# Large Synoptic Survey Telescope

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# LSST: from Science Drivers to Data Products


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**The LSST design is driven by four science themes and desire to engage broad science community and general public in LSST data exploration. The current design, with an 8.4m (6.7m effective) primary mirror and a 9.6 square degree field of view, will allow about 10,000 square degrees of sky to be visited twice per night, with an effective depth of r=24.5 per visit, every three nights. The system will yield high image quality as well as superb astrometric and photometric accuracy, and will regularly produce three classes of data products. Level 1 data products are generated continuously every observing night, including alerts to objects that have changed flux or position, that will be released within 60 seconds. Level 2 data products will be made available as annual Data Releases and will include images and measurements of positions, fluxes, and shapes, as well as variability information such as orbital parameters for moving objects. The LSST Data Management System will also facilitate Level 3 data products by science teams external to the project by providing Applications Programming Interfaces (APIs), about 50 teraflops of user-dedicated processing capability and 12 petabytes of user-dedicated storage. These capabilities will reside "next to" the LSST data, avoiding the latency associated with downloads.**


## LSST Science Drivers

Major advances in our understanding of the universe have always come from dramatic improvements in our ability to "see". In the past decade, large-scale sky surveys have become increasingly appreciated. As a sensitive, multicolor survey over most of the sky, LSST will dramatically impact nearly all fields of astronomy and many new areas of fundamental physics. The essence of LSST is to go wide, fast, and deep, and this strategy will enable an extremely broad range of scientific investigations. The main science themes that LSST will address, and that are used to optimize the system design, are

Constraining Dark Energy and Dark Matter
using a variety of probes and techniques whose synergy will fundamentally test our cosmological assumptions and gravity theories; LSST will provide a sample of 3 billion galaxies with excellent photometry and shape measurements, over 100,000 clusters of galaxies, and a sample of several million Type Ia SNe,

Taking an Inventory of the Solar System
and extending the boundaries of our reach in distance and detectable size of potentially hazardous asteroids; LSST will detect and characterize over 80% of 140m or larger killer asteroids, several million main-belt asteroids, and over 100,000 trans-Neptunian objects (e.g. Sedna-like objects will be detectable to beyond 200 AU),

Exploring the Transient Optical Sky
by characterizing known classes of objects and discovering new ones; LSST will sample a variety of time scales ranging from 10 sec, to the whole sky every 3 nights, with 1000 visits distributed over 10 years

Mapping the Milky Way
all the way to its edge with high-fidelity; main-sequence stars will be detected to 100 kpc, RR Lyrae to 400 kpc, and geometric parallaxes will be measured for all stars within 300 pc.

THE LSST BASELINE DESIGN AND SURVEY PARAMETERS

| Quantity | Baseline Design Specification |
|---|---|
| Optical Config. | 3-mirror modified Paul-Baker |
| Mount Config. | Alt-azimuth |
| Final f-Ratio, aperture | f/1.234, 8.4 m |
| Field of view, étendue | 9.6 $deg^2$, 318 $m^2 deg^2$ |
| Plate Scale | 50.9 $\mu$m/arcsec (0.2" pix) |
| Pixel count | 3.2 Gigapix |
| Wavelength Coverage | 320 – 1080 nm, *ugrizy* |
| Single visit depths[a] ($5\sigma$) | 23.9, 25.0, 24.7, 24.0, 23.3, 22.1 |
| Mean number of visits | 70, 100, 230, 230, 200, 200 |
| Final (coadded) depths[a] | 26.3, 27.5, 27.7, 27.0, 26.2, 24.9 |

[a] The listed values for $5\sigma$ depths in the *ugrizy* bands, respectively, are AB magnitudes, and correspond to point sources and zenith

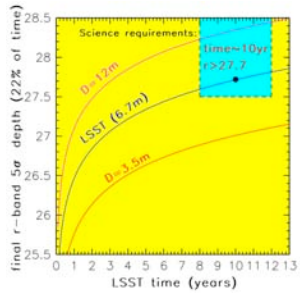



Figure 1: The co-added 5σ depth for unresolved sources as a function of time (assuming 22% of time per band) and the effective primary mirror diameter. Compared to single visits, 3 mag of depth are gained after 10 years of surveying (using 200 visits per band). LSST will survey 20,000 $deg^2$ to this depth.

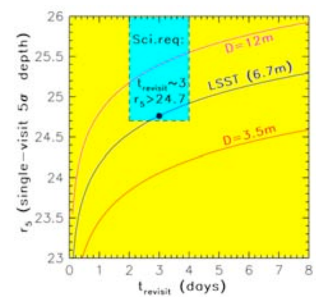



Figure 2: The tradeoff between the revisit time and single-visit depth. The requirement on revisit time (whole sky in two bands every three nights to r>24.5) is equivalent to requirements for exposure time (30 sec), the number of visits (1000 in six bands), and the survey efficiency.

