Large Synoptic Survey Telescope

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A Flat Focal Plane for LSST

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The Large Synoptic Survey Telescope (LSST) is a wide field (9.7 sq. deg) survey instrument with active optics control and will provide better than 0.2 arcsecond instrumental contribution to imaging across the field. A principle requirement for achieving this is a very flat focal plane (~ 10 microns PV) comprised of 189 individual sensors, together with active feedback derived from 4 curvature wavefront sensors at the corners of the focal plane. We present our plans for building up a modular, flat focal plane for LSST and how flatness under operational conditions will be assured. The importance for delivering a flat focal plane is underscored by discussing the specific structure of the LSST beam in the presence of residual wavefront error, and what sorts of systematics in the point spread function can be tolerated, given LSST's weak lensing mission.

1. Introduction

- LSST is designed to provide optimal focus in a plane, with only the axial position of the camera varied for the different bands (u, g, r, I, z, y).
- The optical system is very fast (F/1.2) and this implies a tight tolerance of ~ 4 μm on the flatness of the assembled focal plane.
- Meeting this demand requires precise control of both optical alignment and of the active optic compensation system that monitors wavefront errors and maintains optical figure for each of the three large mirrors.

2. Structure of LSST's beam @ Focal Plane

- We have carried out extensive raytrace calculations to study the properties of the LSST PSF across the field of view.
- The asymmetries in the PSF, crucial for weak lensing investigations (see accompanying Jee et al. poster: 460.26), are a strong function of axial position.
- The *instrumental* contributions to PSF size and shape are plotted in Figure 1. While the size contribution is nearly negligible, impacts to the PSF anisotropy can contribute at most (in localized regions):

  max [$<e_ie_i>$] ~ 1.7e-3 $(\theta_s/0.6'')^{-4}$ $(\Delta z/10\mu m)^2$.

- These residual ellipticity distributions are substantially reduced through the use of principal component analyses in the PSF interpolation scheme (*see Jee et al. poster: 460.26*). Knowledge of the focal plane figure within the 10 μm P-V spec can be helpful in enabling those analyses.
- Polynomial fits to shape parameters of the PSF are displayed as a function of focal plane position in Figure 2. Shape sensitivity to height errors is a maximum for θ ~ 1.2 deg.
- AO limited, residual wavefront errors arising from optic deformation and solid body misalignments don't significantly alter the shape residual envelope seen in Figure 1. We do see features imparted in the parameter maps (e.g., Figure 2).

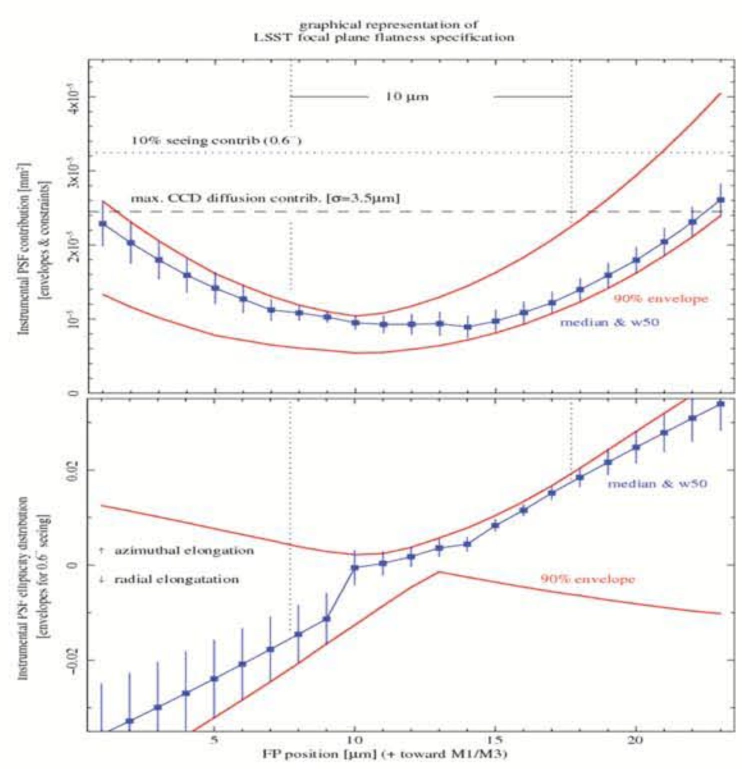


Figure 1: Instrumental contributions to image size and shape distributions for the science array. The 10 μm tolerance envelope is shown.

