HABEX BASELINE OPTICAL TELESCOPE ASSEMBLY

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Introduction: The Habitable Exoplanet Observatory Mission (HabEx) will image and spectroscopically characterize planetary systems in the habitable zone around nearby sun-like stars. Additionally, HabEx will perform a broad range of general astrophysics science enabled by 100 to 2500 nm spectral range and 3 x 3 arc-minute FOV. Critical to achieving the HabEx science goals is a large, ultra-stable UV/Optical/Near-IR (UVOIR) telescope. The baseline HabEx telescope is a 4-meter off-axis unobscured three-mirror-anastigmatic, diffraction limited at 400 nm with wavefront stability on the order of a few 10s of picometers. This paper summarizes the opto-mechanical design of the HabEx baseline optical telescope assembly, including a discussion of how science requirements drive the telescope's specifications, and presents analysis that the baseline telescope structure meets its specified tolerances.

Wavefront (WFE) Stability: Imaging habitable zone exoplanets using a coronagraph requires an ultra-stable wavefront. Temporal or dynamic change in WFE can result in dark-hole speckles that produce a false exoplanet measurement or mask a true signal. WFE instability come from many sources – mechanical and thermal. Mechanical LOS WFE instability occurs LOS drift/jitter causes beam-shear on the secondary and tertiary mirrors. Because the mirrors are conics, beam shear manifests itself as low-order astigmatism and coma (shear of spherical is coma and sub-aperture coma appears to be astigmatism). Inertial WFE instability occurs when the primary mirror is accelerated by mechanical disturbances causing it to react (i.e. bend) against its mounts. Thermal WFE instability occurs when the temperature of the structure or mirrors changes, causing the mirrors to physically move or change shape due to CTE homogeneity. Performance specifications for the baseline telescope have been defined for a Vector Vortex Coronagraph.

Baseline Telescope: To meet the specified WFE stability requires an ultra-stable opto-mechanical telescope. The baseline telescope architecture achieves this level of performance because of the mass and volume capacities of the planned Space Launch System (SLS). SLS mass capacity enables the design of an extremely stiff opto-mechanical structure that can align the primary, secondary and tertiary mirrors to each other and maintain that alignment. And, SLS volume capacity enables the use of a monolithic aperture off-axis primary mirror with no deployments. A fundamental rule for the design was that every proposed system, subsystem or component should be at TRL-9 except for the primary mirror assembly, active thermal control system, and science instruments. The resulting design is extremely robust.

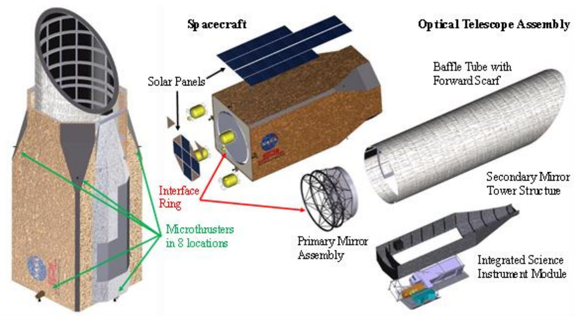

Figure 1: Baseline HabEx Observatory Payload

To evaluate the baseline HabEx telescope's ability to meets its performance requirements, integrated thermal and finite element models (FEM) were constructed to perform structural thermal opto-mechanical performance (STOP) analysis. This analysis predicts dynamic errors (LOS jitter, LOS WFE stability, inertial WFE stability, and impulse ring-down) caused by structural response to mechanical stimuli. And thermal LOS and WFE drift caused by thermal slews. In all cases the telescope meets its required performance specification with margin.

There are two design elements critical to achieving ultra-stable performance: stable structure and low disturbance noise. The telescope secondary mirror structure is designed with a first mode above 25 Hz and the primary mirror structure is above 40 Hz. To minimize the source of stimuli, the baseline HabEx observatory architecture does not use reaction wheels for slewing and pointing. Instead cold gas thrusters are used to slew and point the telescope. They are then turned off. Micro-thrusters are used to maintain pointing for the science exposure. Because the micro-thruster noise spectrum is less than 0.1 micro-Newton and the telescope structure is stiff, any wavefront error instability excited is smaller than the required performance specification. Thermal noise is minimized via active thermal control of the mirrors.

A final benefit of a stiff telescope structure is that it only takes about 5 minutes for the wavefront error to stabilize sufficient for coronagraphy after a slew.