Computing for ngVLA: Lessons from LSST

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A Dedicated Survey Telescope

- A wide (half the sky), deep (24.5/27.5 mag), fast (image the sky once every 3 days) survey telescope. Beginning in 2022, it will repeatedly image the sky for 10 years.

- The LSST is an integrated survey system. The Observatory, Telescope, Camera and Data Management system are all built to support the LSST survey. There’s no PI mode, proposals, or time.

- The ultimate deliverable of LSST is not the telescope, nor the instruments; it is the fully reduced data.
  - All science will be come from survey catalogs and images.
Open Data, Open Source: A Community Resource

- LSST data, including images and catalogs, will be available with **no proprietary period** to the astronomical community of the **United States, Chile, and International Partners**

- Alerts to variable sources (“transient alerts”) will be **available world-wide within 60 seconds**, using standard protocols

- LSST **data processing stack will be free software** (licensed under the GPL, v3-or-later)

- All science will be done by the community (not the Project!), using LSST’s data products.
LSST 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.
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Archive Site
Archive Center
Alert Production
Data Release Production (50%)
Calibration Products Production
EPO Infrastructure
Long-term Storage (copy 2)

Data Access Center
Data Access and User Services

HQ Site
Science Operations
Observatory Management
Education and Public Outreach

Satellite Processing Center
CC-IN2P3, Lyon, France

Data Release Production (50%)
French DAC

Dedicated Long Haul Networks
Two redundant 100 Gbit links from Santiago to Florida (existing fiber)
Additional 100 Gbit link (spectrum on new fiber) from Santiago – Florida
(Chile and US national links not shown)

Summit and Base Sites
Telescope and Camera
Data Acquisition
Crosstalk Correction
Long-term storage (copy 1)
Chilean Data Access Center
Infrastructure: Petascale Computing, Gbit Networks

The computing cluster at the **LSST Archive** (at NCSA) will run the processing pipelines.

- Single-user, single-application, dedicated data center
- Process images in real-time to detect changes in the sky
- Produce annual data releases

**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 Champaign, IL (protected, existing fiber)
Science Pipelines: Scientific Core of LSST DM

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

- N.b. also referred to as “Applications”

- Variety of processing
  - Image processing
  - Measurement of source properties
  - Associating sources across space and time, e.g. for tracking solar system objects
Middleware Layer: Isolating Hardware, Orchestrating Software

Enabling 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 the science pipelines from details of underlying hardware

- Services used by applications to access/produce data and communicate
- "Common denominator" interfaces handle changing underlying technologies
Database and Science UI: Delivering to Users

Massively parallel, distributed, fault-tolerant relational database.

• To be built on existing, robust, well-understood, technologies (MySQL and xrootd)
• Commodity hardware, open source
• Advanced prototype in existence (qserv)

Science User Interface to enable the access to and analysis of LSST data

• Web and machine interfaces to LSST databases
• Visualization and analysis capabilities
Distributed Team, SQuaREd

- UI
- Database
- Core Algorithms ("Apps")
- Middleware
- Infrastructure

Science QA & Reliability Engineering (SQuaRE)
Tools and Processes

- Mailing lists, wikis, Confluence, telecons, videocons, ...
- Github
- Jenkins
- JIRA planning and Earned Value
- Licensing and contributions
- Investigating Slack and Discourse
Data Management Planning Process/Levels

**LSST System Requirements and Operations Plans**

- Detailed 6-month plan
- Developed from Agile Process (Epics, Stories)
- Individual resource assignments
- ~100 activities per cycle
- Granularity of activities: 1 – 3 months
- Granularity of steps within activities: 2 – 20 days

**Project Risks & Milestones**

- DM Roadmap (LDM-240)
- High-level picture
- Granularity: 12 months
- Institutional-level resource assignments
- Budgeting
- Earned-value management
- Basis of monthly reports
- Granularity: 3 - 6 months
- 2 x 6-month development/release cycle per year
- 10-20 activities for each cycle

**DM System Requirements and Roadmap**

- PMCS
- Release Plan

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### LSST Data Management Software Development Roadmap (LDM-240)

