60 seconds of each observation

- Observe ~37 billion objects with ~30T forced-photometry measurements across all visits/filters (ForcedSources)
- Collect ~7 trillion observations in individual visits

LSST Data Management Responsibilities

- Process the incoming stream of images that the Camera system generates to **produce transient alerts** and to **archive the raw images**.

- Approximately once per year **create and archive a Data Release**, a static self-consistent collection of data products generated from all survey data taken from the date of survey initiation to the cutoff date for the Data Release.

- **Make all LSST data available** through an interface that uses community-accepted standards, and **facilitate user data analysis and production of user-defined data products** at Data Access Centers (DACs) and external sites.

Data Product Requirements: Level 1,2,3

p. 32, LSST SRD, http://ls.st/srd
Details in the DPDD

3.5 Data Processing and Management Requirements

Detailed requirements on data processing and management will be described in the LSST System Requirements Document (for example, specifications for catalog completeness and reliability). Here, only a rough guidance is provided. There will be three main categories of data products:

- **Level 1** data products are generated continuously every observing night, including alerts to objects that have changed brightness or position.

. . . Nightly

- **Level 2** data products will be made available as annual Data Releases and will include images and measurements of positions, fluxes, and shapes, as well as variability information such as orbital parameters for moving objects and an appropriate compact description of light curves.

. . . Annual

- **Level 3** data products will be created by the community, including project teams, using suitable Applications Programming Interfaces (APIs) that will be provided by the LSST Data Management System. The Data Management System will also provide at least 10% of its total capability for user-dedicated processing and user-dedicated storage. The key aspect of these capabilities is that they will reside "next to" the LSST data, avoiding the latency associated with downloads. They will also allow the science teams to use the database infrastructure to store their results.

. . . User-driven

LSST DM From a Scientist's Perspective

- A stream of ~10 million time-domain events per
  transmitted to event distribution networks withi
  observation.
- A catalog of orbits for ~6 million bodies in the So

All data available simultaneously to US, Chile, and international partners

Level 1

- 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

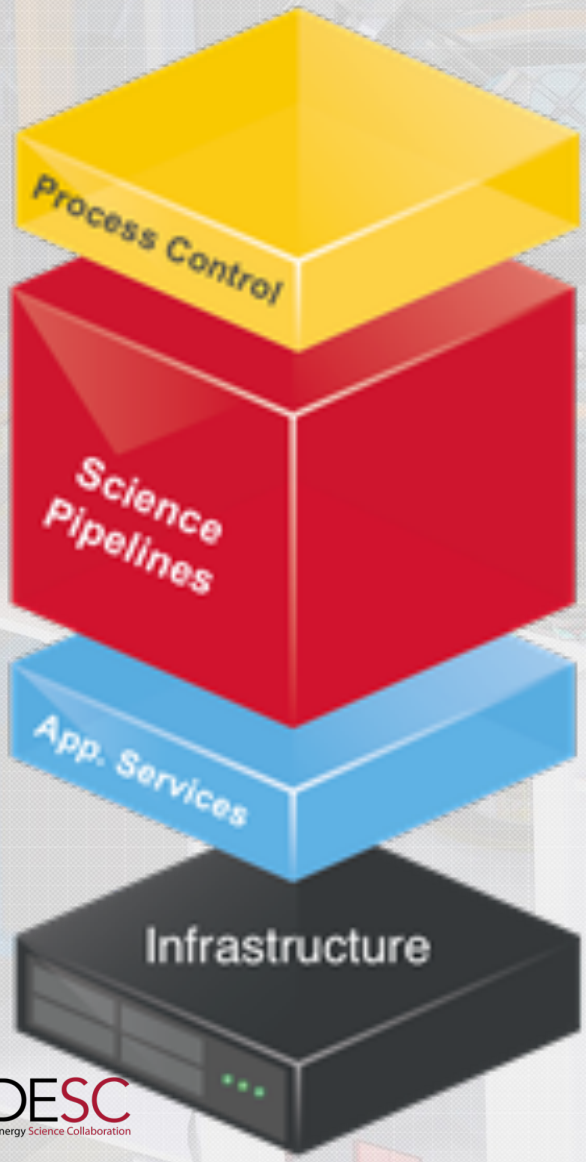
- Services and computing resources at the Data Access Centers to enable user-specified custom processing and analysis.
- Software and APIs enabling development of analysis codes.

