Abstract

The James Webb Space Telescope (JWST) is a large (6.5 m) cryogenic segmented aperture telescope with science instruments that cover the near- and mid-infrared from 0.6-27 microns. The large aperture not only provides high photometric sensitivity, but it also enables high angular resolution across the bandpass, with a diffraction limited point spread function (PSF) at wavelengths longer than 2 microns. The JWST PSF quality and stability are intimately tied to the science capabilities as it is convolved with the astrophysical scene. However, the PSF evolves at a variety of timescales based on telescope jitter and thermal distortion as the observatory attitude is varied. We present the image quality and stability requirements, recent predictions from integrated modeling, measurements made during ground-based testing, and performance characterization activities that will be carried out as part of the commissioning process.

Ground Testing

The image quality requirements are verified during a series of tests at the major stages of integration. Component level (e.g., mirrors), the subsystem level (e.g., Science Instrument Module (SIM), Integrated Science Instrument Module (ISIM)), and the OTIS level.

Component Level Testing: Each of the telescope mirrors have been evaluated at the component level and are within their requirements. The residual rms wavefront was measured at the cryogenic temperatures. The primary, secondary, tertiary, and the steering mirror, the four mirrors that comprise the telescope, are all within requirements. Right: The as-built primary mirror wavefront map (Lightsey et al. 2014).

OTIS level testing: Cryo-occulus testing at the OTIS, the Optical Telescope Element + ISIM level. At right is the OTIS cryo-testing configuration, scheduled to begin at the end of this month and run for 93 days. This test will measure PM to AOS alignment, GM to AOS alignment, AOS to ISIM despase/decen. NIRCam aperture stop to FSM mask, ISIM III via entrance pupil and object surface, ISIM object surface clocking, PM radius of curvature, ISIM object surface alignment, WF control capability, a series of croscheck, PM thermal distortion model validation, and a plateascale calibration.

Integrated Modeling

Expected telescope stability and image quality performance have been simulated with end-to-end modeling. A software package called the Integrated Telescope Model (ITM) generates PSFs based on existing ground test data (where possible) and integrated modeling analysis for thermal distortion (TD), deployed dynamics, and pointing control. Monte Carlo simulations of the commissioning process have been used to evaluate the distribution of optical predictions based on the expectations from test and analysis. These optical alignments are subject to thermal distortion as the Observatory is pointed from one attitude to another. The optical stability is based on structural, thermal, and optical performance (STOP) integrated models. From the structural deformations, optical path difference maps are produced, which are then used to generate the wavefront drift and assess time constants and total wavefront drifts. In addition, the telescope pointing is expected to be robust with respect to environmental disturbances. The integrated modeling shows that the image quality and stability requirements are being met.

Image Quality and Stability

Image Quality: The initial telescope alignment will be completed with a series of activities that make use of specialized NIRCam modes for wavefront sensing. The telescope jitter will be measured before the cryocooler is turned on. After the telescope is aligned at several field points within NIRCam, the image quality will be assessed at multi-instrument multi-field (MIMF) points. Image Stability: The image stability requirements will be validated during commissioning. After the telescope is aligned, routine wavefront monitoring will take place every 2 days with corrections to the telescope no more than every 14 days. The drift and time constants of two conditions will be evaluated using a hot to cold slew activity following the telescope alignment.

References


Ground Testing, Integrated Modeling, and Space Validation