Webb Status

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There were no lazy days of summer for the scientists and engineers working on the James Webb Space Telescope! Rather, summertime saw flurries of activity on many different mission fronts.

Meeting mission milestones

The James Webb Space Telescope project is still holding steady to its planned launch of the observatory in October 2018. A number of different facets to the observatory are reaching critical points in preparation for launch, and the pieces that make up the observatory are slowly coming together.

Although activity is always occurring on different parts of the observatory, each year leading up to launch has a theme to epitomize the important components of the mission in process that year. Manufacturing the spacecraft was the theme for the year 2014, and key advances have been made on several fronts.

Testing of the sunshield at Northrop Grumman commenced, using a full-scale engineering model. This is the largest part of the observatory, expanding to the size of a tennis court when fully unfurled. In July 2014, this full-scale engineering version underwent folding and unfolding tests. Manufacturing of the flight version of individual layers is underway. The sunshield testing and fabrication is described in more detail in a companion article by A. Conti.

A successful critical design review (CDR) of the spacecraft took place earlier in 2014 at Northrop Grumman. As a result, manufacturing the parts that form the spacecraft—such as fuel tanks, gyroscopes, and solar panels—has commenced. The other components of the spacecraft, which provide power and communications for the entire observatory, as well as telescope and image stabilization, also saw significant advancements on the planned timeline.

Preparations are underway for the series of tests that will occur after the next step in the integration of the observatory, when the science instruments get connected to the optics. These tests will occur at the historic Chamber A at Johnson Space Center in 2016. Chamber A is known for its role in testing equipment during the Apollo missions, and was chosen to be the location of the testing of the Integrated Science Instrument Module (ISIM) and the Optical Telescope Element, due to the large size of the chamber, which is needed to accommodate the Webb structure (see Figure 1). In July, the chamber was subjected to a cryogenic proof test and a bake-out, in which the temperature inside the chamber was raised in order to drive off any contaminants.

A refurbishment has made Chamber A, the largest cryogenic-optical vacuum test chamber in the world, ready to support future testing of Webb’s components. The renovations enable the low temperatures required for testing the combined optics and instruments, the ability to maintain vacuum for the weeks-long durations of the testing, and increase the efficiency of the testing by minimizing the amount of nitrogen and helium coolant required. The ground support equipment for this phase of testing includes sunshield and thermal simulators, a vibration isolator, a center-of-curvature optical assembly, an autocollimating-flat assembly, and photogrammetric cameras.

Testing, take two

With the arrival of the last two Webb science instruments in 2013, the ISIM now holds all four science instruments. Some known deficiencies in the flight hardware have already been corrected and the remaining problems will be fixed between the second and third cryo-vacuum test campaigns (CV2 and CV3). To alleviate the degradation experienced by the near-infrared focal-plane arrays, replacement detectors for each near-infrared instrument were manufactured, tested, and certified for flight. The Near Infrared Camera (NIRCam) received its new batch of detectors in November 2013, prior to CV2. Those for the Near InfraRed Spectrograph (NIRSpec), the Near Infrared Imager and Slitless Spectrograph (NIRISS), and the Fine Guidance Sensors (FGS) will be installed into these science instruments by January 2015, well in time for CV3.

Integration and testing is now picking up pace. The ISIM CV2 began in Goddard’s Space Environmental Simulator vacuum tank with a functional test at ambient temperature and pressure on June 16, 2014. This was followed by a series of tests at cryogenic temperatures in Chamber A at Johnson Space Center in 2016.

Figure 1: Picture of Chamber A at Johnson Space Center, where cryo-vac tests are set to take place in 2016. The interior of the chamber is as large as a tennis court; the large size is necessary to fit the instruments and mirror assembly for testing. Renovations to the historic chamber, first used to test equipment for the Apollo missions, are underway to prepare it for the long-duration, low-temperature testing to occur as the parts of the observatory come together. Credit: Chris Gunn/NASA.

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by evacuation and cool-down to about 40K. CV2 testing spanned 76 days of cold testing followed by approximately 17 days of warm-up and concluding functional tests (see Figure 2).

In almost all respects, the science instruments (SIs) performed very well. Optical testing included alignment with six degrees of freedom, measurements of pupil shear, and an extensive series of focus and wavefront error measurements using both internal and external focus-adjustment mechanisms. The testing also involved a broad range of tests for each SI to characterize performance.