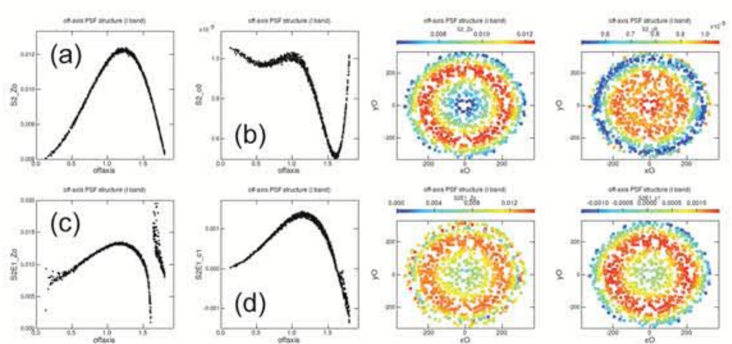


Figure 2: Polynomial coefficients from the (polychromatic, i-band) "design" PSF characterization and their spatial dependence overlaid onto the focal plane. On the left are (a) the axial position of best focus; (b) the instrumental contribution to PSF broadening at the position of best focus; (c) the axial position of the roundest image; and (d) the linear coefficient for defocus induced ellipticity. Corresponding focal plane maps on the right.

3. Building the 10 μm Flat Focal Plane

Our plan for building and characterizing the focal plane to meet the 10μm overall tolerance spec is rather complex, and is drawn out in detail in the flowchart given in Figure 3. The flowchart can be broken down into a smaller number of broader categories, coded by color:

- Optical bench/GRID preparation
- Ball nest (shim) production & calibration
- Mounting point preparation
- Raft delivery for integration
- Raft assembly onto optical bench/GRID
- Integrated Focal Plane operational flatness assurance

Each stage or category requires acquisition of metrology data that are utilized in later stages of the fabrication. All along the way, predictions are generated to compare measurements against, so that unexpected errors are caught as early as possible. A final, focal plane surface height map will be produced (and verified under a range of conditions).

A key technology we developed to enable this work is non-contact, non-interferometric surface metrology – performed in differential mode. We have verified 0.2 μm accuracy with a standoff distance of 150mm, using laser displacement sensors to peer through double-sided optical flat vacuum barriers. Custom stitching algorithms permit forming an over-all surface height map using rapidly acquired data sub-sets with arbitrary reference flat positions.