Level 3

Level 2 Data Products

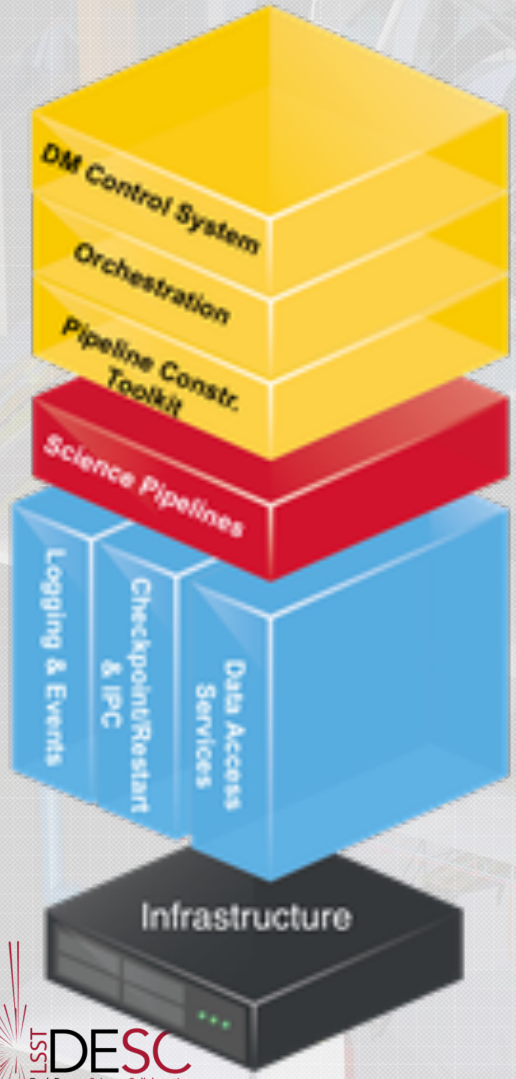
- **Well calibrated, consistently processed, catalogs and images**
  - Catalogs of objects, detections, detections in difference images, etc.
- **Made available in *Data Releases***
  - Annually, except for Year 1
    - Two DRs for the first year of data
- **Complete reprocessing of all data, for each release**
  - Every DR will reprocess ***all*** data taken up to the beginning of that DR
- **Accessing the catalogs**
  - Database and SUI
  - Remote access APIs, VO protocols (e.g., Table Access Protocol)

State-of-the-art Scientific Algorithms



- Science Pipelines carry core scientific algorithms that process or analyze raw LSST data to generate output Data Products
- Open Source!
- Variety of processing
  - Image processing
  - Measurement of source properties
  - Associating sources across space and time, e.g. for tracking solar system objects

Complex Middleware



Orchestrating execution of science pipelines on hundreds of thousands of cores

- Frameworks to construct pipelines out of basic algorithmic components
- Orchestration of execution on thousands of cores
- Control and monitoring of the whole DM System
- Evaluating open source workflow engines now: 3 candidates
- Airflow, Pegasus, PanDA (LHC-ATLAS)

