Wide, Fast, and Deep: Why SLAC is building the world’s largest digital camera

Mike Baumer
Large Synoptic Survey Telescope

3.2 gigapixels

37 billion astronomical objects

100,000 supernovae

...
Wide, Fast, and Deep
Fast
Deep Field
**A Distant Source**

Light leaves a young, star-forming blue galaxy near the edge of the visible universe.

**A Lens Of ‘Dark Matter’**

Some of the light passes through a large cluster of galaxies and surrounding dark matter, directly in the line of sight between Earth and the distant galaxy. The dark matter's gravity acts like a lens, bending the incoming light.

**Focal Point: Earth**

Most of this light is scattered, but some is focused and directed toward Earth. Observers see multiple, distorted images of the background galaxy.
Hubble Space Telescope (1990-present)
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Supernova Cosmology Project (1998)
## Timeline

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Sloan Digital Sky Survey (2000-present)

7000 papers and counting
325K citations
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WHAT IF I TOLD YOU
YOU DON'T HAVE TO CHOOSE

— Prof. Tony Tyson, ~1990s
Dark Energy Survey (2012-present)
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5000 deg$^2$

4x area

20,000 deg$^2$

¼ of sky in 6 months

Entire sky in 4 nights!

6x fainter

Limiting mag 22.5

24.5
## Timeline

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Wide: Giant monolithic mirrors
Wide: f/1.2 optical beam
Fast beam requires super-flat focal plane
Focal Plane must be flat ± 10 µm!
How CCDs work
How CCDs work
How CCDs work
How CCDs work

Bias Voltage

+ + + e^- e^- e^- e^- e^- + + + + + + + + + +
Parallel Transfer
LSST Focal Plane

- Eight Outputs
- Serial Shift Registers
- Blooming column length 5/3 frame
- Wavefront Sensors (4 locations)
- Guide Sensors (8 locations)

Diagram showing:
- Front End Crate—triangular shape fits in Grid corner bays
- Corner Raft Tower
- 4 towers, one in each corner
- Raft Control Crate—mounts to Cold Plate
- Spring-loaded hold-down clamp—supports Raft off Grid
- Science Raft Tower
- 21 towers

January 2012
Fast: segmented readout

Crazy idea: put the readout electronics in the dewar, cold! Then digital data line through dewar wall.
Deep: Red-sensitive CCDs

Because you’d hate for red photons to have gone to all that trouble to traverse the universe, only to speed right through your detector…
Problems with thick CCDs
Brighter-Fatter Effect
Data

ATLAS to-disk rate: 300MB/sec
LSST average: 750 MB/sec!
Total Disk usage: ~0.5 Exabytes!
Real-time alerts
Checklist

- Large, precise mirrors
- Rigid telescope structure (minimize vibration)
- f/1.2 “fast” optics
- Super-flat sensors and precise mechanical design
- Fast segmented readout
- Vacuum clean electronics
- Thick, red-sensitive CCDs
- Exa-scale data management
- Government-scale project management
- ...
Curvature floating
Systematics and
Planck priors included
SLAC’s role

Integration + Testing

- CCDs
- raft baseplate
- V-grooves for kinematic mount
- housing (cold mass)
- pre-tensioning arm
- electronics cooling bars
- FEE boards

x18
LSST steps and timeline

Key Milestones
- NSF-sponsored milestones
- DOE-sponsored milestones
- Privately-sponsored milestones

- NSF Preliminary Design Review
- Camera CD-3 Review
- Prototype Science Sensor Review
- First article sensor contract start
- Camera CD-3a Review
- MREFC funding begins
- Start summit facility, dome, mount, secondary optical finish contracts
- Primary mirror complete
- Camera CD-2 Review
- Archiving Site Ready for Equipment Configuration
- SLAC/LET Facility Ready
- Lower enclosure ready for dome
- First production science wall complete
- Dome and Summit Substantial Completion
- Base facility complete
- Camera Summit equipment ready at SLAC
- Camera dome ready
- 5.0/0.1.1 Ready for CoreCam
- 1.1-1.2 Assembly Complete
- Software Release 5.0/0.1.1 Ready for CoreCam
- Telescope and site ready for CoreCam
- Camera ready at SLAC
- Engineering first light
- Camera ready at summit System I&T begins
- Software Release 10.0/10.1.1 Ready for Science Verification
- Data Access Centers complete
- Science verification complete
- Full science operations