<table>
<thead>
<tr>
<th>Release</th>
<th>Institution</th>
<th>R4.0</th>
<th>R5.0/5.1</th>
<th>R6.0/6.1</th>
<th>R7.0/7.1</th>
<th>R8.0/8.1 - #1 Release for ComCam</th>
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<td>8/31/18 FY18</td>
<td>8/31/19 FY19</td>
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#### Feature Implementation
- Source detection and measurement of PSF flux, aperture flux, adaptive moments
- WCS determination module capable of fitting WCS to multiple CCDs at a time (in a single visit)
- Snap processing, CR detection and removal
- Improved sky background estimation
- Preliminary deblender

#### Performance Improvement
- WCS terms needed to describe distortions at edges of chips and near the bloom stop
- Astrometric registration of a stack of images
- Pixel-level intensity-dependent PSF correction
- Multi-CCD sky background determination
- Cross-talk removal
- Fringe removal

- Recognition and retention of trails (moving objects) in visit creation
- ISRI functional with as-built CCD and raft characteristics (based on characterization of sensor/raft prototypes)
- Measurement functional with as-built CCD and raft characteristics

#### Major Axes
- Major axes are 12-month cycles x WBS
- Cells represent milestones/major results
- Cells to left are predecessors to cells to the right

### Notes
- http://ls.st/ldm-240
### LDM-240 DM Key Performance Metrics

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- Major axes are 12-month cycles x metric
- Cells represent planned achievement of metric
- Progressively increasing performance from to left to right
- SRD minimum spec is met first, then design spec, then (if applicable) stretch
EV Data Flow

1) Create Epics In JIRA

2) Complete Resource Loading Workbook

3) Epics and resources are loaded into Primavera

4) Resource time-phasing is Baselined in Cobra as the Budget (BCWS)

What systems supply these numbers???

<table>
<thead>
<tr>
<th>WBS / WP</th>
<th>Budget BCWS</th>
<th>Earned BCWP</th>
<th>Actuals ACWP</th>
<th>SV</th>
<th>CV</th>
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1) Status Stories in JIRA Completed

2) Stories are loaded in Primavera as activity steps

3) Status is Integrated into Cobra at the Work Package level and the basis for the Earned (BCWP) Calculation

1) Financial System

2) Deltek Cobra 5

1) Accounting records all actual costs

2) Monthly export of Actuals is loaded into Cobra and is the basis for Actuals (ACWP)

Institution Invoice and WBS/Account Breakout
Roadmap

- 2016: Finish end-to-end, start refining components, developer multipliers, run easily on precursor data
- 2017: Reprocess DES, continuous simulated Alert Production
- 2018: Ready for ComCam
- 2019: Ready for full Camera
- 2020: Ready for Science Verification
Team Culture (emphasis added, truncated)

The **LSST DM community includes LSST-paid staff at multiple institutions and external contributors** from around the world. We have built a strong team that collaborates well. As we hire new people, we want to make sure we are maintaining a healthy, supportive, productive culture. While *culture is best transmitted by daily example*, having some formal standards for conduct can aid newcomers and reinforce good patterns.

Since LSST is an AURA center, the **AURA standards of workplace conduct** provide a starting point. As stated there, we in DM dedicate ourselves to fostering a **civil and inclusive community characterized by mutual respect for the contributions of all individuals**. As a community, we embrace the values in that document, in addition to any **local institutional standards**.
Lessons Learned

- AURA/LSST is in many ways a completely new entity, with inherent start-up activities
- Hiring has been slow, particularly for lead roles
- Team is not yet developing at maximum productivity
- It is hard to mesh scientists, managers, and engineers on one team
- Algorithmic progress is hard to measure and even harder to predict
- Architectures are evolving rapidly: e.g. Cloud, AstroPy, Hadoop ecosystem
- It is hard to balance technical priorities, trading off between performance/scale versus adaptability and usability

- Reorganize work with delayed staffing, relieve current leads of less-critical tasks
- Focus on developer multipliers
- Establish team culture and norms
- Focus on "end-to-end" system
- Document design path and replan
- Track new architectures, maintain portability
- Make sure we don’t accumulate too much “technical debt”