System Perturbations

Telescope & Site perturbations:

1. 6 DoF rigid body misalignment of M1M3 (as a single body), M2, and the Camera due to fabrication and installation errors after initial (not AOS) alignment
    - The rigid body displacements due to all sources (including gravity and temperature) will be within the accuracy of the laser tracker (LT). A study on the accuracy of the laser tracker was reported in Document-1187. Results are summarized in the table on page 19. (use the section with Number of Points = 10).
    - We assume these rigid body misalignments to be Gaussians centered at zero, with standard deviations half of the numbers given in the above document.
2. 6 DoF rigid body gravitational displacements of M1M3 (as a single body), M2, and the Camera, and the residuals of these displacements after open loop (Look-up-Table) corrections, as a function of zenith angle.
    - see 1. above
3. M1M3 and M2 gravitational shape errors and their residuals after open loop (Look-up-Table) and Force Balance corrections, as a function of zenith angle
    a. M1M3 zenith and horizon pointing print through map (05/2014)
        - Data is given in Document-16407.
        - The first two columns are the x- and y- coordinates of the FEA nodes in meter. The third and fourth columns are the surface sag for the zenith and horizon print throughs in nanometer.
        - Details on how data is obtained and how to use it is in Document-16408.
    b. M2 zenith and horizon pointing print through map
        - Document-14865 by Myung.
        - Data is in the following sheet of the Excel file:
            - Gravity(Zen&Hor): First 2 columns are x and y of the surface nodes in meter. The third and fourth columns are the surface sag for the zenith and horizon print throughs in meter.
4. M1M3 and M2 polishing errors (constant shape errors due to fabrication)
5. M1M3 fabrication errors in terms of M3 piston, decenter, and tilt relative to M1.
6. An estimate for dome and mirror seeing in the form of long exposure (15 seconds) OPD or PSF as the function of zenith angle, external wind speed, and air temperature.
7. Temperature and temperature distribution histories and/or statistics for the air inside the dome, as well as for the various components of the system: structure, glass, camera skin.
8. 6 DoF rigid body displacements and shape distortions of M1M3 and M2 due to temperature changes and uneven temperature distributions (*the effects on M2 may be negligible*)
    - For the rigid body DOFs, see 1. above.
    - M1M3 shape distortions due to temperature change and temperature gradients (08/2013)
        - First 2 columns are x and y of the surface nodes in normalized coordinates; Columns 3-7 are: surface deformation in unit of micron due to 1C change in bulk temperature (3), radial temperature gradient (4), x temperature gradient (5), y temperature gradient (6), and z temperature gradient (7).
        - Data provided by Doug Neil.
    - M2 shape distortions due to temperature change and temperature gradients (08/2013)
        - Document-14865 by Myung.
        - Data is in the following sheets of the Excel file:
            - Tz&Tz_ao: First 2 columns are x and y of the surface nodes in meter. The third and fourth columns are the surface shape changes due to 1C axial (z direction) thermal gradient in meter. Third column is without aO correction. The fourth column with aO correction.
            - Tr&Tr_ao: First 2 columns are x and y of the surface nodes in meter. The third and fourth columns are the surface shape changes due to 1C radial (r direction) thermal gradient in meter. Third column is without aO correction. The fourth column with aO correction.
9. Residual M1M3 thermal deformation after thermal control corrections.

Camera perturbations:

On 8/2/13, Andy Rasmussen collected some camera FEA related data and compiled them into this fits table: output_fitstable.fits

Andy's notes are here.

The units are millimeter.

On 8/6/14, Andy provided the surface deformation data on FEA grids (see below). Andy's notes are here.

1. 6 DoF rigid body misalignment of L1, L2, L3, and the Filters due to fabrication and installation errors.
2. 6 DoF rigid body displacements of L1, L2, L3, and the Filters as a function of
    a. zenith angle and camera rotation angle
        - See the fits table above.
    b. camera soak temperature
        - See the fits table above.
3. L1, L2, L3, and Filter figuring errors (constant shape errors due to fabrication)
4. L1,L2,L3, and Filter gravitational shape errors as a function of
    a. zenith angle and camera rotation angle (seem to be negligible)
        - See the fits table above.

- Data on FEA grid also available:
  - L1 1st surface and L1 2nd surface.
  - L2 1st surface and L2 2nd surface.
  - L3 1st surface and L3 2nd surface.

b. camera soak temperature
  - See the fits table above.
  - Data on FEA grid also available:
    - L1 1st surface and L1 2nd surface.
    - L2 1st surface and L2 2nd surface.
    - L3 1st surface and L3 2nd surface.

