# Large Synoptic Survey Telescope

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# LSST: from science drivers to reference design and anticipated data products

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**The LSST will be a large, wide-field ground based telescope designed to obtain sequential images covering the entire visible sky from Cerro Pachón in Northern Chile. The current baseline design, with an 8.4m (6.7m effective) primary mirror and a 9.6 sq. deg. field of view, will allow about 10,000 square degrees of sky to be covered in two photometric bands every three nights (assuming two 15-second exposures per field). The system is designed to yield high image quality as well as superb astrometric and photometric accuracy. The survey area will include 30,000 sq. deg. with Dec<+34.5, and will be imaged multiple times in six bands covering the wavelength range 320—1050 nm. The vast majority (about 90%) of the observing time will be devoted to a deep-wide-fast survey mode which will observe a 20,000 sq. deg. region in the *ugrizy* bands about 1000 times (including all bands) during the 10-year survey. The deep-wide-fast survey data will serve the majority of science programs. The remaining 10% of observing time will be allocated to special programs such as Very Deep and Very Fast time domain surveys. We illustrate how LSST science drivers led to these choices of system design parameters.**

## 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, the 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 deep, wide, and fast, 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 4 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 object 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.

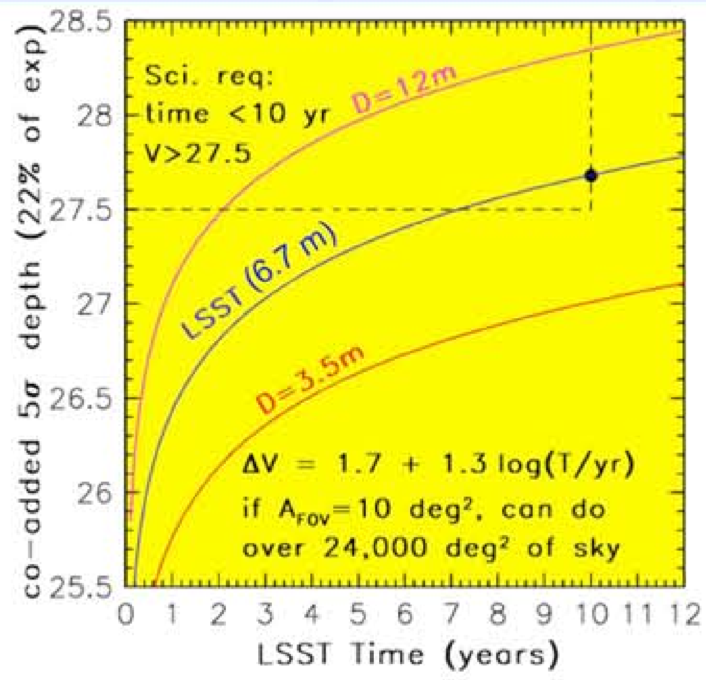



**Figure 1: The co-added 5-sigma depth for unresolved sources as a function of time (assuming 22% of time per band) and the effective primary mirror diameter. Compared to single visits, 3 mag of depth are gained after 10 years of surveying (using 200 visits per band). LSST will survey 20,000 sq. deg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

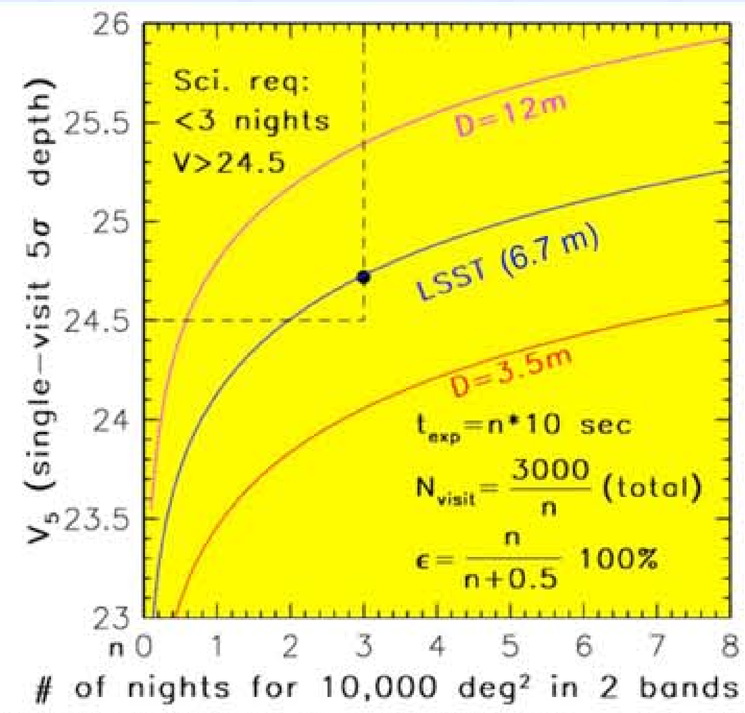



**Figure 2: The trade off between the revisit time and single visit depth. The requirement on revisit time (whole sky in two bands every three nights to V>24.5) is equivalent to requirements for exposure time (30 sec), the number of visits (1000 in six bands) and survey efficiency.**

TABLE 1
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 – 1050 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 5σ depths in the *ugrizy* bands, respectively, are AB magnitudes, and correspond to point sources and zenith

