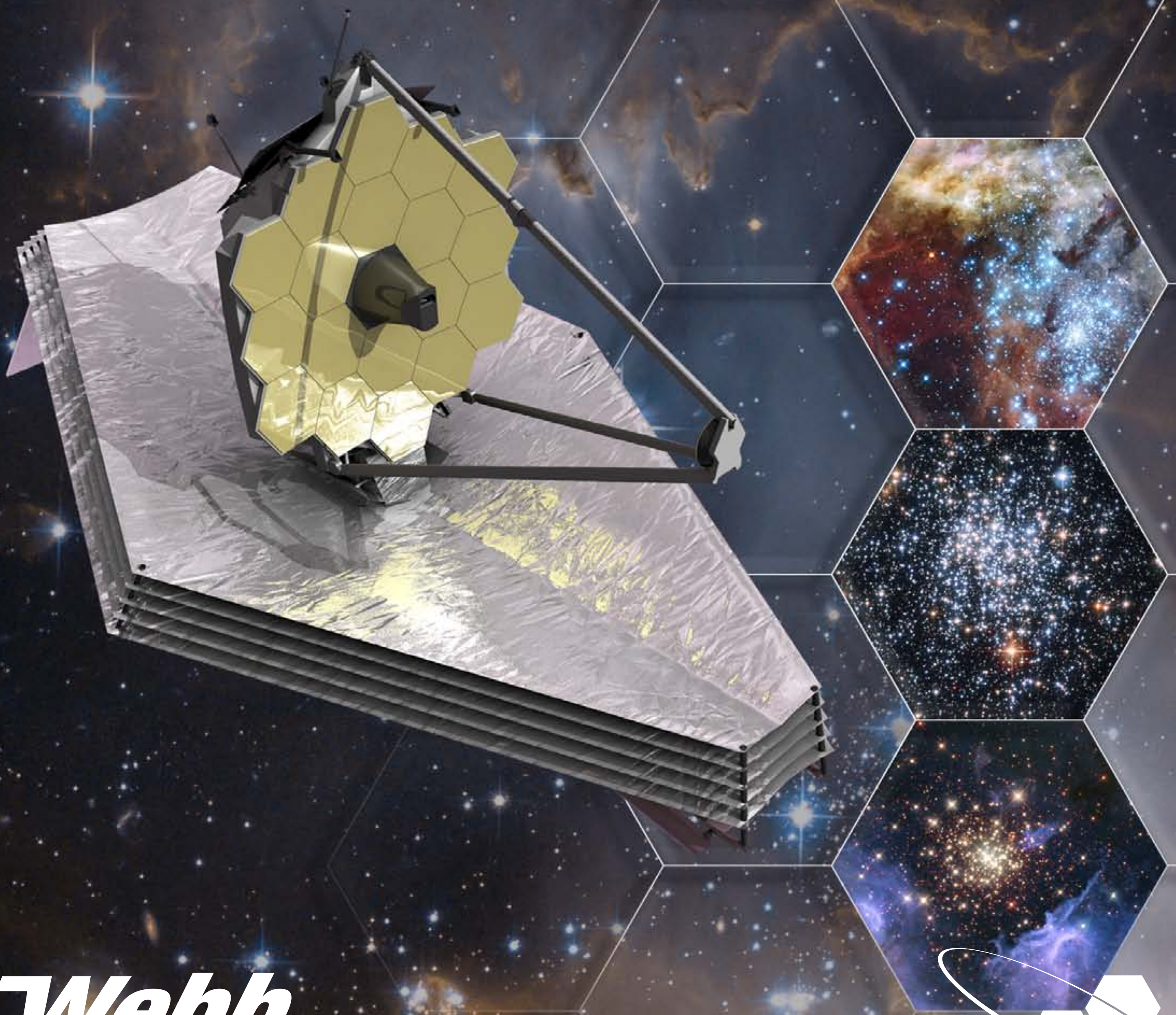
National Aeronautics and Space Administration



Webb Update

Summer 2016

jwst.nasa.gov

Webb
Update
Issue #20, Summer 2016
James Webb Space Telescope

The James Webb Space Telescope Builds Up Expectations

By Mike McElwain

The James Webb Space Telescope (JWST) has made tremendous progress with integration and test activities, keeping on schedule for an October 2018 launch date. Since the last newsletter (Winter 2016) that highlighted the installation of the 18 segments comprising the telescope primary mirror at NASA's Goddard Space Flight Center, the flight secondary, tertiary and fine steering mirrors have been aligned and installed as the OTE (Optical Telescope Element). The final testing of the flight science instruments installed in the ISIM (Integrated Science Instrument Module) prior to attachment onto the observatory was completed after 108 days in the Goddard cryo-vac chamber. With the subsequent attachment of the ISIM behind the OTE, these two elements have now been merged into OTIS (Optical Telescope element and Integrated Science Instrument Module). In addition to the OTIS integration at Goddard, two additional hardware integration and test lines are progressing in parallel at Northrop Grumman Aerospace Systems (NGAS), the Project's observatory contractor. These lines of integration are for the flight sunshield and spacecraft.

