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.

JWST Observatory Overview

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 realizations 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 distortion 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 waveform drifts. In addition, the telescope pointing is expected to roll about the fine guidance sensor as the star trackers change thermal states.

Image Quality and Stability
The JWST image quality and stability requirements were defined for the end-to-end observatory system, from the primary mirror segments to the science instruments (OTIS), sunshield, and spacecraft. After testing at the sub-system level, these elements will be integrated together at Northrop and tested again at the Observatory level before launch.

Space Validation
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 using 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.

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)), 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: Cryoecessary 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 AO alignment, GM to AO alignment, AOS to ISIM despase/decamer, NICAM aperture stop to FSM mask decoder, ISIM tilt via entrance pupil and object surface, ISIM object surface clocking, PM radius of curvature, PM to FSM alignment, WF control capability, a series of crosschecks, PM thermal distortion model validation, and a plate-scales calibration.

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References

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