An Overview of the LSST Telescope and Site

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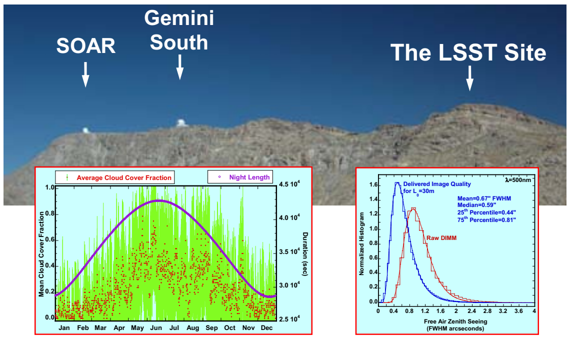
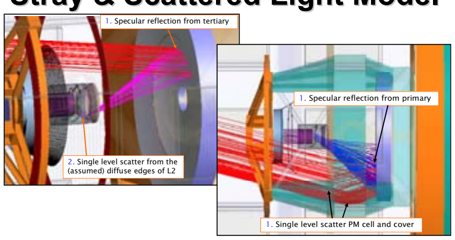
The LSST uses a modified Paul-Baker 3-mirror optical design with 8.4-m primary, 3.4-m secondary and 5-m tertiary mirrors. The 3- mirror telescope feeds a 3 element refractive corrector to produce a 3.5-degree diameter field of view over a 64-cm flat focal surface with excellent image quality. The etendue (collecting area times field of view), a measure of survey capability, for the LSST is many times that of any other existing or proposed facility. The primary and tertiary mirrors will be fabricated from a single substrate at the Steward Observatory Mirror Lab using their structured borosilicate spin casting technology starting in mid 2007. The optical design has been analyzed for correctability and is remarkably tolerant to anticipated fabrication errors with a limited number of compensators. The active optical compensation and figure control of the three mirrors and camera is done by tomographic analysis of four wavefront sensors at the edge of the field of view. Stray and scattered light analysis shows the LSST will achieve its signal to noise requirements.

Observatory Site: Cerro Pachón, Chile

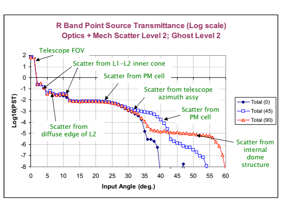


In May 2006, upon the recommendation of an international panel the LSST Board has selected Cerro Pachón, Chile as the site for the observatory. Cerro Pachón is currently home to the 4.2-m SOAR and 8-m Gemini South telescopes. The daily average cloud cover over the past 10 years (above left, average in red, standard deviation in green) indicate that on average more than 75% of the nights on Cerro Pachón are usable for observations. The atmospheric seeing at the summit is very good. Measurements from the DIMM (above right) located near Gemini South indicate that the median seeing for LSST will be 0.67 arcsec. This has been confirmed at Gemini and SOAR.

Stray & Scattered Light Model

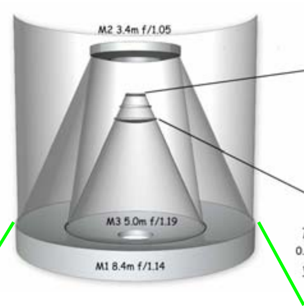


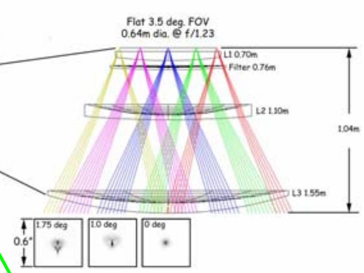
A comprehensive 3-D non-sequential ray trace model of the telescope and camera has been developed using FRED™. Two examples (above and right) of scattered light paths modeled by the 3-D non-sequential ray trace.



The model has been used to analyze the relative importance of scattering of critical surfaces with the telescope and camera structure. This done by calculating the integrated flux on the focal plane of a source for various angles away from the optical axis (left).

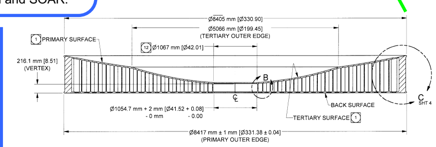
Optical Design



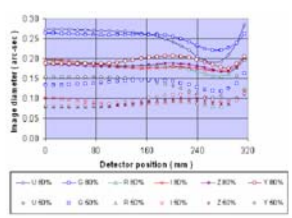


The LSST optical design is a modified Paul-Baker 3-mirror telescope belonging to the Mersenne-Schmidt family that produces very large fields of view with very good image quality [Wilstrop (1984), Angel et al. (2000), Seppala et al (2002)]. The three mirror telescope (left) feeds a 3-element refractive camera system that produces a 3.5 degree field of view over a 64-cm diameter flat focal surface. The primary mirror (M1) of the LSST is 8.4-m in diameter with a 5.1-m inner clear aperture to accommodate the 5-m diameter tertiary mirror (M3). The 3.4-m convex secondary mirror (M2) has a 1.8-m perforation that matches the annular shape of M1 and accommodates the assembly of the camera into the overall system. The annular geometry of M1 produces 35-sq. meters of on-axis collecting area, equivalent to a 6.7-m diameter unobscured clear aperture that is required to meet the sensitivity requirements dictated by the science.

