LSST Data Management
Jacek Becla
(interim) DM Project Manager

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LSST in a Nutshell

- Decade-long, deep, wide, fast time-domain survey of optical sky
  - Highest ranked project in 2010 Decadal Survey

- Consists of
  - 8-meter class wide-field ground based telescope
  - 3.2 Gpix camera
  - Automated data processing systems

- Construction funding
  - Telescope & Site, DM, EPO funded by NSF, MREFC, $473M
  - Camera fabrication funded by DOE, MIE, $168M

- Science themes driving LSST requirements:
  - Taking a census of moving objects in the solar system
  - Mapping the structure and evolution of the Milky Way
  - Exploring the transient optical sky
  - Determining the nature of dark energy and dark matter
Located in Central Chile
Commissioning in < 3 years

|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|

- Early Start of NSF MREFC Funding
- Federal Budget Approved
- Nominal Start of NSF MREFC Funding
- Late Start of NSF MREFC Funding

Adjust Start for 1 August and Transition to MREFC

Operations Review

- Operations Plan Review
- Submit Operations Proposal

Start Early Commissioning with ComCam

Install Camera

Science Verification

Early Completion

Start Early System Integration and Test (ComCam)

Early System Integration and Test (ComCam)

ComCam Commissioning Complete

Full System Integration and Test

System Integration Test Complete

System First Light

Start Science Verification

Science Verification Complete

MREFC Program Complete

April 1, 2019 Early Ops Start

13 Mo Contingency

Start of Early Operations Funding

Early Operations Phase

Start of Full Science Operations
LSST DM From a Scientist’s Perspective

- 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.
- 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.

- 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.
Infrastructure: Petascale Computing

Running processing pipelines
- Dedicated data center
- Process images in real-time to detect changes in the sky
- Produce annual data releases

Data Access Centers will provide end-user analysis capabilities and serve the data products to LSST users
Setting up a Prototype DAC at NCSA

1. Compute and storage resources in OpenStack cluster.
2. 1000-core processing cluster and 2.5-PB GPFS storage for QA and verification testing, stack development.
3. 30-node qserv database and SUI service integration environment
4. Infrastructure for testing object storage technologies and inter-site data transfer.
**Long Haul Networks** to transport data from Chile to the U.S.

- 200 Gbps from Summit to La Serena (new fiber)
- 2x100 Gbit (minimum) for La Serena to Miami, FL (protected, existing fiber)
- Add’l 100 Gbit link Santiago, Chile to Boca Raton, FL
State-of-the-art Scientific Algorithms

- Science Pipelines carry core scientific algorithms that process or analyze raw LSST data to generate output Data Products

- Variety of processing
  - Image processing
  - Measurement of source properties
  - Associating sources across space and time, e.g. for tracking solar system objects
Prototype LSST Science Pipelines Are Running on HSC Survey …

HSC "ultra deep" gri imaging in COSMOS, with a total of 1.5 hours in g and r and 3 hours in i; (280/550 LSST visits).

The visits were processed, calibrated, registered, added, and the resulting coadds processed using the LSST stack.

These catalogues are being used to carry out first-year HSC science.

Processing data at scale:

**HSC Survey S16A Data Release**

**Exposures:** 8192 images  
(note: deeper than LSST, exposure time is ~minutes)

**Areal coverage:** 174 deg$^2$

**Total data volume:** ~200TB

**Notes:**
- Using a fork of LSST science pipelines adapted to HSC camera (will not be necessary as of Dec’16)
- Using HSC-Survey’s orchestration middleware

*Credit: HSC collaboration, Robert Lupton and LSST DM @ Princeton.*
High-redshift quasars selected from the HSC `wide' data (10 minutes per band in gr and 20 minutes in /izy/; equivalent to 30 and 60 LSST visits, respectively).

Followup spectra were taken at Subaru, resulting in the discovery of second-highest known QSO redshift.

Credit: Yoshii Matsuoka et al. 2016.

HSC has been a good test bed for early LSST technology. Both HSC and LSST benefited.
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

Isolating science pipelines from underlying hardware

- Services used by pipelines to access/produce data and communicate
- "Common denominator" interfaces handle changing underlying technologies
Massively Parallel, Scalable Database for Spherical Data

- Ad hoc user query analysis
- Petabyte level scans
- Complex correlations
- Laptop scale to petascale
- Commodity hardware
- Open source
Qserv

- Home-grown, specialized, shared-nothing query service
- Relies on MySQL and XRootD
  - XRootD used for scheduling queries and communication
- Unique state-of-the-art features:
  - Special optimizations for concurrent scans
  - Spherical geometry
- Reaching beta state
Cutting-edge Visualization

Firefly – Open source WEB UI Framework, for building web-based interactive, exploratory analytics for large science archives

Exposing native JS API, can easily embed Firefly widgets into HTML pages (e.g. IPython notebooks)

Industry standard build/deployment tools (npm, webpack)

Note: To be deployed in production at IRSA in November 2016
It Has to Run. Reliably.
DM Team

- Distributed team
- ~60 FTEs / 80+ people
- Mix of domain-experts and software engineers
- Hiring and on-boarding almost complete
- ~5x expansion comparing to start of MREFC
Computing in Astronomy and HEP – what is similar and what is not?
Data

- **Size**
  - HEP produces more data, Astro is catching up (LSST, SKA)

- **Model**
  - Astro data structures simpler, fit RDBMS
  - But some queries don’t!

- **Cross-survey**
  - Astro data from other surveys correlate well

- **Standardization**
  - Significant efforts in Astro (VO, ADQL, TAP)

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**LSST:**

- O(100) PB all databases
- Largest data release o(10) PB
- Images O(400) PB
  - Virtual and persisted
Software

- Many similarities
  - Open source & tools
  - Data reduction
  - Pipelines
  - Data releases
  - User-facing frameworks, well defined APIs
Infrastructure

- Tiered data centers
  - HEP ahead, Astro starts to follow
- Dedicated long-haul networks
- Cloud anyone?
Data Analysis in Astro

- Wide range of users in Astro
  - Professional astronomers, amateur astronomers, classrooms, public

- Wide range of questions
  - Complex full-sky correlations, scans, simple selections

- Wide range of tools
  - SQL, iPython, Jupyterhub
Summary

- Computing in astronomy
  - Large scale / distributed
  - Some unique challenges
  - Many commonalities with HEP computing

Let’s collaborate more!