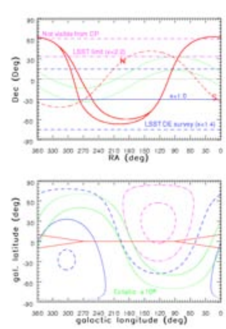



Figure 3 (*above*): A summary of LSST sky coverage, in equatorial (*top panel*) and galactic (*bottom panel*) coordinates. The two dashed blue lines outline the 24000 $deg^2$ region for which minimum airmass reaches values less than 1.4. The galactic plane regions with the highest stellar density are enclosed by solid red lines and include 1000 $deg^2$.

## Constraints on LSST's Etendue

Detailed consideration of LSST science drivers results in a requirement to obtain multi-band imaging of 20,000 square degrees to a depth of r=27.5 (5σ for unresolved sources, on either an AB or Vega based system). The primary depth drivers are the number of galaxies usable in weak lensing analysis and the ability to detect main sequence stars at 100 kpc. With the field of view area limited to 10 square degrees by achievable image quality, the time to complete such a survey scales with the square of the primary mirror's diameter. As illustrated in Figure 1 (top left), in order to complete the survey in 10 years, the chosen effective diameter of LSST's primary mirror is 6.7m (8.4m geometric diameter).

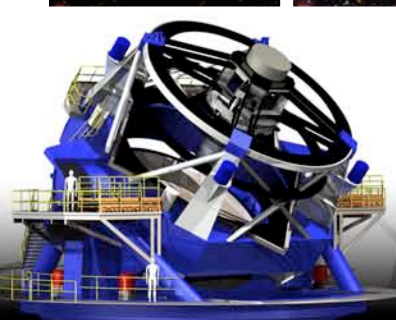
## Constraints on Exposure Time

The total exposure time per field and for all six bandpasses is 8 hours. The weak lensing and other systematics are minimized by maximizing the number of realizations of the seeing. The minimum exposure time which maintains high survey efficiency is about 30 seconds and results in about 1000 visits, each of which reaches a V magnitude of 24.5. At this pace, the 10,000 square degrees of sky visible at any given time can be tiled in two bands every three days. The total number of visits in each band after 10 years of surveying (see Table, left). This combination of the depth, area and revisit time simultaneously addresses the needs of LSST's four main science themes (see Figure 2, top right). The revisit time of several days will result in well-sampled light curves for Type Ia supernovae, and will enable orbital linking of moving objects. Detection of moving objects will also benefit from short exposure times that prevents trailing losses. A per-visit depth of r=24.5 will allow LSST to fulfill the Congressional mandate to detect 90% of 140m NEOs, will detect RR Lyrae stars to 400 kpc, and make parallax measurements for a complete solar neighborhood sample down to the hydrogen-burning limit.

## LSST Sky Coverage

The LSST will be sited on Cerro Pachon in northern Chile. From that site, sky regions with Dec. < 33.5 degrees can be observed at an airmass of 2.2 or smaller, a limit that is used to define the LSST Survey. This airmass results in a 0.6 mag loss of sensitivity at 500 nm compared to an observation in zenith (due to both seeing degradation and atmospheric absorption), and corresponds to an observable area of 31,000 square degrees. Sky regions with -75<Dec<+15 can be observed at an airmass of 1.4 or smaller, providing especially good image quality for weak lensing and other science investigations that require it. The total accessible solid angle in this range exceeds 20,000 square degrees, outside of the confusion-affected parts of the galactic plane. Figure 3 (left) summarizes these constraints in equatorial and galactic coordinates.

Figure 4 (*above*): An example of improvements in image quality and depth. The left panel shows a random 8x8 square arcmin patch of sky as imaged by the Sloan Digital Sky Survey (r<22). The middle panel shows the same patch of sky as imaged by the Deep Lens Survey to about the same depth as single LSST visit (30 sec exposure, r<24.5). The right panel shows a co-added Deep Lens Survey image that is still a magnitude shallower (r<26) than anticipated co-added LSST images (and with about a factor of two worse seeing).



### Three main classes of LSST data products

**Level 1 data products** are generated continuously **every observing night**, including alerts to objects that have changed flux or position, that will be released within 60 seconds.

**Level 2 data products** will be made available as **annual Data Releases** and will include images and measurements of positions, fluxes, and shapes, as well as variability information such as orbital parameters for moving objects.

**Level 3 data products** will be **created by science teams** external to the project using suitable Applications Programming Interfaces (APIs) that will be provided by the LSST Data Management System. The Data Management System will also provide about 50 teraflops of user-dedicated processing capability and 12 PB of user-dedicated storage. The key aspect of these capabilities is that they will reside "next to" the LSST data, avoiding the latency associated with downloads.

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