The 18 primary mirror segment assemblies (PMSAs) were installed with the OTE mounted on the Ambient OTE Assembly Stand (AOAS) located inside the large cleanroom facility at Goddard. The AOAS amounts to a giant optical bench with laser tracker & radar metrology equipment to determine hardware positions relative to fixed mechanical references on the structure. For the primary mirror segment installations, the secondary mirror support structure was moved into an over-deployed state, providing clearance for a robotic arm that moved the segments into position. The location of each mirror segment in six degrees of freedom was accomplished with the combination of the arm and a set of precision machined shims attached to the segments. Following the PMSAs installation, the secondary mirror was integrated with the secondary mirror support structure (SMSS). The secondary mirror was installed using a manual installation fixture, since it was a single optical element in a more accessible and contamination neutral position. The secondary mirror was successfully integrated on March 1, 2016 (Figure 1).

The JWST telescope is a three mirror anastigmat, a common optical design that is used to provide control of spherical aberration, coma, and astigmatism over a large field of view. With the primary and secondary mirrors installed, it remained to install the flight tertiary mirror and a final flat mirror (the fine steering mirror), which directs the light collected by the telescope to the science instruments. The tertiary and fine steering mirrors had already been assembled into a structure (the aft optical system, AOS), enclosed with a black cover for stray light mitigation, and cryo tested as a separate sub-system. The flight AOS assembly was then attached in Summer 2015 to an engineering unit backplane with two flight spare PMSAs and used in the second optical ground support equipment (OGSE-2) Pathfinder test in Chamber A at Johnson Space Center. This Pathfinder test previewed many of the tests to be conducted on OTIS, ensuring that the chamber and support equipment were ready as well as providing an opportunity to refine test procedures and as a valuable training session for personnel. The OGSE-2 test met its objectives, and the flight AOS system was subsequently shipped to Goddard for integration with the OTE.

Following the OGSE-2 pathfinder test cycle, the AOS was delivered to Goddard in December, 2015 and moved into the cleanroom. This was the last time the optics in the AOS would be easily accessible, and therefore, the tertiary and fine steering mirrors were were inspected for cleanliness. Some acrylic particles

Figure 1. The secondary mirror was installed with the support structure in the stowed position. The process used a manual fixture situated down wind of the telescope in Goddard's cleanroom.

Credit: NASA/Chris Gunn.

were seen on the tertiary mirror so it was cleaned and its optical performance verified. Remedial actions were also undertaken to mitigate any further particulate fallout in the AOS and in any other area of the observatory that might have a similar particulate sensitivity. The AOS was successfully installed into the OTE backplane completing the OTE integration phase. The installed flight AOS can be seen in the center of the PMSA cluster in Figure 2 with the OTE mounted in an upright (cup-up) orientation in the AOAS.

Nearly coincident with this completion of the OTE integration, the ISIM had completed its third and final cryo-vacuum test, called CV-3. For the ISIM installation, the OTE needed to be turned over in a cup-down orientation, with the primary mirror segments facing the floor. Primary mirror covers, which protect the flight mirrors during installation procedures, as well as from particulate fallout while cup-up, were removed. Technicians positioned on diving boards lifted the covers off the segments (Figure 2).

Prior to rotation to a cup-down orientation, the telescope was rotated into a horizontal pointing orientation (for various tests including wing deployment as well as attachment of some flight electrical harnesses). In this orientation, the JWST OTE was fully exposed, in all of its shiny gold glory, on April 25, 2016 (Figure 3). The most visually appealing hardware is the telescope itself, which is marked by a high-reflectivity, very thin, gold coating on the primary mirror segments and the secondary mirror. Visual inspection and photography confirmed the primary mirror covers were successful in protecting the mirror from particles. It was time to turn the OTE over to the cup-down configuration, but en route to that configuration, the telescope was intermittently positioned facing the cleanroom viewing window. A crowd gathered to share this unique perspective, and Senior Project Scientist John Mather even took a selfie reflected from the JWST mirror. This configuration was ephemeral and shortly thereafter the OTE was rotated to cup-down and moved back into the AOAS for the fixed ISIM radiator and ISIM installation.