5. Overall detector plane 6 DoF rigid body misalignment and displacement due to
   a. fabrication and installation errors (seem to be negligible)
   b. gravitational effects as a function of zenith angle (seem to be negligible)
      - See the fits table above.
   c. gravitational effects as a function of camera rotation angle
      - See the fits table above.
   d. thermal effects (detector plane thermal motions)
      - See the fits table above.
6. Overall detector shape errors due to
   a. gravitational effects as a function of zenith angle (seem to be negligible)
      - See the fits table above.
   b. gravitational effects as a function of camera rotation angle
      - See the fits table above.
   c. thermal effects (detector plane thermal motions)
      - See the fits table above.
7. Rafts 6 DoF rigid body misalignment and displacements due to
   a. fabrication and installation errors (sensor profile/height and raft mounting z-position repeatability, albeit current estimates for the later one seem to be small)
      - Cumulative sensor height distributions at 31 field positions across the focal plane (provided by AndyR, 9/3/14)
      - For example, file cumdist_rad0.379_az120.qdp is for field point (radius=0.379 degree, azimuth angle=120 degree).
      - 3 levels of alignment: Sensor, Sensor-on-Raft, and Raft-on-Grid.
      - This plot shows the cumulative distributions for each of 31 sample locations, color coded by radial distance.
      - Cumulative distributions provided in two-column format.
   b. gravitational effect as a function of zenith angle (*seems to be negligible*)
   c. thermal effects (*seem to be negligible*)
8. Raft shape errors due to
   a. fabrication/polishing errors (*seem to be negligible*)
   b. gravitational effect as a function of zenith angle (*seems to be negligible*)
   c. thermal effects (sensor package distortion due to cool down)
9. "*PSF*" broadening due to charge diffusion and CTE in the CCD and their idiosyncrasies
10. Internal thermal seeing in the form of long exposure (15 seconds) *OPD* or *PSF,* as the function of zenith angle
11. Temperature and temperature distribution histories and/or statistics for the air inside the camera, as well as for the various components of the system: structure and glass.
12. 6 DoF rigid body displacements and shape distortions of L1, L2, L3, and the Filters due to uneven temperature distributions.

Operational Parameters:

1. Altitude histogram from a representative 10 year run (08/2013)
   - Raw data provided by Srini (OpSim 3.61).
   - Binned by Bo into 90 bins. Note that altitude angle = 90 degree - zenith angle.
2. Summit temperature variations (08/2013)
   - The night temperature on Cerro Pachon rarely gets above 16C or below 2C. (provided by Chuck, page 8 of AOS review document)
   - We assume the temperature is Gaussian distributed and use (2C, 16C) as the (-2sigma, 2sigma) bounds.
3. we expect the M1M3 thermal control system to control the thermal gradients in the M1M3 mirror substrate to within 0.4C in x and y lateral directions, and 0.1C in radial and axial directions. (05/2009)
   - Page 8 of Document-7574.
   - We assume the thermal gradients to be Gaussian distributed, with (-2sigma, 2sigma) ranges covering (-T/2, T/2), where T is 0.4C or 0.1 C (see above).
4. Camera rotation angle is assumed to be a uniform distribution between -90 and 90 degrees

Mirror Bending Modes:

1. M1M3 bending modes (07/2014)
   - data in ASCII format. 1st two columns are x and y coordinates of the FEA nodes. Unit is meter. The coordinate system is the same as the LSST Optical Coordinate System (OCRS), i.e., x is along the elevation bearing; when telescope is pointed at horizon, y points up, and z points toward the sky. Col. 3 - 22 are first 20 M1M3 bending modes in meter. These are surface sag with 156 axial actuators. The piston-tip-tilt on the mirror surface has been kept. Details on how the bending modes are obtained can be found in Document-16390.
2. M2 bending modes (07/2014)
   - data in ASCII format. 1st two columns are x and y coordinates of the FEA nodes. Unit is meter. The coordinate system is the same as the LSST Optical Coordinate System (OCRS). Note that when M2 faces down, positive z points up. Col. 3 - 22 are first 20 M2 bending modes in meter. These are surface sag with 72 axial actuators. The piston-tip-tilt on the mirror surface has been removed. These will be updated as we have information on the as-built mirror.