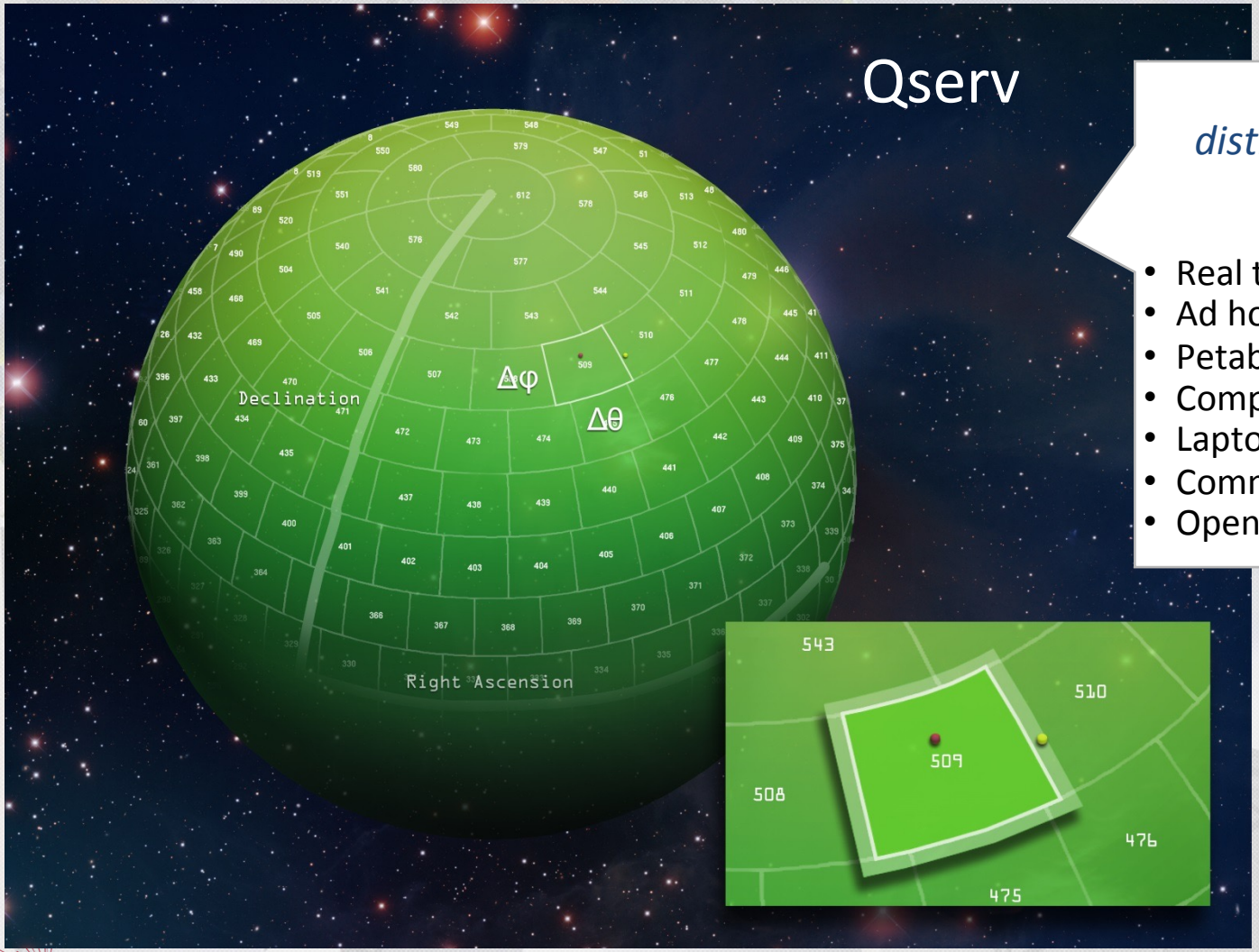
NCSA

Isolating science pipelines from underlying hardware

- Services used by pipelines to access/produce data and communicate
- "Common denominator" interfaces handle changing underlying technologies
- Example: “Butler” for abstracting away data storage

SLAC

Massively Parallel, Scalable Database for Spherical Data



Massively parallel, distributed, fault-tolerant ***database***

- Real time for L1
- Ad hoc user query analysis
- Petabyte level scans
- Complex correlations
- Laptop scale to petascale
- Commodity hardware
- Open source