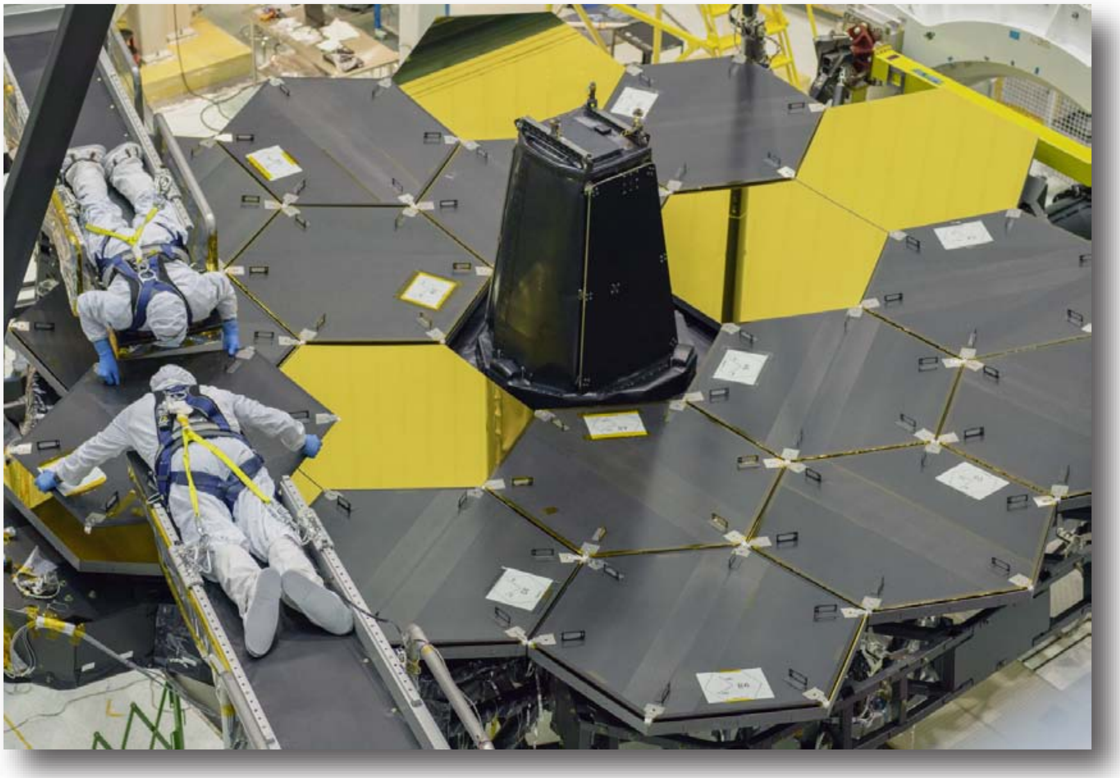


Figure 2. The AOS is visible as the black cone in the center of the primary mirror. It supports the tertiary mirror and a flat fine steering mirror. The primary mirror segment covers were removed by hand prior to reorienting the telescope.

Credit: NASA/Chris Gunn

Figure 3. Senior Project Scientist John Mather watches as the JWST primary mirror rotates in full view from the cleanroom viewing window. The primary mirror will ultimately be used to look into the distant universe.

Credit: NASA/Chris Gunn

The ISIM consists of a rigid, composite structure that supports and maintains the alignment of the four science instruments. The critical alignment of the ISIM to the AOS relies on an optical interface that must be positioned to within tolerances of a few hundred microns in key degrees of freedom. This level of positioning required detailed 3-dimensional metrology of the OTE structure and the ISIM itself. Once the relative positions of all the components were computed it was time to install the ISIM. The installation procedure required craning the ISIM and lowering it into its final resting position within the backplane support fixture. In one 17-hour work day, the ISIM was picked up using a spreader bar, transported by crane over the telescope backplane support fixture, and lowered into position (Figure 4). The ISIM was attached to the OTE through a set of kinematic struts. Subsequent metrology and a review of the data confirmed the AOS to ISIM alignment was within the optical performance requirements. This integration marked the commencement of the OTIS phase within the JWST project (Figure 5).

There are still numerous remaining OTIS integration activities to take place within the Goddard cleanroom, including installation of radiators, instrument electronics, and hundreds of thermal blankets. Following OTIS assembly, acoustic and vibrational tests will take place in Goddard facilities to confirm that the OTIS system will survive the mechanical loads that will occur during launch and ascent. Center of curvature optical and dynamic testing will take place before and after the environmental tests to confirm the integrity of the structure and joints. Following these ambient tests, OTIS will be shipped by cargo plane to the Johnson Space Center, where it will be cryo-tested in Chamber A for optical, thermal, electrical, and software control. This cryo-test is currently scheduled to take place in the middle of 2017 and lasts for approximately 90 days. Following the cryo-testing, OTIS will be transported to NGAS where it will be integrated with the spacecraft element and undergo Observatory-level testing. The Observatory will be packed and shipped to French Guiana for launch at the Arianespace launch complex.

It is clear the next ~two years will be filled with many anticipated project milestones, but of course, all expectations are looking towards the new discoveries this space telescope will enable when operations commence in space.

Figure 4. The JWST science instruments are lowered into position using a crane. The primary mirror segments can be seen facing the floor for this installation. A video of the installation process can be downloaded at http://svs.gsfc.nasa.gov/12273.

Credit: NASA/Chris Gunn

Figure 5. A subset of the JWST team poses for a group photo in front of the JWST telescope. The NASA insignia can be seen in reflection on the JWST primary mirror.

Credit: NASA/Chris Gunn

Webb Update
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Final Pathfinder Test Will Pave the Way for Next Year's Flight OTIS Cryo-Vacuum Test Campaign

By Randy Kimble

Preparations are proceeding rapidly at the Johnson Space Center for the final in the series of Pathfinder tests that are paving the way for next year's cryo-vacuum test of the JWST flight telescope. (The JWST telescope level of assembly is known as the OTIS = Optical Telescope Element (OTE) + Integrated Science Instrument Module (ISIM).)

As reported in previous Newsletters, two earlier Pathfinder tests focused on checking out the Optical Ground Support Equipment (OGSE) and dry-running the optical test procedures and analyses that will be executed for the flight telescope in its test program. Hence those tests, successfully accomplished during 2015, were known as OGSE-1 and OGSE-2.

