The James Webb Space Telescope: Observatory Status and Preparations for Launch

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JWST Science Themes

First Light & Reionization

Assembly of Galaxies

Birth of Stars and Protoplanetary Systems

Planets and the Origins of Life
JWST Team

Organizations
- Mission Lead: Goddard Space Flight Center
- Project Scientist: Dr. John Mather (Nobel Laureate)
- International Partners: ESA & CSA
- Observatory Contractor: Northrop Grumman Aerospace Systems
- Operations Center: Space Telescope Science Institute

Instruments
- NIRCam (Near Infrared Camera) – Univ. of Arizona
- NIRSpec (Near Infrared Spectrograph) – ESA
- MIRI (Mid-Infrared Instrument) – ESA/JPL
- Fine Guidance Sensor/Near Infrared Imager and Slitless Spectrograph – (FGS/NIRISS) – CSA
How JWST Works

Ariane 5 Launch Vehicle

JWST Deployed

- Primary Mirror
- Cold Side (~40K)
- Secondary Mirror
- L2 Halo Orbit

JWST is folded and stowed for launch

- Integrated Science Instrument Module
- 5 Layer Sunshield (visible next slide)
- Solar Array
- Spacecraft Bus

L2 Halo Orbit

- Hubble
- Moon
- Webb

Distance:
- 570 km (Earth to Hubble)
- 384,400 km (Hubble to Moon)
- 1.5 million km (Moon to L2)

JWST is deployed in the L2 Halo Orbit, which is a specific region of space where the gravitational pull of Earth and the Moon balance out, providing a stable location for the telescope to observe the universe.
Optical Telescope Element (OTE)

### SI Field Location Requirement (RMS WFE, nm) Measured (RMS WFE nm)

<table>
<thead>
<tr>
<th>SI Field Location</th>
<th>Requirement (RMS WFE, nm)</th>
<th>Measured (RMS WFE nm)</th>
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<tbody>
<tr>
<td>NIRCam</td>
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<td>114</td>
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<tr>
<td>NIRSpec</td>
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<tr>
<td>MIRI</td>
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<td>117</td>
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<tr>
<td>NIRISS</td>
<td>150</td>
<td>119</td>
</tr>
</tbody>
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See Lightsey 10698-3
Verifying JWST’s Performance

- JWST imaging quality and stability were defined for the end to end Observatory optical system.
- Optical system must meet these requirements with both the static and dynamic errors.
- **Ground testing** where possible, with component level testing, ISIM level testing, and OTIS level testing.
- **Integrated modeling** where testing is not feasible. A software package called the Integrated Telescope Model (ITM) generates PSF based on ground test data and uses integrated modeling analysis for thermal distortion, deployed dynamics, and pointing control.
- **Commissioning activities** will validate the performance for primary metrics such as image quality and stability.
Observatory Sensitivity: Imaging

See https://jwst.stsci.edu/science-planning/
Courtesy of Jane Rigby
Observatory Sensitivity: Spectroscopy

See https://jwst.stsci.edu/science-planning/
Courtesy of Jane Rigby
JWST Integration & Test Flow

SC Avionics Tests → SC Panel I&T
SC Core Structure I&T → Spacecraft Bus / Sunshield I&T (NGAS)
SC Propulsion I&T → Spacecraft Bus / Sunshield I&T (NGAS)
Sunshield Component Tests → Spacecraft Bus / Sunshield I&T (NGAS)
EP Sunshield Observatory Core & Sub-Scale Sunshield Thermal Tests → Spacecraft Bus / Sunshield I&T (NGAS)
Pathfinder OTE I&T → Flight OTE Ambient I&T (GSFC)
AOS I&T → Cryo-Cooler I&T
SMA I&T → Cryo-Cooler I&T
PMSA I&T → ISIM I&T
DTA I&T → OTIS I&T (GSFC)
SMSS I&T → OTIS I&T (GSFC)
Flight OTE Structural I&T (NGAS) → OTIS I&T (GSFC)
Cryo-Cooler I&T → OTIS Cryogenic Testing (JSC)
Science Instrument I&T → OTIS I&T (GSFC)
ISIM Structure → OTIS I&T (GSFC)
IEC I&T → OTIS I&T (GSFC)

- Observatory I&T Activity
- Spacecraft Element I&T Activity
- OTIS (OTE+ISIM) I&T Activity
- Optical Telescope Element I&T Activity
- ISIM Element I&T Activity
- Cryo-Cooler I&T Activity
OTE + ISIM = OTIS

JWST OTE –V1, ISIM Installation

ISIM Installation from AOAS

*Circa SPIE AT+I 2016 Edinburgh
Following the integration of the OTIS assembly, the payload executed the ambient test program at Goddard.

Assorted mechanism deployments (e.g., ADIR, bib, wings, DTA, IEC, frill first motion), PMSA gap tests and alignment measurements were sprinkled in among these electrical functional test activities.

Post-environmental deployment tests included actuation of the Launch Restraint Mechanisms.

See Keski-Kuha 10698-125
Starting in Nov. 2016, the OTIS vibration test was carried out in three axes, with V2/V1 on a horizontal shaker and V3 on a vertical shaker.