Cutting-edge Visualization and Science User Interface Toolkit

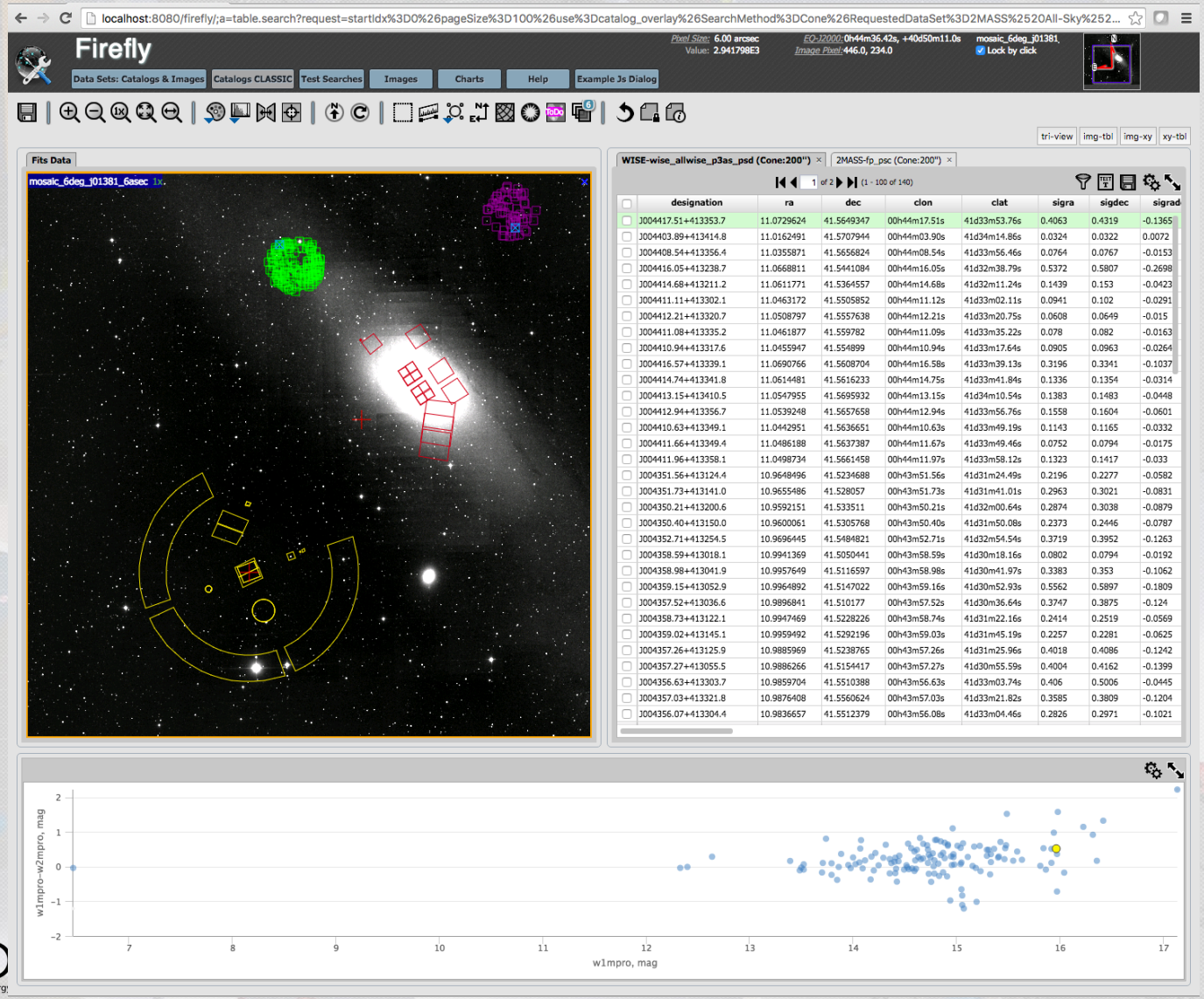


Image Processing Overview

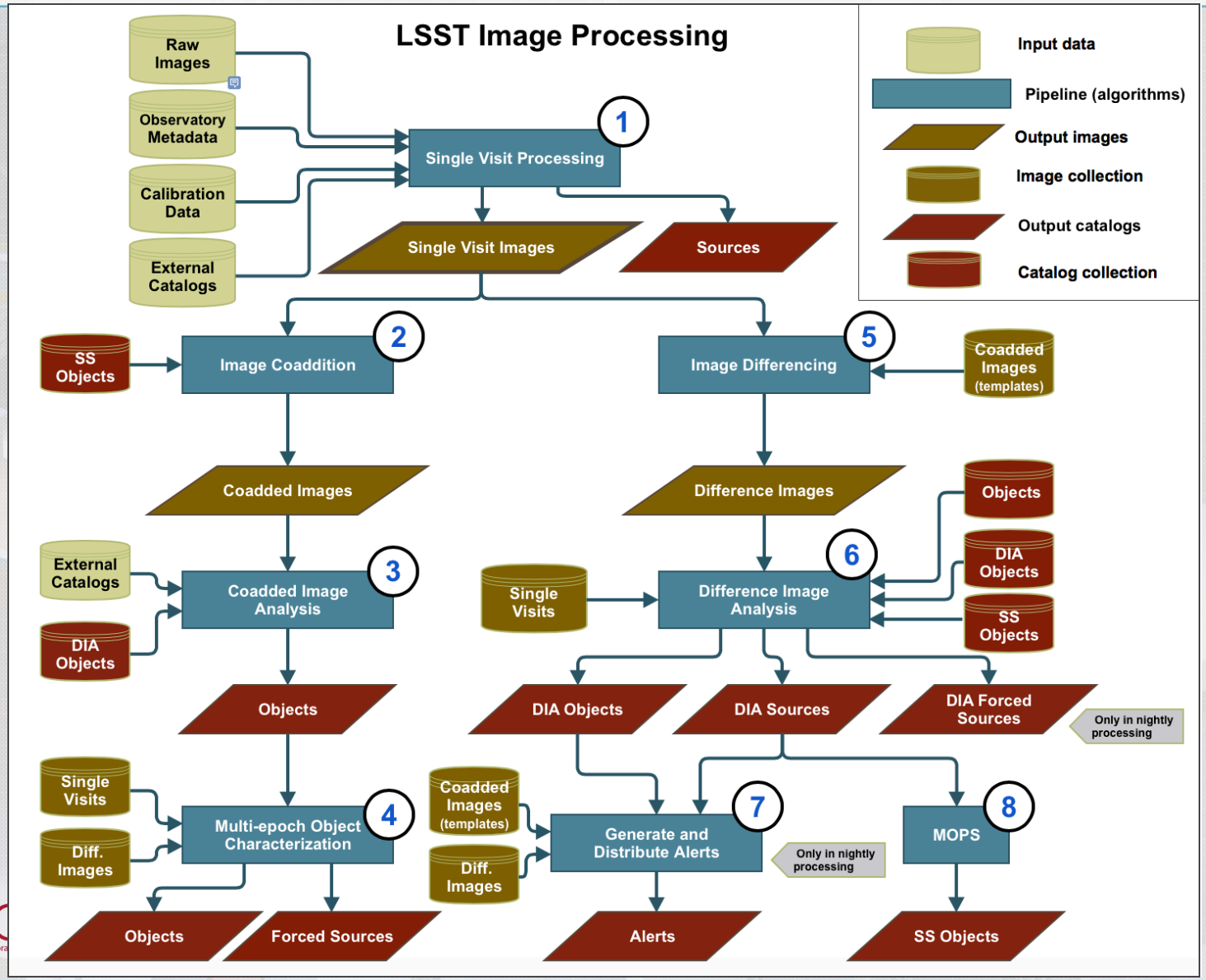
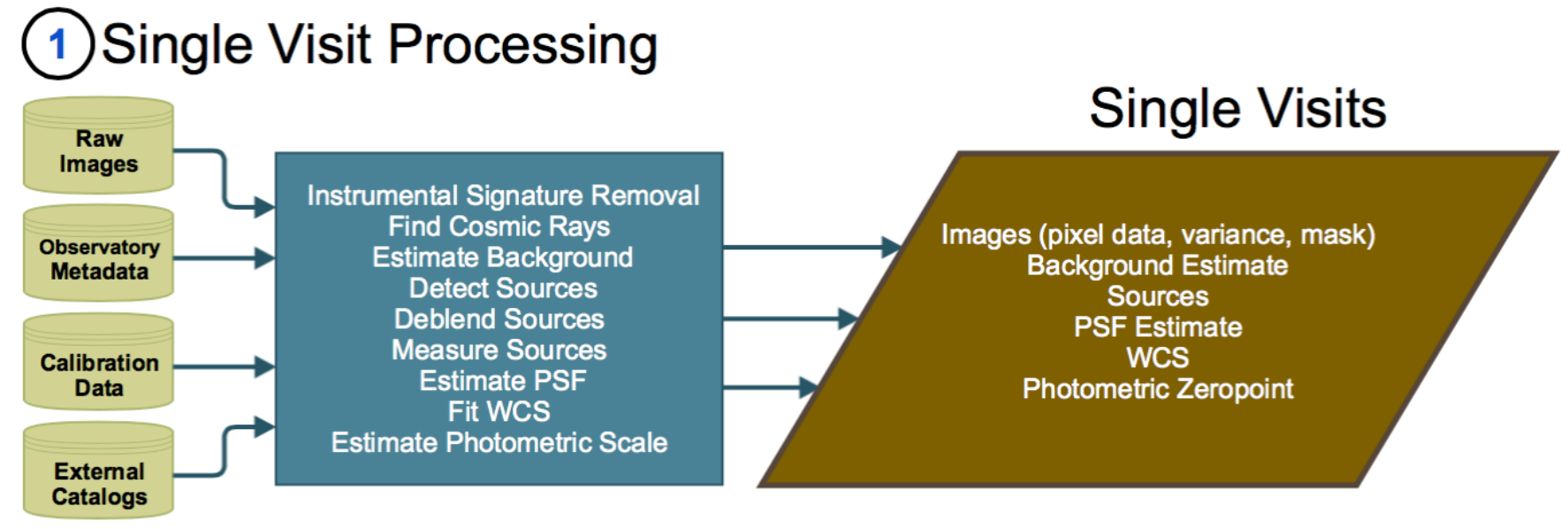