The upcoming and final Pathfinder test is known as the Thermal Pathfinder (TPF) – as the name implies, this round emphasizes validating the thermal ground support equipment and procedures that will be needed for the OTIS cryo-vacuum campaign. The augmented hardware, shown schematically in Figure 1 and in a photograph in Figure 2, includes 1) the Space Vehicle Thermal Simulator (SVTS), which emulates the central "Core" region where the observatory transitions from the "cold telescope" side of the sunshield, through the sunshield to the "warm spacecraft" side of the sunshield, plus a small central portion of the sunshield coldest layer itself; 2) the Deep Space Edge Radiator Sinks (DSERS) – cold, dark (radiation-absorbing) surfaces that will absorb the thermal radiation from the radiators and thermal blankets surrounding the ISIM, to simulate the deep space environment; 3) an enclosure for capturing the radiated power from the warm ISIM Electronics Compartment (IEC).

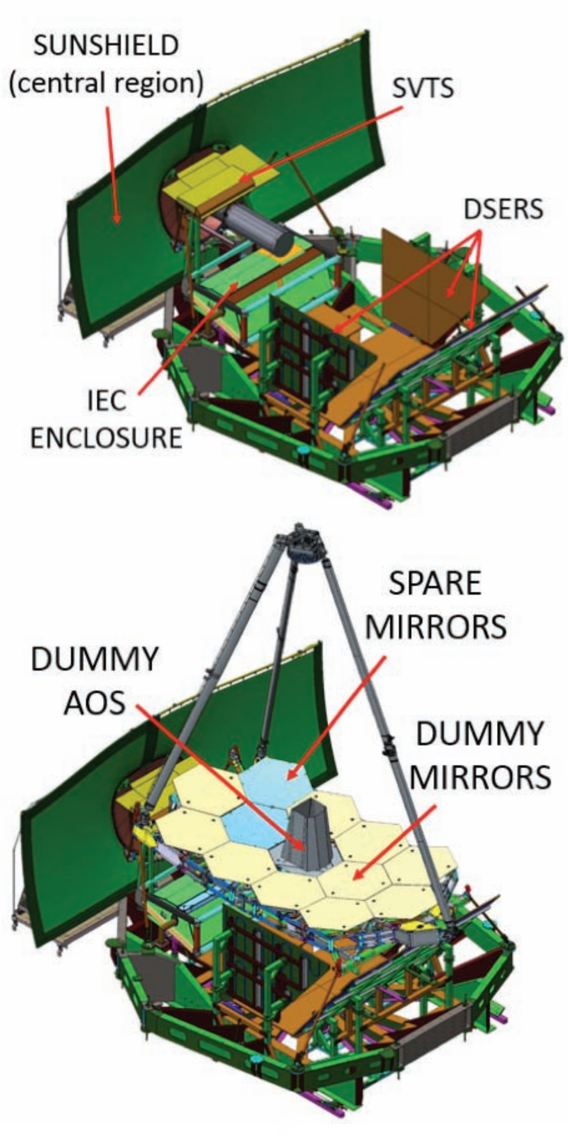

Figure 1. A schematic diagram of the main test article for the TPF test. Top: the principal thermal ground support equipment items. Bottom: those items along with the Pathfinder structure, which is augmented with a dummy Aft Optical System and ten dummy Primary Mirror Segments.

Credit: NASA

In addition to this new thermal GSE, the Pathfinder payload itself has been substantially modified for the TPF run. Previously, the bare Pathfinder structure, emulating the central section of the telescope backplane (i.e. minus the wings), carried only two spare Primary Mirror Segment Assemblies. For the Thermal Pathfinder test, that entire center section is populated, with ten additional dummy Primary Mirror Segments – those dummy segments are made of honeycomb aluminum and coated with gold, like the real flight mirrors. The structure is then closed out with thermal blankets in a flight-like way, so that the thermal properties closely mimic those of the flight system.

