Completion of the JWST Spacecraft/Sunshield and Telescope/Instrument Elements

Randy A. Kimble[1], Charles W. Bowers[1], Michael W. McElwain[1], Malcolm B. Niedner[1], Erin C. Smith[1], and the JWST Project Team

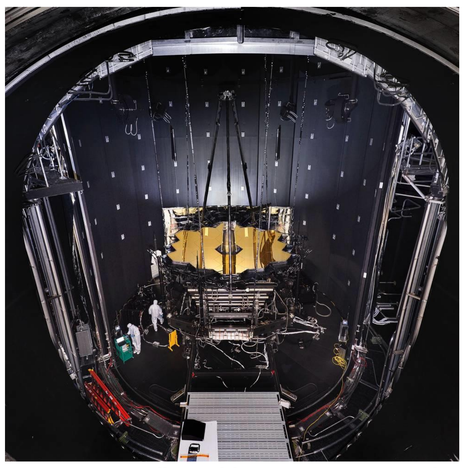
[1]NASA Goddard Space Flight Center

Introduction

Several years ago, the integration of the James Webb Space Telescope converged to two major components: 1) the combination of **the telescope and instruments** (with their support structure and electronics), known as **the OTIS** (a name derived from the OTE = Optical Telescope Element plus ISIM = Integrated Science Instrument Module), and **2**) the **Spacecraft Element**, which is the combination of the **warm spacecraft bus** (with all of the usual systems for power, attitude control, communications, propulsion, command & data handling, etc) **and JWST's critical, deployable, five-layer sunshield.**

In 2019, the integration and test programs for both of these elements were completed. We present here some of the highlights along the way toward those milestones. The two components have since joined to form the full-up **JWST Observatory**, whose integration and test program is described in the companion poster (372.09) by McElwain et al.

OTIS Cryo-Vacuum Testing



JWST OTIS, configured for cryo-vacuum testing

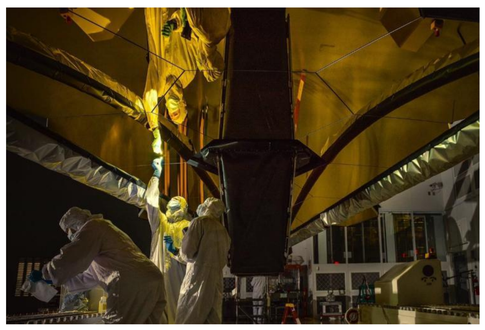
The culmination of the environmental test program for the OTIS was a remarkable hundred-day cryo-vacuum test of the payload conducted at the Johnson Space Center in July-October 2017. The test functionally exercised the telescope plus instrument suite at their cryogenic operating temperatures, with interferometric testing of the full primary mirror, end-to-end sub-aperture optical testing to the instrument focal planes, thermal balance measurements for model validation, along with numerous operational tests and demonstrations. An overview of this highly-successful campaign is given by Kimble et al. Proc. SPIE 10698 (2018).

Frill/closeout repair at Northrop Grumman

One of the few technical issues identified in the OTIS cryo-vacuum test was that the frill/closeout assembly surrounding the primary mirror (pictured above) had insufficient slack and exerted unwanted forces on the mirror backplane at operating temperature. This introduced the potential for wavefront instability with temperature variations in flight. One of the key activities after delivery of OTIS to Northrop Grumman was to carefully rework this assembly to restore the intended slack, mitigating the concern for flight.

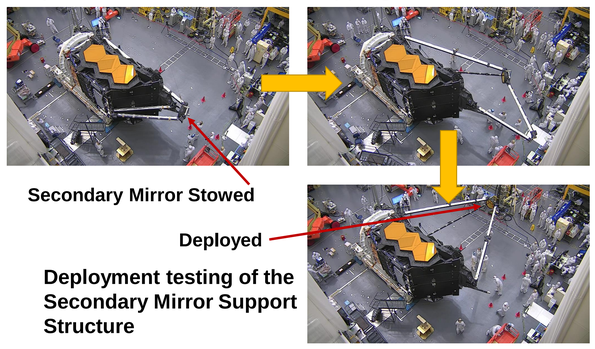
OTIS Activities at Northrop Grumman

The OTIS was delivered to Northrop Grumman's Redondo Beach facility in early 2018. Key activities since then have included cleaning the primary mirror and completing the final OTIS-element post-environmental deployment tests.



Brush cleaning of the JWST primary mirror

In April 2019, the primary mirror segments were carefully cleaned with a light-contact brush technique. This cleaning was very effective and essentially reset the clock with respect to particulate accumulation. The secondary mirror, which remains accessible late in the flow, will be cleaned shortly before shipment to the launch site. Current projections indicate that the payload will comfortably meet its contamination requirements at the time of shipping.



Deployment testing of the Secondary Mirror Support Structure

The final post-environmental deployment test for the OTIS was the gravity-offloaded deployment of the **Secondary Mirror Support Structure.** This tripod features two rigid struts and one hinged strut with the drive and latching mechanisms. Final deployment testing of the **Aft Deployable ISIM Radiator** was also accomplished after delivery to Northrop Grumman.