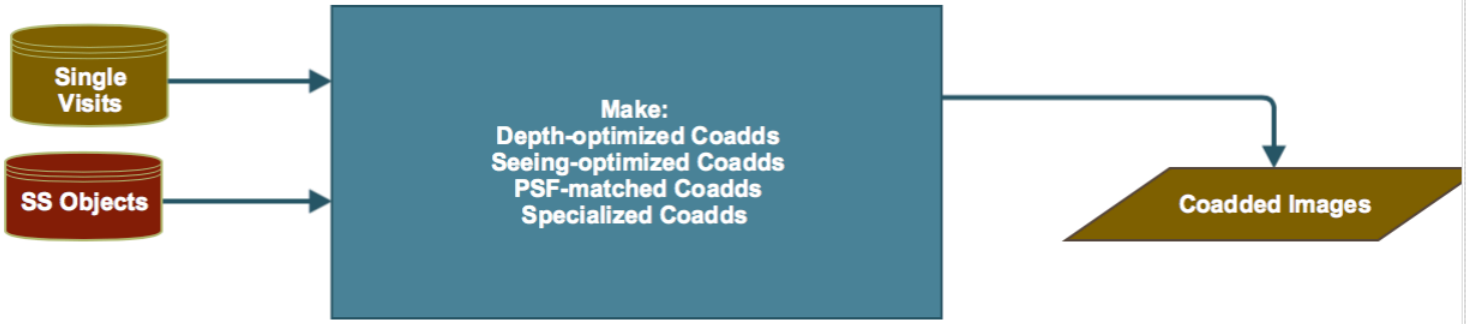
Image Processing Detail: Single visits



Designed to handle instrumental effects, variations of the PSF due to seeing, etc