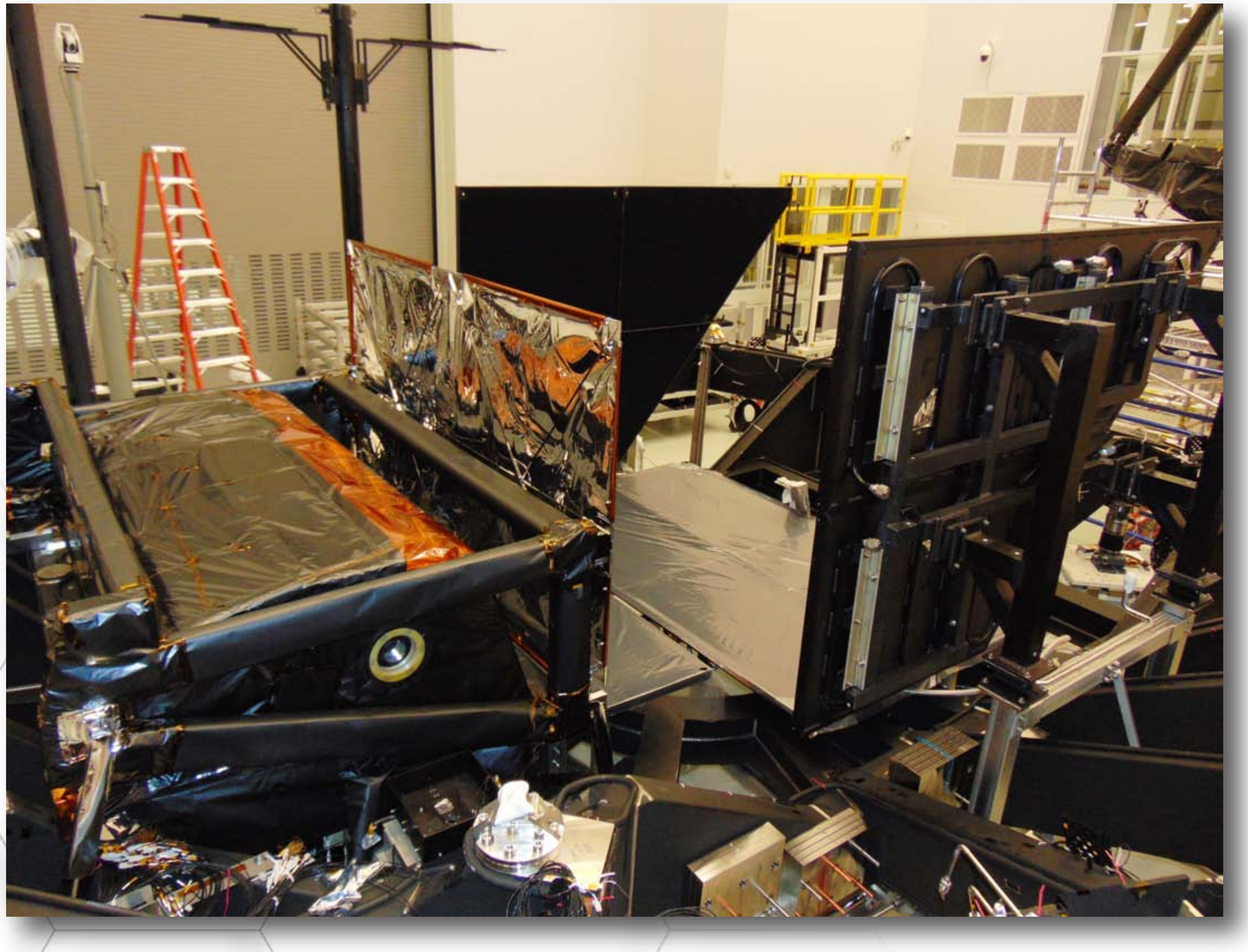

Figure 2. Photograph of the actual TPF thermal GSE, including the DSERS and IEC enclosure.

Credit: Jesse Huguet

In addition to this new thermal GSE, the Pathfinder payload itself has been substantially modified for the TPF run. Previously, the bare Pathfinder structure, emulating the central section of the telescope backplane (i.e. minus the wings), carried only two spare Primary Mirror Segment Assemblies. For the Thermal Pathfinder test, that entire center section is populated, with ten additional dummy Primary Mirror Segments – those dummy segments are made of honeycomb aluminum and coated with gold, like the real flight mirrors. The structure is then closed out with thermal blankets in a flight-like way, so that the thermal properties closely mimic those of the flight system.

Figure 3. The Pathfinder structure, thermally configured for the Thermal Pathfinder Test to be carried out shortly at the Johnson Space Center. The dummy Aft Optical System (AOS) is visible in the center of the primary mirror segments. Among those segments can be seen one gold-coated flight-spare beryllium segment (just in front of the AOS), one uncoated beryllium engineering unit segment, and ten gold-coated aluminum thermal simulator segments.

Credit: NASA/Chris Gunn

The principal goals of the Thermal Pathfinder test are 1) to dry-run the cooldown and warmup procedures the way they will be executed with the flight telescope – obeying all rate and temperature gradient constraints, with no gas-assisted cooling or warming; 2) to achieve an OTIS-like stable thermal balance condition with the Pathfinder hardware; 3) to demonstrate successful contamination control protocols as will be executed for the flight telescope. In achieving these thermal goals, the performance of the SVTS, the DSERS, the IEC enclosure, the IEC sequestration vent (for capturing the water outgassed from its warm electronics), the ISIM pre-cool straps, and the MIRI GSE cryocooler (with simulated IEC, ISIM and MIRI heat loads for the latter items) will all be demonstrated and characterized.

In addition, optical measurements of the two flight spare Primary Mirror segments will be carried out with the Center of Curvature Optical Assembly (COCOA) and the Absolute Distance Measurement Assembly, demonstrating the successful repair of some minor issues encountered in the OGSE program. These optical measurements will also provide an important assessment of the success of the various mitigations for payload vibration that have been implemented since OGSE-2. (Note that the optics team has demonstrated that all critical OTIS measurements can be performed even with the level of vibration experienced in OGSE-2; however, a decreased vibration environment will make the measurements that much easier.) Additional, more detailed thermal, optical, dynamics, and contamination goals round out the TPF program. The preparations for the TPF test are very far along, with pumpdown expected in early September. The test is planned to last for ~52 days.

