Large Synoptic Survey Telescope

Tony Tyson
LSST Director &
LSST Collaboration
LSST Science Book, v2.0 is available now at www.lsst.org and in print in a few weeks

- Strong case
- 243 authors
- 598 pages
- November publication
- Living document (on lsst.org)
Chapters in the Science Book

– Introduction
– LSST System Design
– System Performance
– Education and Public Outreach

– The Solar System
– Stellar Populations
– Milky Way and Local Volume Structure
– The Transient and Variable Universe
– Galaxies
– Active Galactic Nuclei
– Supernovae
– Strong Lenses
– Large-Scale Structure
– Weak Lensing
– Cosmological Physics
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LSST All Hands Meeting at NCSA
31 Institutional Members of LSST

- Brookhaven National Laboratory
- California Institute of Technology
- Carnegie Mellon University
- Chile
- Columbia University
- Cornell University
- Drexel University
- Google Inc.
- Harvard-Smithsonian Center for Astrophysics
- IN2P3 Labs France
- Johns Hopkins University
- Kavli Institute for Particle Astrophysics and Cosmology at Stanford University
- Las Cumbres Observatory Global Telescope Network, Inc.
- Lawrence Livermore National Laboratory
- Los Alamos National Laboratory
- National Optical Astronomy Observatory
- Princeton University
- Purdue University
- Research Corporation for Science Advancement
- Rutgers University
- Space Telescope Science Institute
- SLAC National Accelerator Laboratory
- The Pennsylvania State University
- The University of Arizona
- University of California, Davis
- University of California, Irvine
- University of Illinois at Urbana-Champaign
- University of Pennsylvania
- University of Pittsburgh
- University of Washington
- Vanderbilt University
Choice of aperture and exposure time

Driven by all four science themes from:
limiting depth, areal coverage, number of exposures and revisit time.

**Single image depth**

**Stacked image depth**

![Graphs showing single and stacked image depth over time and LSST time](image-url)
Camera Specifications

- Pixel count: 3.2 Gpixels
- Pixel pitch: 10 microns
- Readout time: 2 sec
- Nominal exposure time: 15 sec
- Plate scale: 50.9 microns/arcsec
- Focal plane temperature: -100 deg
- Camera rotation angle: ± 90 deg
- Filter change time: 120 sec
The LSST CCD Sensor

16 segments/CCD
189 Science CCDs
8 Guiders, 4 wavefront sensors
3168 Total Camera Outputs
Primary Mirror Fabrication Continues on Schedule

Special hole polishing completed at hardpoints for increased mirror strength

Back surface inspection after final polish

Steel polishing cell delivered and actuator installation has begun
Secondary Mirror Substrate nearly complete at Corning

- Secondary mirror blank will be delivered in November 2009.

M2 substrate after slumping / annealing

Grinding inside bevel before acid etching
Architectural and Engineering Services Procurement Process underway in Chile

- Summit building is on critical path for construction
- Design process and contractor selection to be completed prior to Final Design Review (FDR)
- Plan significant Chilean involvement – NOAO South to contract effort for LSST group

Proposals due end Oct.
The LSST site
DSS: digitized photographic plates

7.5 arcminutes
Sloan Digital Sky Survey
LSST -- almost

40 Galaxies per sq.arcmin
i<25 mag
S/N > 20
LSST survey

- 4 billion galaxies with redshifts

- Time domain:
  - 1 million supernovae
  - 1 million galaxy lenses
  - new phenomena
LSST Science Charts New Territory

Probing Dark Matter And Dark Energy

Mapping the Milky Way

Finding Near Earth Asteroids

opens the time window!
Science requirement: 40 galaxies/arcmin$^2$

Shown:
Weak Lens mass reconstruction using 40 galaxies/arcmin$^2$

$i < 25$ mag
Seeing 0.65”

$10^{14}$ solar mass cluster at $z = 0.53$
Priors and cuts using restricted templates


$i < 25$ “gold” sample: $S/N > 20$

We expect to reduce outliers and bias using surface brightness priors and treating the photo-z as pdfs and not just a number.
Combining four LSST probes

Curvature floating Systematics and Planck priors included

too simple
Comparison of Stage-IV facilities for DE

LSST comparable and complementary to JDEM

Space: x2 resolution & IR

Ground: far more exposures translates directly into control of systematics.

Going to lower surface brightness enables shape measurement of more galaxies

Hu Zhan 2009
Testing general models of dark energy

![Graph showing fractional errors with systematics](image)
First light in 2016, with 3-Gigapixel camera
One 6-Gigabyte image every 17 seconds
30 Terabytes every night for 10 years
200-Petabyte final image data archive anticipated
20-Petabyte final database catalog anticipated
Real-Time Event Mining: ~100,000 events per night, every night, for 10 yrs
Repeat images of the entire night sky every 3 nights
Image simulation lets us validate the system performance

LSST is simulating image performance from end-to-end, including:

- Cosmology + Milky Way + Solar System
- Atmosphere: Turbulence, Refraction, Motion
- Optics: Telescope + Camera
- Focal Plane: Detectors + Electronics

*Image simulations are used during all phases of the project*
LSST construction costs

Total Project Cost: 455M 2009USD

- Telescope $151M
- Contingency $101M
- Data Management $78M
- Camera $86M
- Project Management $17M
- Commissioning $12M
- Education & Outreach $9M
40% of the LSST Annual Operations cost is associated with the data products.
Operations and data budget

The total LSST annual operating budget is $36.7M ($FY’09)
Approximately 40% is Data Management

- Data Management: $14.7M (40%)
- Project Management, EPO, Data Quality: $9.2M (25%)
- Telescope & Camera Operations: $12.8M (35%)

128 FTE’s total
What makes LSST and its data products uniquely valuable?

- Unprecedented survey (2000 x SDSS plus time domain)
- 20 billion objects
- Will constrain the properties of dark energy with unprecedented precision
- High precision, high uniformity
- Open source, open data
- Bridge to CS, Math, Stat
- Promotes and enables research
- Leverages existing facilities
- Needed now
- Movie of the universe opens new windows
- Broader impact
Proposed LSST timeline

Major Project Milestones:

1. Sep 2005 NSF D&D Funding Start
2. Feb 2007 NSF MREFC Proposal Submitted
5. Oct 2011 NSF Critical Design Review; Construction Funding Start
   DOE Critical Decision 2a Review; DOE Acquisition Funding Start
6. Apr 2013 First Camera Raft Complete
7. Aug 2017 First Engineering Light with Eng Camera
   System Integration and Test Begins
8. Mar 2016 Archive Center Complete
9. Sep 2016 System First Light with 3.2 GP Camera
   System Science Validation Begins
11. Apr 2018 First LSST Data Release
12. Oct 2018 Second LSST Data Release