Image Processing Detail: Co-add Analysis

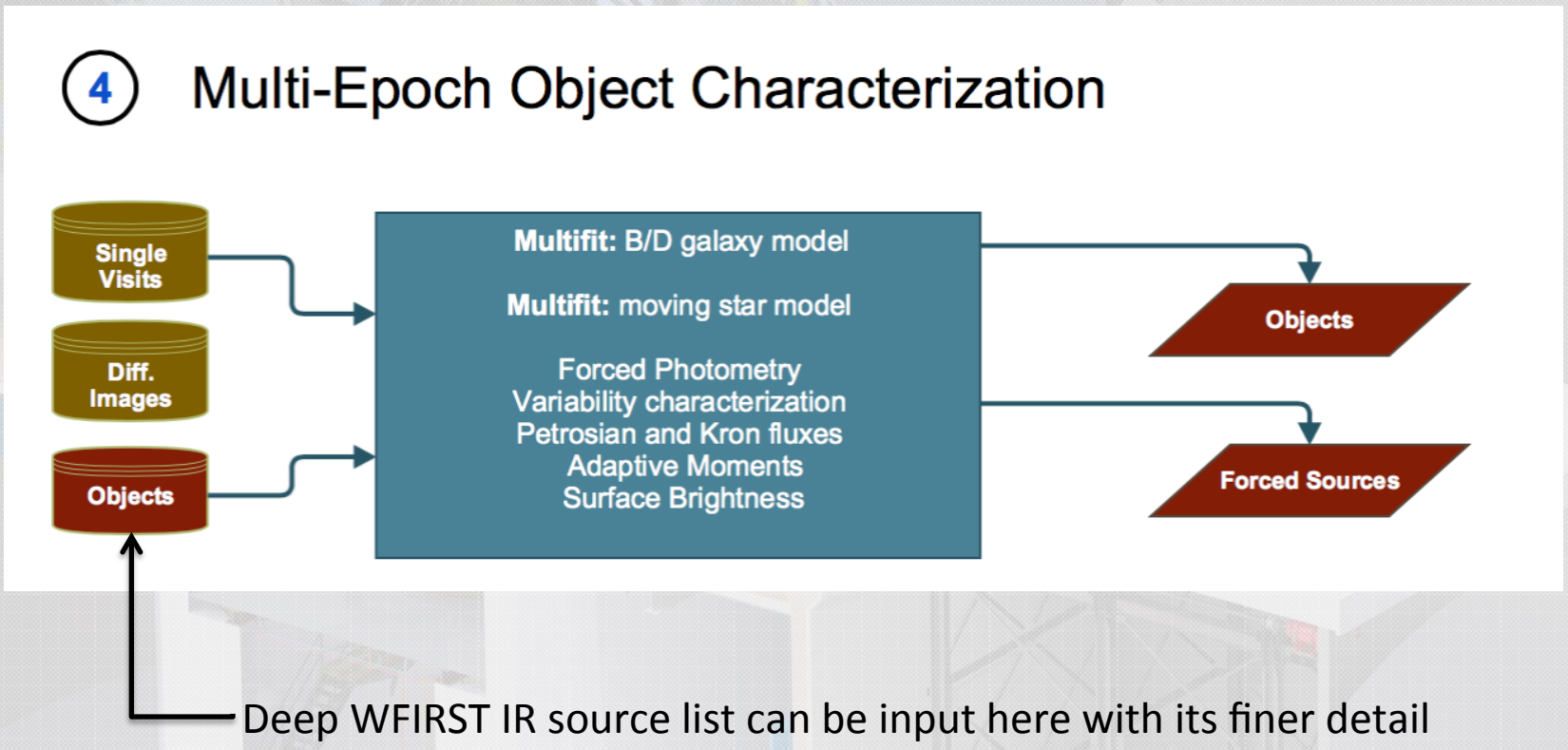
2 Image Coaddition



3 Coadd Image Analysis

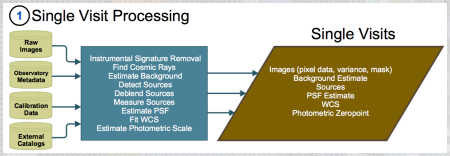
WFIRST could contribute to deblending

Image Processing Detail: MultiFit



Processing Numerology: CPU Needs Estimate

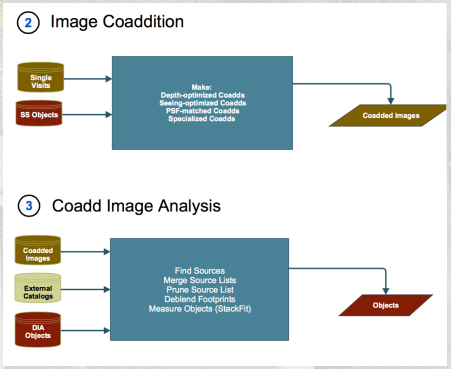
Total processing time for L2: ~120M CPU-hrs for 1 year's survey – O(18000 sq deg, 300k visits)



7% - 8.4M CPU-hrs

Ballpark:

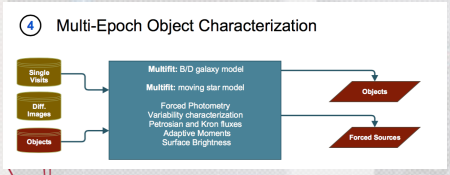
~2200 sq-deg/yr WFIRST x4 passes (184 sec) yields ~150k images



2 - Scales with images (1/2)

30% - 36M CPU-hrs

3 - Scales with sky area (1/8)



60% - 72M CPU-hrs

4 - Scales with images (1/2)

Guess at 30-40% additional processing load.