In the meantime, the team is very actively developing the detailed planning products for executing the flight OTIS test next year. The principal activities have long been known, and most have already been dry-run with non-flight hardware in the Pathfinder program. Now the activities are being defined in detail for execution with the flight telescope and instruments. The steps involve the preparation of detailed Task Information Sheets to define activities (contents, constraints, prerequisites, etc) and Analysis Information Sheets to lay out step by step the process of analyzing the data that will be obtained. Ultimately these plans lead to the development of the formal test procedures and command scripts that will be executed to carry out the OTIS test.

The development of the OTIS test timeline is maturing rapidly, with the sequencing of all of the principal test activities well defined. All tests have been prioritized, and time estimates have been made for their execution. The current baseline is a test of ~93 days duration. The OTIS cryo-vacuum test, the final cryo-test for the telescopes and instruments – a huge milestone in the JWST program – is planned for spring/summer of 2017.

Core2—A Key Test for Predicting JWST's Thermal Performance in Space

By Malcolm Niedner

Because JWST is an infrared telescope, it is especially important that key hardware—detectors, mirrors, surfaces with a view to mirrors, filters, etc.—be within specified cold ("cryogenic") temperature ranges when the telescope is in operational science mode. If this were not the case—if those components were too warm—the detection and measurement of astronomical light by JWST's detectors would be compromised by the telescope's own heat radiation. Put another way, although the faint light from distant galaxies (for example) would still be in the optical beam focused on the detectors, in a too-warm scenario the telescope would see too much of itself, with the result that many scientific objectives of JWST would not be met.

It comes as no surprise, then, that strict thermal requirements are levied on all parts of JWST, particularly those "closest to the science," and that the thermal control system (TCS) responsible for meeting those requirements is a major engineering focus of the design, construction, and testing of the JWST. The TCS design must regulate and suppress "parasitic" heat flows entering the cold "telescope side" of JWST from its hot, sun-facing "spacecraft side" in a way that meets requirements. The most obvious cooling element in the TCS design is the 5-membrane, tennis-court sized sunshield (Figure 1) that keeps sunlight off the telescope mirrors and science instrument enclosure, but the sunshield is not the end of the thermal control story. For example, whereas the "passive cooling" it provides is part of the solution for the three near-infrared science instruments in the Integrated Science Instrument Module (or ISIM), "active cooling" via a powered cryocooler is necessary for the fourth instrument—the mid-infrared instrument (MIRI)—because its detectors must operate significantly colder than the near-infrared ones.

This brief article does not focus on the large sunshield or the cryocooler, however, but on the so-called "core region" of JWST. The core is a very critical region because it is where the hot spacecraft (always sun-facing) connects to the cold optical telescope (never sun-facing) via a "deployable tower assembly" (DTA) and electrical harnessing, both of which pass through an opening in the center of the sunshield and connect the two major elements—spacecraft and telescope. An additional major part of the core region is the ISIM electronics compartment (IEC), an enclosure located on the cold telescope side, but containing electronics that run warm—at essentially spacecraft temperatures. IEC's proximity to ISIM—it's located directly below ISIM—is a non-trivial thermal control challenge. Figure 1 is an artist rendering that shows the locations of the sunshield's central opening, the DTA, and the IEC; also indicated are components that must be kept cold.

