Building the Next Great Science Engine!

Constructing the Large Synoptic Survey Telescope

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Large Synoptic Survey Telescope

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Large Synoptic Survey Telescope (LSST)
To build an observing facility, conduct 10-year survey, process, archive, and serve images and data products.
Major Funding Partners

- NSF: US$ 473 M
- U.S. Department of Energy: US$ 168 M
- LSST Corporation: US$ 30 M
Gravitation distortions of galaxies tell us that most matter is “dark”

Type 1a supernovae tells us the universe is accelerating.
(2011 Nobel Prize in Physics)
Mass-Energy Content of the Universe

Einstein’s Mass – Energy Equivalence:

$$E = MC^2$$

96% of the Universe is stuff we know nearly nothing about!
Egypt – 50BC
Dendera Zodiac

China 710AD
Dunhuang Star Chart

China 1020AD
Su Song

Dutch 17th century
Frederik de Wit
John William Draper – March 1840
First photograph of the moon

100 years later...

1st NGS-POSS photographic sky survey is completed in 1958
First “digital” survey was done by hand

Galaxy counts from 1246 photographic plates
17x17-inch: 6° x 6°

Counts in 1.6 million “pixels” each
10x10 arcmin in size

2 people: Observations and analysis

<10 mins to reanalyze with Galaxy Zoo users?

Shane-Wirtanen 1967
From the 1970s, microdensitometers (PDS) digitized photographic plates storing them on cards or tapes.

The automated plate measuring (APM) machine (APM) from the 1990’s scanned Schmidt plates at 0.5 arcsec resolution in just over 4 hours.

Color ~ Distance
Boyle & Smith invent the Charge Bubble Device at Bell Labs

1969: CCD invented as a shift register
1971: English Electric Valve Company – later to be E2V – invents CCD video camera
1975: Sasson at Kodak invents digital still camera using 100x100 pixel Fairchild device
1976: KH-11 recon satellite launched with 800x800 pixel CCD

First astronomical CCD image
1st Generation CCDs

Circa 1980:

Early CCDs were small, noisy and expensive...

...but, they were very sensitive and linear in their response

400x256 Pixel RCA CCD
1990s a linear universe

CCD cameras enabled a linear digital view without scanning.

Large format CCDs with their 70-90% efficiencies became more competitive than photographic plates.

Mosaic cameras provided coverage that began to match the Schmidt telescopes.
2000-2005: SDSS-I (the first SDSS survey)
2005-2008: SDSS-II
2008-2014: SDSS-III
2014-2020: SDSS-IV

Southern Galactic Cap
Northern Galactic Cap
What if we could discover and observe most everything that changes on sky?

What if we could build a system that could digitally record the whole sky in a matter of days...

... and do this over and over and over again for years on end.

What if we could look Deep, Fast and Wide all at the same time?
The LSST dream started in mid 90’s

Tony Tyson – UC Davis:
Dreamed of an all sky survey to explore Dark Matter and the time domain

Roger Angel – U Arizona:
Dreamed of an optical design for large wide-field telescope

1998: Chuck, can this machine be built?
LSST Project begins to form in early 2000s

We can make 8.4m diameter mirrors

8-meter class telescopes have been built

CCD sensors technology is sufficient

Surely computers will be up to the task in a few years

The first LSST design and development proposal in 2003
UofA Mirror Lab Technology

8.4 m (27.6 ft) diameter mirror

light weighting
honeycomb

M1 surface

M3 surface
A “Mirror” is Complex Assembly
Low Deflection Needed - Mirror and Vacuum

- Deck Plate with stiffeners and Support Girders
- Telescope Pylon Interface Mounting Pads
- Vacuum Cylinder Pressure Boundary
- Vacuum Support Trusswork
- M1M3 Mirror within Light Baffle/Cooling Plenum Ring
- Mirror Thermal Control - Coolant Recirculation Piping
- Hardpoint Actuator
- Cell Deck Plate with Pneumatic Support Actuators
- Cell Floor Stiffened against Vacuum Load. Personnel access floor above stiffeners not shown.
M1M3 Cell Assembly Fabrication Underway in Tucson!

Large 8-m structures under construction at CAID and thousands of parts being fabricated by LSST staff.