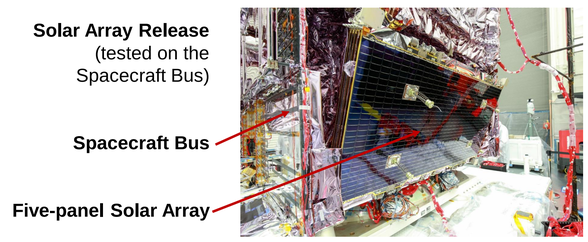
While waiting for the Spacecraft Element to complete its integration and test program, the OTIS team also accomplished significant risk-reduction testing, validating software updates on the flight hardware, and previewing electrical test activities that will be carried out with the Spacecraft. **Thermal blankets in regions that interface with the Spacecraft were installed.**

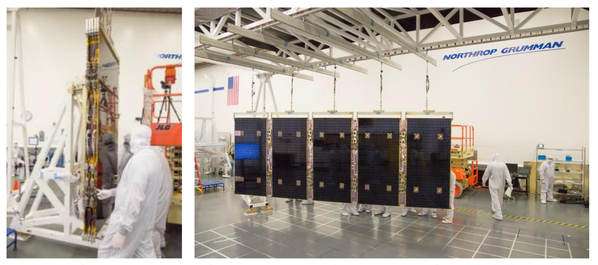
Spacecraft-Level Deployments

Deployed, tensioned sunshield

Prior to the Spacecraft Element environmental test program, deployment testing of the five-layer sunshield was accomplished. Enhancements to the Membrane Tensioning System to improve its reliability were identified, which have since been implemented successfully.

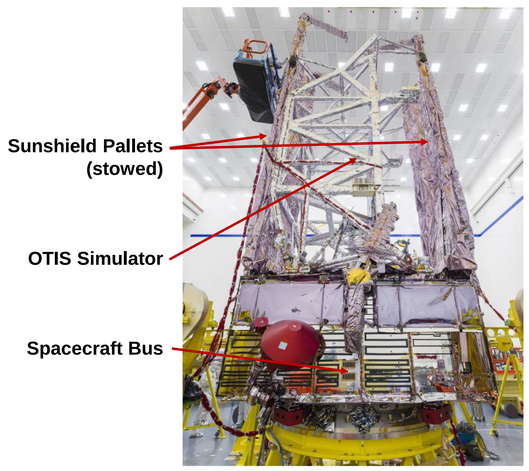
The other deployable features of the Spacecraft Element were also tested thoroughly in appropriate configurations.





Solar Array Deployment Testing – Panel Unfolding

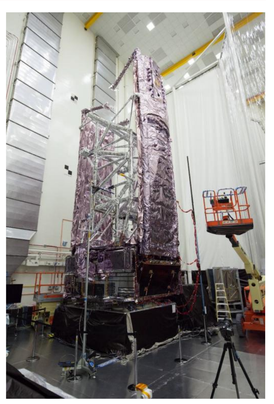
The solar array, for example, was tested for release of the launch restraint devices while mounted to the spacecraft; however, for proper unfolding of the five panels, a specialized gantry system was used to provide gravitational offloading.



After complete deployment and functional testing of the Spacecraft Element, it was configured for environmental testing: acoustics, vibration, and thermal-vacuum. For that test program, the Spacecraft was configured with an OTIS simulator, which emulated the mass, center-of-gravity, and stiffness of the real OTIS.

Spacecraft Element Environmental Testing

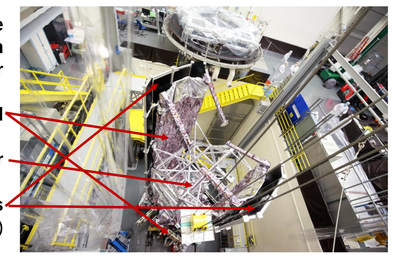
In the Acoustic Test Chamber

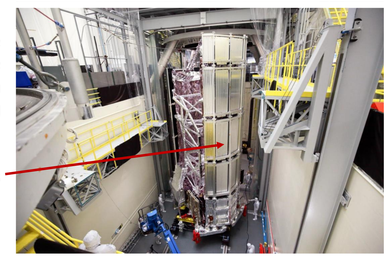


On the Vibration Table

After careful transporting of the payload to the environmental test facilities on Northrop Grumman's campus, the Spacecraft Element underwent successful acoustic and vibration testing (sine sweep, in all three axes). Testing was at so-called "Proto-flight Levels", meaning that the goal of the tests was to expose the payload to +3dB above expected flight loads.

The final environmental test for the Spacecraft Element was a ~40-day thermal-vacuum test. In this test, the sunshield was in its stowed (launch) configuration, but the Spacecraft Bus (with all of its avionics) was exposed to the relevant temperature ranges expected in flight operations, plus margin.





During the Spacecraft Element thermal-vacuum test, the Spacecraft Bus was taken through four thermal cycles between hot and cold proto-flight temperatures (flight expectations plus margin), while the Sunshield was taken through two cycles. Comprehensive functional tests (for primary and redundant systems) were executed at both the hot and cold temperature plateaus. In addition, there were soaks at cold survival temperatures and cold turn-ons. Primary and redundant heaters were tested. Thermal balance measurements were taken at hot and cold for thermal model correlation. Finally, 23 of the Sunshield's Membrane Release Devices were released at temperature; the rest were released later at ambient.

The Two Final Pieces of JWST Came Together in August 2019

After the successful completion of the Spacecraft Element functional and environmental test program, the two final pieces of the Observatory were ready for mating, which was initiated in August 2019. See poster 372.09 (McElwain et al.) for a report on the Observatory-level integration and test program, which is now well underway.