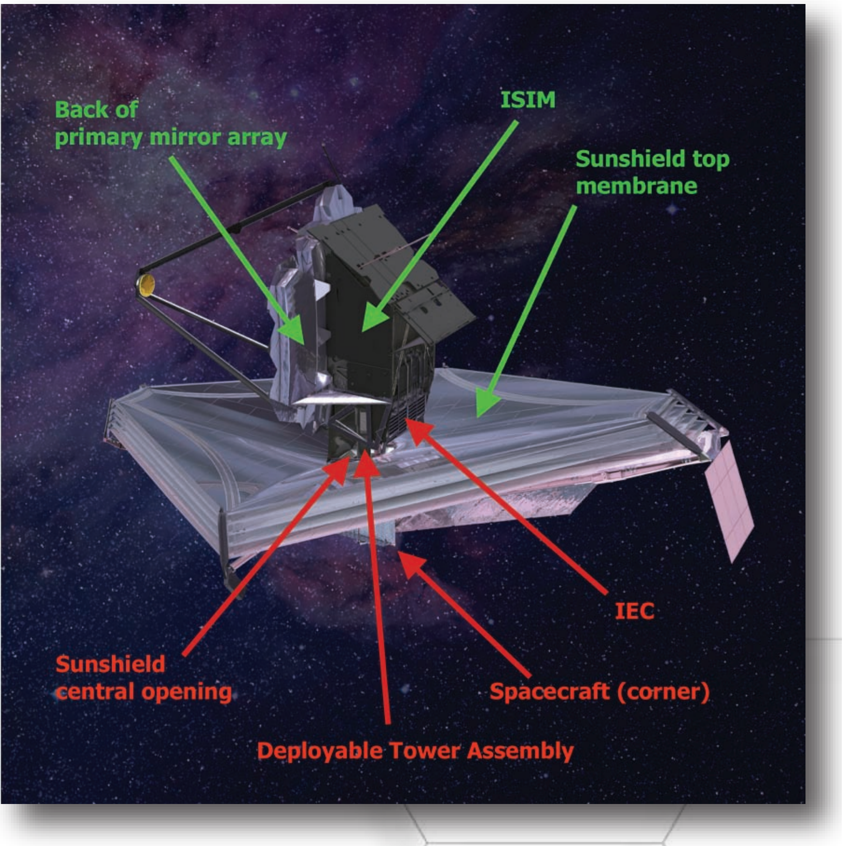

Figure 1. Artist rendering of JWST, showing the 5-membrane sunshield separating the spacecraft (below, corner showing) and the telescope (above). Red arrows point to some features of the "core region" that produce/conduct heat. Areas that must be kept cold are indicated by green arrows.

Credit: NASA/Northrop Grumman

To sum up the importance of the core: heat loads from the spacecraft below the center of the sunshield, and from the IEC located below ISIM, need to be dealt with in ways that reject as much heat as possible to space, in the process preserving scientific performance. This is achieved with a carefully designed set of thermal control surfaces (not seen in detail in Fig. 1). In broad brush, these features keep a large fraction of the spacecraft- and IEC-generated heatloads out of the ISIM volume and away from the backsides of the primary mirror segments. Hot instruments and mirrors are bad for science.

To test the TCS design of the core region, the Project has recently carried out an important thermal vacuum campaign, "Core2," in NASA Goddard's Space Environment Simulator (SES) chamber. The "2" obviously indicates this was a second such test (the first was done quite a few years ago, in 2009), and it was executed with much greater detail and fidelity to the core hardware that will actually fly in space. Simply put, Core2 was a highly targeted, thermal only, cryogenic vacuum test—there were no optics, unlike the ISIM, Pathfinder, and upcoming OTIS tests ("OTIS" = Optical Telescope Element + ISIM).

Core2 obtained cryogenic vacuum data on a high fidelity, flight-like mock-up (no flight hardware involved) of the core region, as shown in Figure 2. The ultimate test objective was to obtain the most accurate possible characterization and correlated thermal model of the core—we want to be able to predict JWST thermal performance in space, and the ways in which the core transmits and rejects heat are of key importance. Viewed in this context, Core2 was a test developed and executed in the spirit of the Pathfinder series: testing of high fidelity/non-flight hardware provides knowledge about the flight hardware that reduces risks.

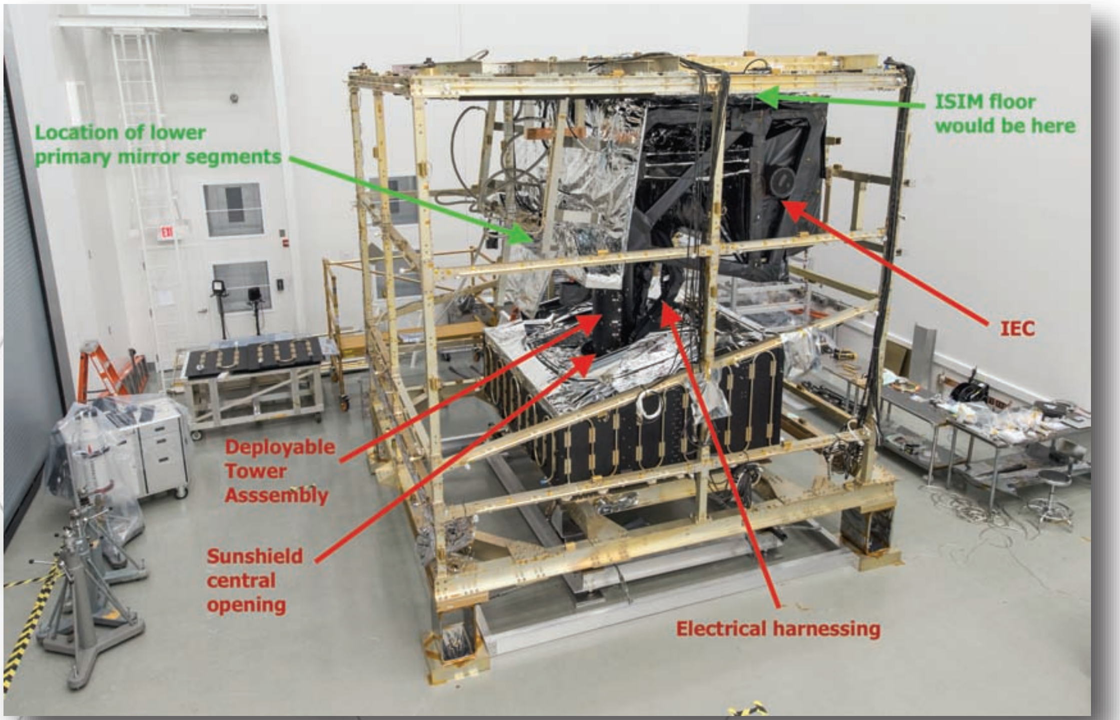

Figure 2. The Core2 test article well into assembly, prior to the test. A few of the key core components discussed in the text are indicated. Red arrows point to hardware that produces or conducts heat, green arrows to items that must be kept cold. The spacecraft simulator, which also produces heat, is contained inside the black-sided volume at the bottom of the stack.