M1M3 Cell Assembly – System test with Mirror planned for 2018 at UofA
To quickly cover the sky LSST needs to go fast

Simulations show that covering the sky in 4 nights mean LSST must move 3.5 degrees on sky, and settle for next image in 5 seconds
Altitude plot showing HA/Dec of simulated survey pointings.

- 20 deg elevation limit
- Galactic plane
- Moon (Dark=Full) (Light=New)
- Zenith
- Ecliptic plane
Stiff 300 ton moving structure

10 deg/sec rotation
10 deg/sec^2 acceleration
Telescope Mount Assembly in Spain

- Power draw is key design feature
- Combined with Dome:
  - 2MW
  - 1500 homes

20 MPH
To go wide LSST needs field-of-view

- Gemini South Telescope (Primary Mirror Diameter: 8 m, Field of View: 0.2 degrees)
- LSST (Primary Mirror Diameter: 8.4 m, Field of View: 3.5 degrees)

(Full moon is 0.5 degrees)
Astronomy’s Largest Digital Camera

Camera Parameters

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
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<tbody>
<tr>
<td>15 years</td>
<td></td>
</tr>
<tr>
<td>Incident half-angle in air</td>
<td>14.2°-23.6°</td>
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<tr>
<td>Focal plane diameter</td>
<td>634 mm</td>
</tr>
<tr>
<td>Maximum mass</td>
<td>3060 kg</td>
</tr>
<tr>
<td>Maximum diameter</td>
<td>1650 mm</td>
</tr>
<tr>
<td>Total length</td>
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63 CM Diameter Focal Plane is 189 sensors packed in 21 rafts

Raft Electronics Board (REB) with Custom Integrated circuits make a 166M Pix camera
Camera Sensors Fabricated by Two Vendors

RTM1 and RTM 2 have been assembled – each with sensors from each vendor.

39% of Science Sensors have been delivered!
Sensor Gaps are Tight – Collecting Efficiency
Camera Optics Fabrication Well Underway in Tucson

1.6m Diameter L1

L1-L2 structure

L2 under test
Exterior building composition shaped by topography & aerodynamics.

Summit Support Facility Design will Impact Observatory Performance.

Computational Fluid Dynamics (CFD) Of Building Site and Dome.

without panels

with deflector panels
Early site work to level the site(s) was exciting but a smooth process
Building a 4,500 sq. ft. facility on a 8,600 ft mountain has its challenges

First is a Party.....Laying of the first stone is Chilean tradition
And then you chisel, carve, and dig....
Dig deep and then fill it up.
The weather can be a challenge
Data Management must transport, process, archive and serve 15 Tb of raw data / night – 500Pb in 10 years.
New dedicated optical fiber to the summit

LSST SITE!
LSST networks connect Chile with 2 x 100 gigabits per second fiber optic links. With 200 gigabits per second it is possible to:

- Download the entire Lord of the Rings trilogy in HD from Chile to the US in 1.5 seconds.
- Stream music or video over 4G simultaneously to 2000 cellphones.
- Send one LSST image from Chile to our processing center in Champaign Illinois in under 1 second.
LSST is building tools so YOU will be able to get involved

The Education and Public Outreach group will give you access to LSST data through easy-to-use digital tools

Contribute to real research through Citizen Science
Explore the universe interactively in the SkyViewer
Dig into the data with online Science Notebooks
Participate!

You will be able to contribute to real research through hundreds of NEW citizen science projects using LSST data.

zooniverse.org
Explore!

Explore the LSST Night Sky - at home or on your phone! You will be able to see exciting objects the telescope found the previous night.

Preliminary designs for the EPO web portal.
You will have easy access to LSST data online using intuitive science notebooks for educators and everyone. Customize and collaborate.

What will you discover?
The LSST enables Wide-Fast-Deep coverage of the entire available sky

A single unprecedented survey:
- 5.5 million images
- Catalog 20 billion galaxies and 17 billion stars
- Use 6 filters covering 320 – 1050 nm
- Produce 10 million transient alerts per night
- High precision, high uniformity, calibrated data

Each sky patch will be visited >800 times
www.lsst.org

2022 - The Survey Begins