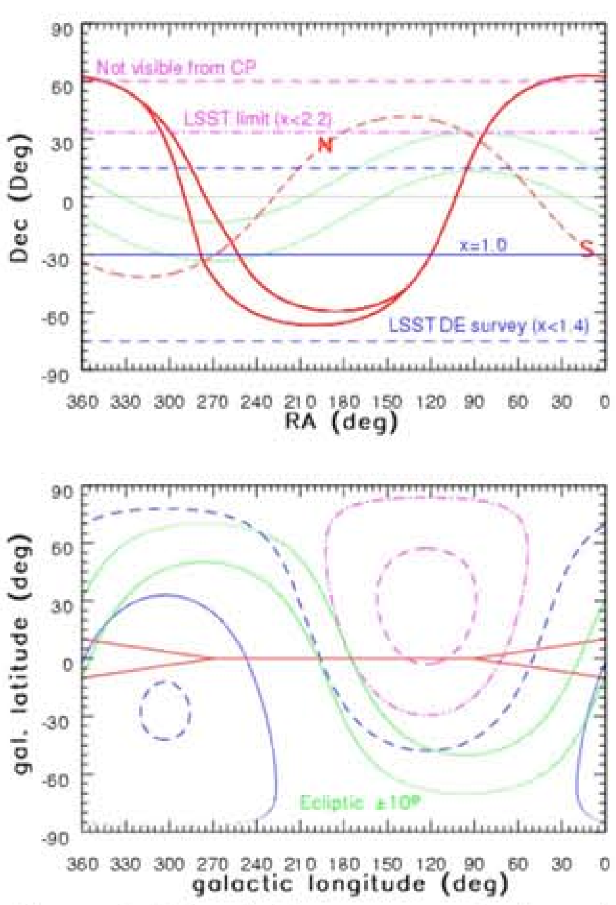



**Figure 3 (above): A summary of observing constraints for LSST survey from Cerro Pachón, in equatorial (top) and galactic coordinates (bottom). The two dashed blue lines outline the 24,000 sq. deg. region for which the minimum airmass reaches values less than 1.4. The galactic plane regions with the highest stellar density are enclosed by solid red lines and include 1,000 sq. deg.**

## Constraints on LSST's Etendue

Detailed consideration of LSST science drivers results in a requirement to obtain multi-band imaging of 20,000 sq. deg. to a depth of V=27.5 (5-sigma 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 sq. deg. 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).

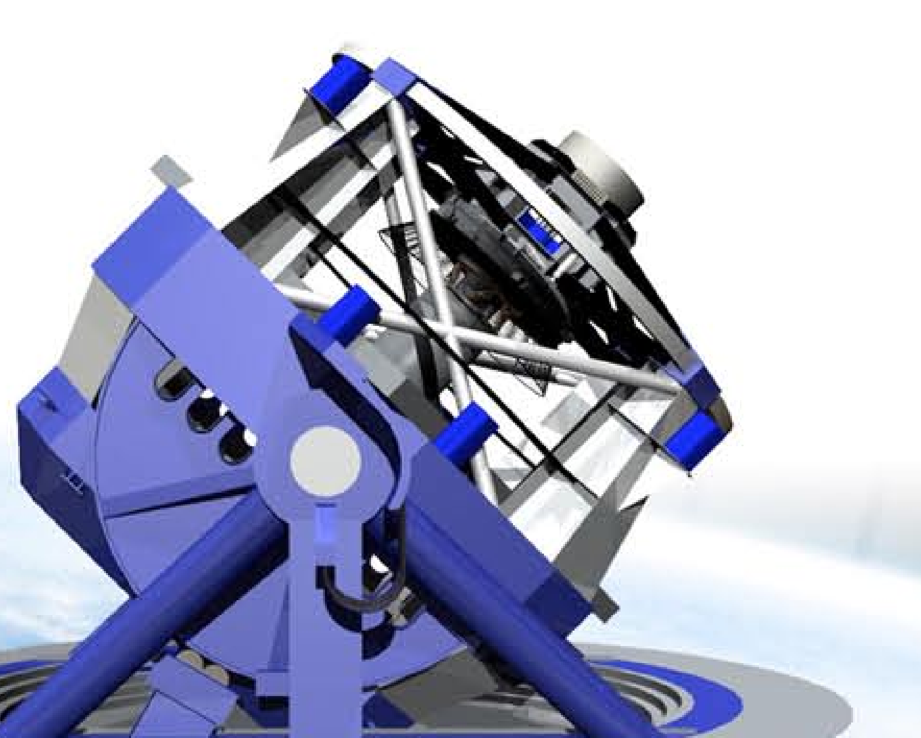
## Constraints on Exposure Time

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 exposures, each of which reaches a V magnitude of 24.5. At this pace, the 10,000 sq. deg. 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 are listed in **Table 1 (left).** This combination of the depth, area and revisit time simultaneously addresses the needs of LSST's 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 time that prevents trailing losses. A per-visit depth of V=24.5 will allow LSST to fulfill the Congressional mandate to detect 90% of 140m NEOs, to detect RR Lyrae stars to 400 kpc, and to make trigonometric parallax measurements for a complete solar neighborhood sample down to the hydrogen-burning limit.

## LSST Sky Coverage

The LSST will be sited on Cerro Pachón in northern Chile. From that site, sky regions with Dec<33.5 deg. 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 sq. deg. 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 sq. deg., outside of the confusion-affected parts of the galactic plane. **Figure 3** (left) summarizes these constraints in equatorial and galactic coordinates. The current implementation of these and other constraints in a simulated LSST survey are discussed in detail in the accompanying poster by Cook et al. (460.04).

**Figure 4 (below): An example of improvements in image quality and depth. The first three panels (left to right) show a random 8x8 sq. arcmin large patch of sky as imaged by the Palomar Observatory Sky Survey (r<21), the Sloan Digital Sky Survey (r<24.5), and the Deep Lens Survey (r<26). The fourth panel shows a processed Deep Lens Survey image that is still a magnitude shallower than anticipated LSST images (and with about a factor of two worse seeing).**



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