A measure of survey capability is the integrated throughput or etendue, defined as collecting area × FOV solid angle (AΩ), which for this design is 319m2deg2. The intrinsic image quality from this design is excellent. The 80% encircled energy is <0.3" in all spectral bands and <0.2" in r and i spectral bands which are both critical to weak lensing science. The variation in illumination is better than 10% with the system efficiency constant from the field center to radius of 1.2 degrees at 61%, then gradually decreasing afterward to 55% at the FOV edge. The effective focal length of the optical system is 10.31-m making the final f-number 1.2345. The image scale is 50 microns per arcsecond at the focal surface. This choice of effective focal length for the optical system is balanced between image sampling, overall system throughput, and feasibility. The 3-mirror optical design also has very low geometrical distortion, <0.1% over the full FOV, making the LSST an excellent system for positional astrometry.

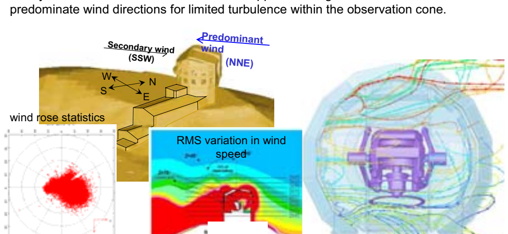


The 8.4-m diameter primary mirror is a unique optic with both the primary reflective surface and the 5-m tertiary reflective surface fabricated into a single glass substrate. Made with borosilicate glass using spin cast technology, the 17,600 kg mirror offers significant advantages in the reduction of degrees of freedom during operation and better stiffness for the otherwise annular primary surface. Supported on 160 actuators and with thermal controls this optic will take advantage of the successful history of similar technology mirrors.



Dome CFD Model

A Computation Fluid Dynamics (CFD) model of the dome has been used to chose a 30 meter diameter cylindrical enclosure for LSST with 22 light baffled openings for natural ventilation during observing. Results show 33 enclosure air changes per hour in a low 1 m/s wind and 170 air changes in a median 5 m/s wind. A CFD model of the entire facility and summit was used to orient the support building to the terrain and predominate wind directions for limited turbulence within the observation cone.



Sample CFD results

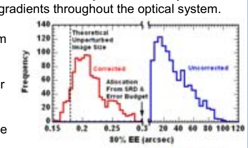
Alignment and Correctability

Of the 77 parameters (radii, conic constants, aspheric terms, thicknesses and positions in the three dimensions) used to describe the LSST optical design we have selected 12 to be adjustable as compensators to correct for errors in fabrication of the individual optical elements and their assembly into the LSST as a whole. These 12 compensators are:

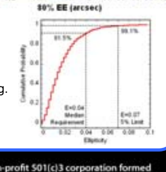
- The spacing between the focal plane array (FPA) and L3;
- The spacing of the FPA+L3 (the cryostat) relative to the other lenses;
- The positions of the secondary and camera assembly in 5 degrees of freedom (dX, dY, dZ, dθX, and dθY) each.

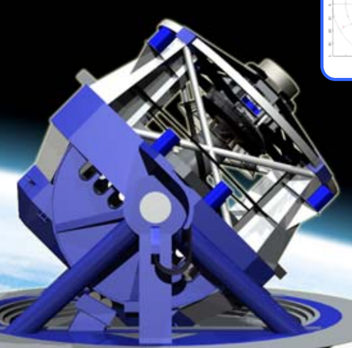
Four of these parameters: FPA – L3 distance and the axial positions (dZ) of the Cryostat, camera assembly and M2, are one-time adjustments to correct for radially symmetric figure errors. The 5 degrees of freedom (dX, dY, dZ, dθX, and dθY) each for the camera assembly and M2 are dynamic compensating parameters to correct for flexure and thermal gradients throughout the optical system.

Monte Carlo modeling shows that as the LSST optical system is perturbed over the range of tolerances, including misalignments and surface errors, it is highly correctable. The histogram of the RMS image quality over the full FOV for the perturbed models before (right, blue) and after (left, red) correction shows a dramatic improvement of nearly 2 orders of magnitude in expected image quality after correction by the 12 compensators.



Because control over PSF ellipticity is of vital importance to the science missions of LSST we also track PSF ellipticity through the simulations. Ellipticity is measured referenced to 0.6" arcsec seeing by convolving diffraction image with a 2-D Gaussian having a FWHM equal to the seeing. The cumulative probability (right) distribution in the i-band shows that the requirements on PSF shape from the SRD are easily met.





The effort to build the Large Synoptic Survey Telescope is overseen by the LSST Corporation, a non-profit 501(c)3 corporation formed in 2003, with headquarters in Tucson, AZ. The LSST research and development effort is funded in part by the National Science Foundation under Scientific Program Order No. 9 (AST-0551161) through Cooperative Agreement AST-0132798. Additional funding comes from private donations, in-kind support at Department of Energy laboratories and other LSSTC Institutional Members.

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