For each axis, the team gradually increased sine sweep test levels from -24 dB through -18, -12, -9, -6, -3 dB, where 0 dB is the final “protoflight” level.

V2 vibe anomaly identified as gapping in a launch restraint mechanism (LRM). The V1 and V3 did not have any anomalies.

OTIS was measured to have a higher stiffness and lower damping than the mechanical models predicted.

Ancillary tests showed LRM preload degradation from dynamic exposure, which is being evaluated.

Lessons learned from OTIS Sine Vibe Testing presented to and incorporated in the Spacecraft Element sine vibe test planning.
Prior to the acoustic test, OTIS temporarily moved to SSDIF to make adjustments to the tent.

The acoustic test increased the levels from -18, -12, -6, -3 up to 0 dB, where 0 dB is the final “protoflight” level.

Temporary hold at -6 dB during the acoustic progression to assess the stress and fatigue on a primary mirror segment flexure. It was deemed safe to proceed and the test completed successfully.

Acoustic test went well and met all protoflight minimum specifications at all octave bands.

The microshutter array (MSA) is sensitive to acoustic exposure. The test set-up was adjusted to reduce the high frequency acoustic exposure that was most problematic for the MSA. Post-acoustic test imaging inspections suggest the MSA was not affected by this test.
OTIS Ambient Testing - Results

- **OTIS completed the vigorous ambient test program and is in excellent health.**
- All mirror actuators operated successfully on both A and B sides.
- Mirror figures consistent with pre-environmental measurements.
- Post-vibe launch restraint mechanisms (LRMs) released properly.
- Test vibe levels were reduced at a few resonant frequencies that had a higher dynamic response than anticipated. This will be mitigated by adding particle dampers following the cryotest at the Johnson Space Center and before the Observatory-level vibe testing.
- Measured contamination levels are well within budgets at this phase of integration and test.
JWST Integration & Test Flow

SC Avionics Tests → SC Panel I&T
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SC Propulsion I&T
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PMSA I&T
DTA I&T
SMSS I&T
Flight OTE Structural I&T (NGAS)
Cryo-Cooler I&T
Science Instrument I&T
ISIM Structure
IEC I&T
Flight OTE Ambient I&T (GSFC)
OTIS I&T (GSFC)
OTIS Cryogenic Testing (JSC)
Spacecraft Bus /Sunshield I&T (NGAS)

2017
2016
2018

Observatory I&T (NGAS)

ISIM I&T
2014

Cryo-Cooler I&T

ISIM Structure
2012

Observatory I&T Activity
Spacecraft Element I&T Activity
OTIS (OTE+ISIM) I&T Activity
Optical Telescope Element I&T Activity
ISIM Element I&T Activity
Cryo-Cooler I&T Activity
Johnson Space Center Chamber A

JWST Space Telescope Transporter for Air, Road and Sea (STTARS)

Apollo command module test in JSC’s Chamber A (1968)

JWST configuration for OTIS cryo-test inside JSC’s Chamber A (2017)

See Kimble 10698-3
Sunshield/Spacecraft Status

- Sunshield and spacecraft fully integrated.
- Successfully completed pre-environmental deployments.
- Successful spacecraft compatibility testing with TDRSS and the Deep Space Network.
- Spacecraft element environmental tests (e.g., acoustic, vibration, thermal vacuum) this year.
OTIS Arrival in Northrop’s Highbay
SCE Environmental Test Flow Overview

1. M8/Stowed SCE with OTIS Simulator
2. PAS Shock Test (Mechanical Only)
3. Transport to M1/LATF
4. Acoustics @ Protoflight
5. Transport to M4
6. We are here.

- Stow for OTIS Install (3rd fold)
- Full SCE Deployment (2nd deploy)
- Transport to M8
- Thermal Vacuum
- 3-axis Vibe @ Protoflight

We are here.
Observatory I&T Flow Overview

- **Observatory I&T Start**
- **OTIS Install and DTA Deploy**
  - Risk reduction activities underway
- **Complete Stow**
- **Transport to Vibe Facility**
- **Vibe @ Acceptance**
- **Stow and Ready to Ship**
- **Full Observatory Deployments**
- **Transport to Highbay**
- **Acoustics @ Acceptance**
- **Transport to LATF**
JWST commissioning is “the collection of flight activities required to activate, checkout, and calibrate the Observatory subsystems, including the science instruments to perform Cycle 1 science.”

The flight operations team is in place and has been going through various training programs and rehearsals in preparation for commissioning.
Summary

- JWST will carry out transformative science from the very early universe and across cosmic time.
- JWST OTE and ISIM have been combined to form OTIS, which completed its test program at NASA Goddard and Johnson. It is now delivered to Northrop’s Space Park.
- The spacecraft element has completed its integration activities and is currently in its environmental test program.
- To date, JWST testing and analysis suggests that all performance requirements can be achieved.
Following JWST

Webpages
www.jwst.nasa.gov
webbtelescope.org/

Webb e-book

Social Media
www.jwst.nasa.gov/webcam.html