Gigabit Networks

French Processing Center

(CC-IN2P3, Lyon, France)

Data Release Production (50%)

French DAC

Archive Site

Archive Center

Alert Production

Data Release Production (50%)

EPO Infrastructure

Long-term Storage (copy 2)

US Data Access Center

Data Access and User Services

HQ Site

Science Operations

Observatory Management

Education and Public Outreach

Summit and Base Sites

Telescope and Camera

Data Acquisition

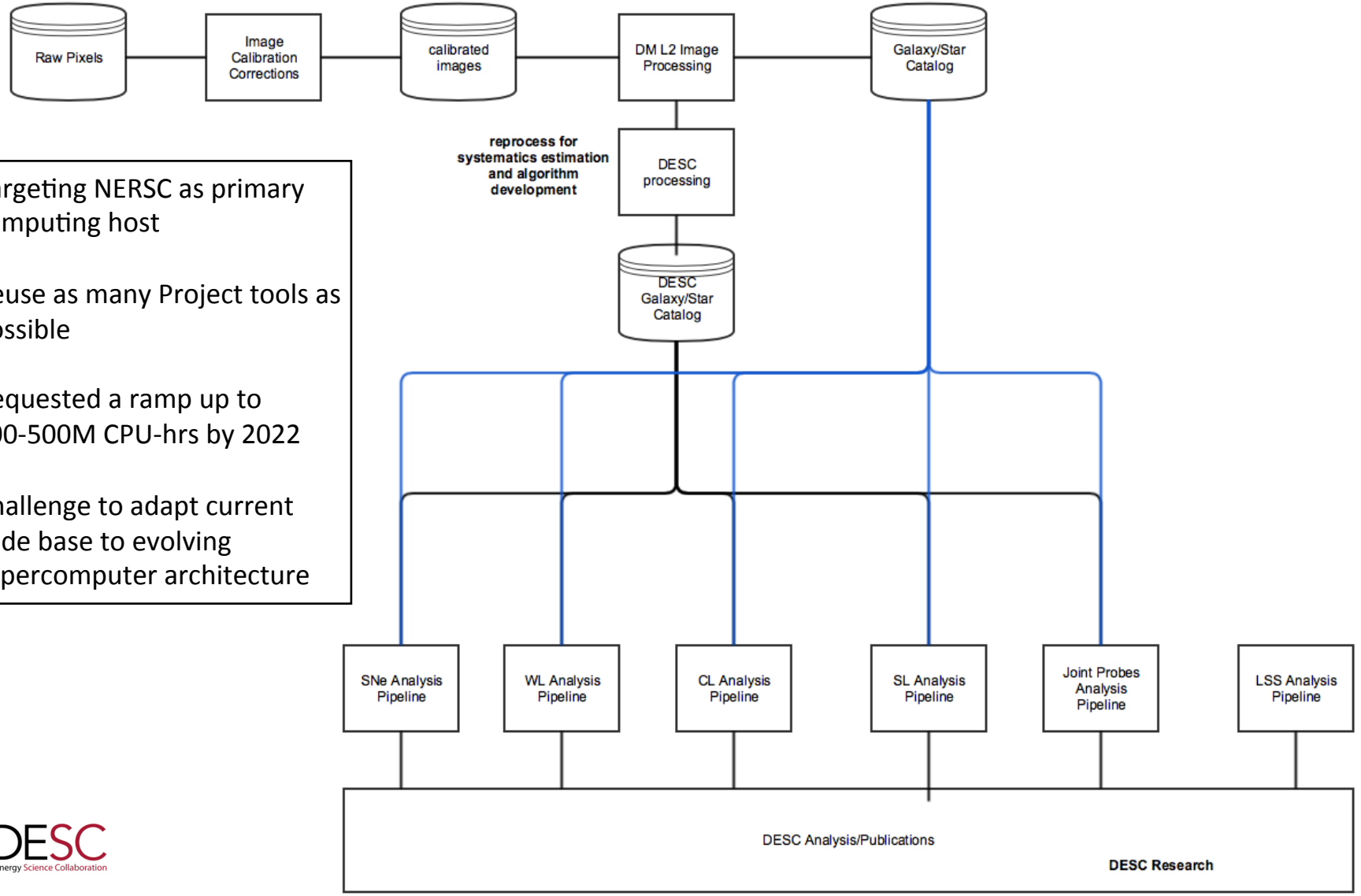
Crosstalk Correction

Long-term storage (copy 1)