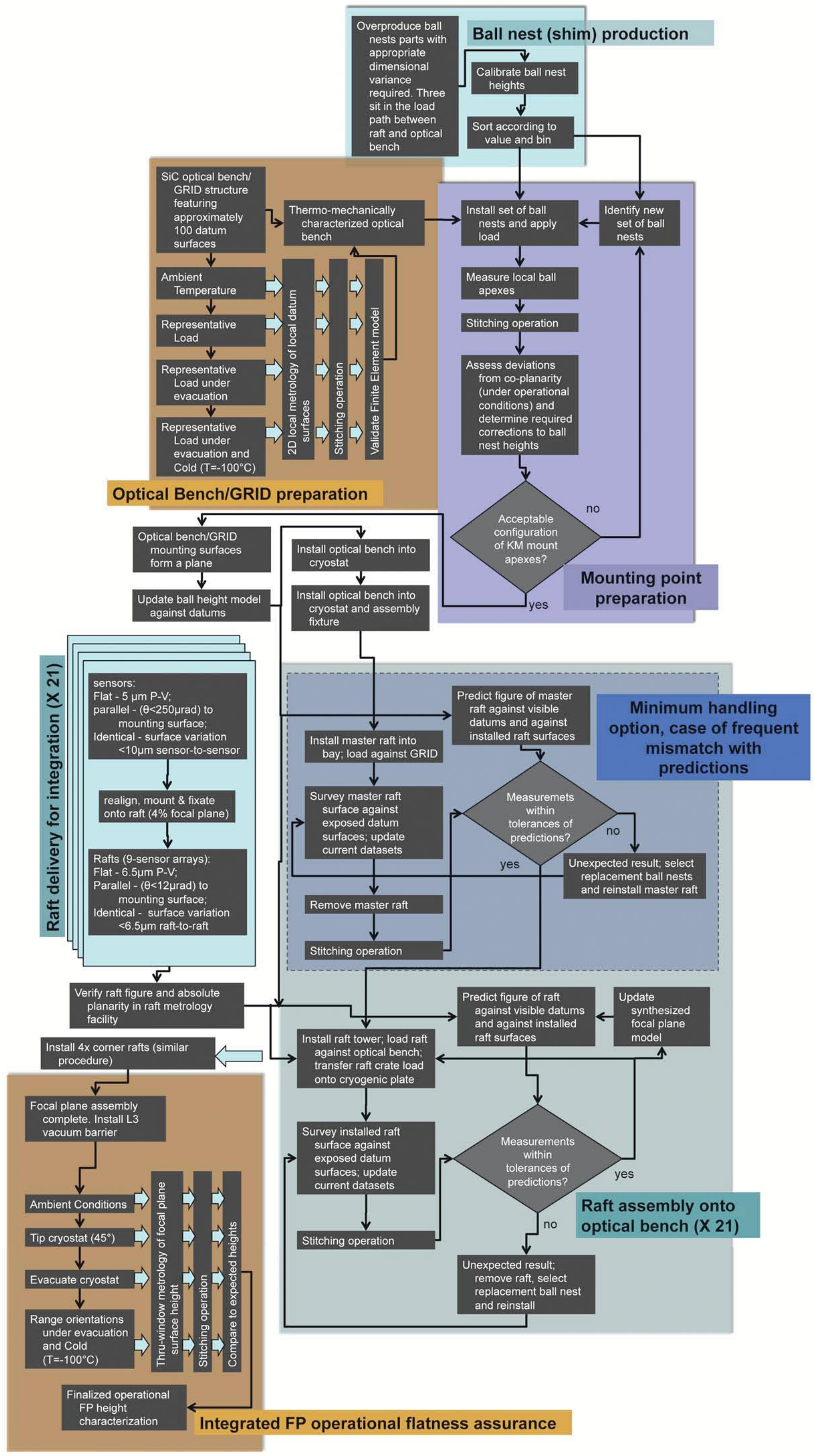
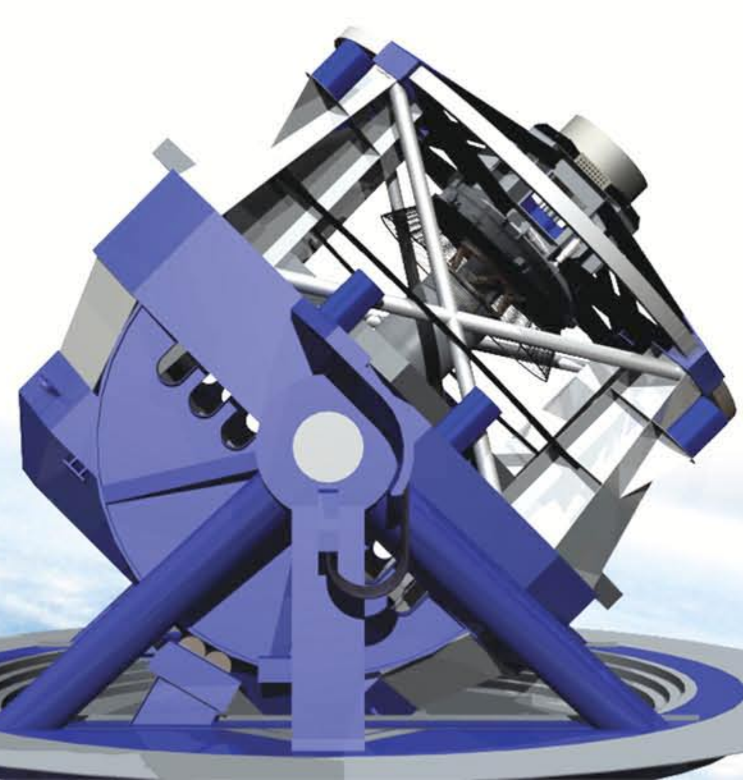


Figure 3: This fabrication flowchart summarizes the various activities, dependencies, measurements and decision points that will be required at the time of assembly and integration. The end product will be a focal plane (residing within the cryostat) that meets the flatness requirements under operating conditions.



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