Credit: NASA/Desiree Stover

An important aspect of Core2 is that its highly targeted thermal objectives were originally contained in next year's test of the flight OTIS. Although the OTIS test in Johnson Space Center's "Chamber A" will have a thermal component (as well as optical, electrical, software, etc.), the Core2 test was actually more densely instrumented with thermal sensors—650 of them—in the core area than OTIS is. In the end, Core2's having taken on key thermal objectives will allow OTIS to concentrate more on telescope functionality and optical testing.

Here are a few specific details of Core2 as tested in the SES (see Figure 3). The test, which commenced April 12, was designed to run approximately 48 days. By May 23, Core2 had completed four of the five planned thermal balance points, at each of which the 650 measured temperatures had reached equilibrium according to the level of heat inputs supplied by the surrogate IEC electronics boxes (actually heater plates) and the spacecraft simulator. However, two of the eleven very accurate, very sensitive heatflow-measuring sensors called "Q-meters" (these were in addition to the thermometers) that had been placed in especially key locations were showing some anomalous behavior. The thermal engineers were able to diagnose what the likely problem was, and they devised a way to fix the two units after the SES chamber was warmed-up and repressurized. To cut to the end result, the faulty Q-meters were removed, repaired, and reinstalled, and starting on June 10, a test extension began that ran 33 days and successfully reached two carefully chosen thermal balance points.

The thermal engineers are very pleased by both the quality and quantity of the data, and at the time of this writing the analysis of the test data is ongoing. The final correlation of a thermal model with test data is very involved when many hundreds of thermometers take data at, and in transition to, multiple thermal balance points; and when over a thousand parameters are used in the thermal model. The work is ongoing, just as it is across the entire JWST waterfront of integration, test, and verification activities, other aspects of which are written about by McElwain and Kimble in this edition of the Newsletter.

Figure 3. The Core2 test article being removed from NASA/Goddard's Space Environment Simulator (SES) following testing. When installed in the chamber, there were only 8 inches of vertical clearance with the chamber roof.

Credit: NASA/Desiree Stover

JWST Guest Speakers

Would you like a colloquium at your university on JWST? How about a talk at a conference you are organizing? These JWST scientists are willing to give a talk. The JWST project has allocated some funding to pay the expenses for talks in the US; talks in other countries can also be arranged. In addition to the specific topics listed below, the speakers are also available to give JWST Mission Overview talks and talks at the general public level.

To arrange a talk, please email jwst-science@lists.nasa.gov or contact the speaker directly. For European and Canadian universities and institutions interested in inviting speakers to give talks covering the full range of scientific topics addressed by JWST, please contact Pierre Ferruit (ESA JWST Project Scientist, ESTEC, pferruit@rssd.esa.int) or René Doyon (CSA JWST Project Scientist, Univ. of Montreal, doyon@ASTRO.UMontreal.CA) respectively.

- Rene Doyon, Universite de Montreal, "JWST NIRISS Science"
- Jonathan Gardner, GSFC, "JWST and Galaxy Evolution"
- Matt Greenhouse, GSFC, "JWST Mission Overview and Status"
- Heidi Hammel, AURA, "Planetary Exploration with JWST"
- Nikole Lewis, STScI, “JWST and Transiting Exoplanet Science”
- Jonathan Lunine, Cornell University, "JWST, Exoplanets, and the Solar System"
- John Mather, GSFC, "Getting Ready for Discovery: JWST Capabilities"
- Michael McElwain, GSFC, “JWST Exoplanetary Science”
- Stefanie Milam, GSFC, “Innovative Solar System Science with JWST”
- Bernie Rauscher, GSFC, “JWST and its HAWAII-2RG and SIDECAR ASIC Detector Systems”
- George Rieke, University of Arizona, "Debris Disks and the Evolution of Planetary Systems," or “The Place of JWST in the Growth of Infrared Astronomy”
- Marcia Rieke, University of Arizona, "NIRCam for JWST: Exoplanets to Deep Surveys"
- Jane Rigby, GSFC, “Gravitationally Lensed Galaxies and JWST,” or “AGN and JWST”
- Eric Smith, NASA HQ, “Why are we building the James Webb Space Telescope?” or “JWST: Lessons Learned (so far)”
- George Sonneborn, GSFC, "Imaging and Spectroscopy with JWST"
- Massimo Stiavelli, STScI, "Studying the first galaxies and reionization with JWST"
- Amber Straughn, GSFC, "JWST and Galaxy Assembly"
- Chris Willot, NRC, “JWST Spectroscopy of the Distant Universe”
- Rogier Windhorst, Arizona State University, "First Light, Reionization and Galaxy Assembly with JWST" or "JWST and Supermassive Black Hole Growth"

Upcoming Conferences with Invited JWST Presentations

Keep up with JWST Conferences and Workshops here: https://jwst.stsci.edu/events

Watch JWST testing take place in Goddard's cleanroom live on our WebbCam at jwst.nasa.gov

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