Chilean Data Access Center

DESC Computing Model

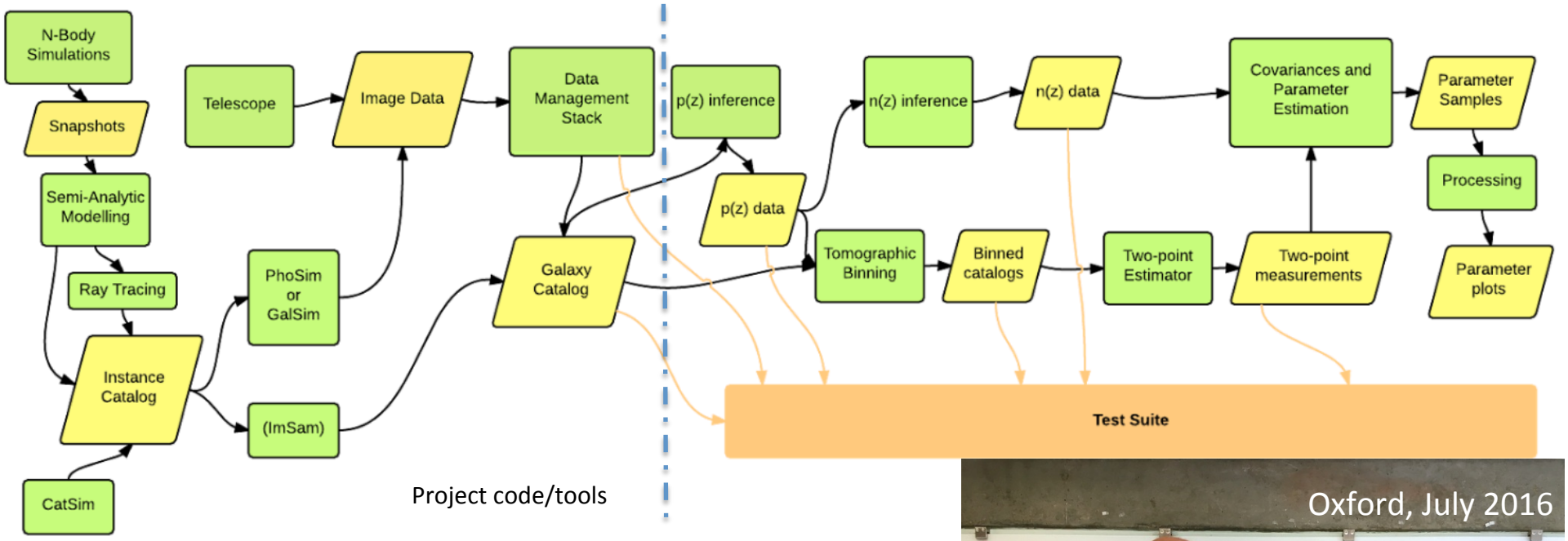
- Targeting NERSC as primary computing host
- Reuse as many Project tools as possible
- Requested a ramp up to 300-500M CPU-hrs by 2022
- Challenge to adapt current code base to evolving supercomputer architecture



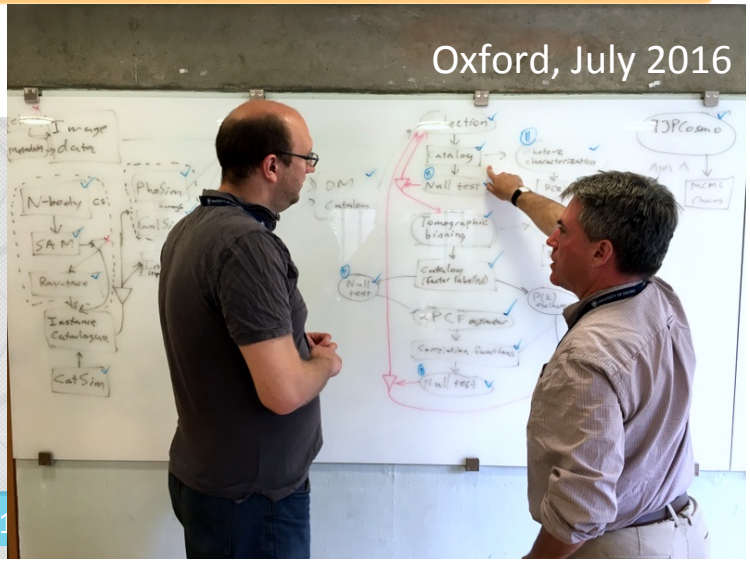
DESC Preparedness Strategy: Pathfinders and Data Challenges

- Preparation timeline driven by 3 Data Challenges, ComCam and Science Verification
  - Expecting a reasonably complete DM release for ComCam
- Early Pathfinders:
  - "Twinkles" : SL/SNe-driven sky through light curve chain, driver for
    - Expertise with input catalogs, image simulation, DM stack, light curve extraction from Qserv database
    - Bulk workflow tools to drive pipelines
    - Distributed code development environment
    - Try out SUIT
  - Weak Lensing pipeline : high level analysis chain
    - Development of analysis framework
    - Use of workflow tools

Example of Early Pipeline Development: Weak Lensing



Project code/tools



Summary/Questions

- DM is producing Open Source tools for image processing and shape analysis; data access; and database analysis
  - Timeframe for functional system is ComCam – 2019
  - DESC is depending on using as much of the toolkit as possible
- In principle the tools are designed to handle images with different PSFs etc
- It appears that a joint processing would add something like a 30-40% load on top of the first few years of LSST DRPs

Thanks to K-T Lim and Gregory Dubois-Felsmann for advice!