Various tests were successfully run using the Operations Script Subsystem, the commanding system to be used in flight. These scripts were developed at the institute as part of our flight operations work. These tests included the FGS running through its primary functions, from star identification to fine guiding.

With NIRCam’s newly replaced detectors, a lengthy tune-up of their Application Specific Integrated Circuits (ASICs) was executed. The goal was to configure them for optimal noise, bias, and well depth performance. This process will be repeated in CV3 for the newly replaced detectors in NIRISS and FGS. The new NIRSpec detectors will be installed with previously tuned, spare ASICs.

The testing did reveal some problems; the most serious was a data-flow issue that caused the Instrument Control and Data Handler (IC&DH) to spontaneously reboot when simultaneously receiving interrupt requests from multiple detectors at very high rates. A modification to the flight software addressed the problem, and it did not occur again through the remainder of CV2.

Another problem that occasionally occurred during high data-rate observations was mixing of data originating in separate detectors. Operational constraints are now being established to keep the rates within acceptable limits.

There were two notable issues with the science instruments. The replacement NIRCam detectors performed superbly, but one of them, in module A, drew excessive current and was shut down during most of CV2 to prevent damage. It has now been established that the problem is with the detector itself and it is being replaced.

The second issue was that observations using the NIRISS GR15OR grism showed a streak of scattered light that was not present in CV1. Post-CV2 examination of the grating has revealed delamination in a small section of the grism and it is being replaced.

Testing also found some issues with the ground system. In some instances, data from different SIs were combined in the same data file, header keywords were missing, or the data files were not generated at all. Some of these problems have already been addressed and the remaining ones are being investigated.

While the final judgment on CV2 must await a more complete analysis of the data, it is clear that overall the test has been a great success. The important goals of demonstrating SI performance, alignment, and stability appear to have been met. The test team is well positioned to make the final hardware replacements in preparation for CV3, the final thermal-vacuum test campaign at Goddard. CV3 is scheduled to take place in the latter half of 2015.

**Webb operations from the ground up**

We refer to Webb as the successor to Hubble, because many of Hubble’s ground-breaking discoveries motivate the capabilities of Webb. The science operations of Webb at the Institute are also rooted in Hubble, as they will utilize the experience that engineers and scientists at the Institute have built up in the almost 25 years of Hubble operations. There are differences, however, between how Hubble operates and how Webb will operate. One notable difference is that the flight operations of Webb will be controlled from the Institute, in addition to the science operations. (Flight operations for Hubble occur at Goddard, with data transmitted to the Institute for dissemination to the science community.) To evaluate the work happening at the Institute for Webb’s science operations, the project conducted the Science and Operations Center (S&OC) System Design Review (SDR) on July 14–16, 2014. This review was independent of the Webb project and organized by Goddard. The primary focus of this first SDR was S&OC architecture and science operations; a future SDR (in 2016) will focus on flight operations and commissioning. Subsystems reviewed included the project reference database, proposal planning, data management, software for wavefront sensing and control, and operations scripts. By all review criteria, the S&OC received the green light to proceed. Strengths noted by the review committee included the heritage from Hubble in designing some of the science operations systems, and the ability to implement new Webb software in Hubble operations to provide feedback and operational experience in advance of Webb operations. A lot of effort was needed from the Institute’s Webb staff to prepare and execute the review. We commend their efforts.

**Preparing the astronomical community for Webb**

Although the launch of Webb is less than four years away, the Webb mission office at the Institute is already preparing the astronomical community to think about the types of transformational science enabled by Webb. We perform this outreach through a variety of organized interactions with the community. At major meetings, like the biannual meetings of the American Astronomical Society, we make sure that a wide cross-section of the community hears about the current status of the Webb project, and apprise...
them of issues about which they can provide input. Webb had a booth at the June 2014 AAS meeting in Boston, where we sought feedback on the design of the exposure-time calculator, and conducted a survey concerning optimizing documentation for scientists. A Webb town-hall meeting took place at the 225th AAS meeting in Seattle, Washington, and included a timely discussion on January 6 led by scientists at the Institute on policies to optimize community engagement and maximize early science from Webb. A webcast of the Town Hall is available at https://www.youtube.com/watch?v=ZTJJAuziywl.

Webb’s highly complex instrument modes, combined with its limited lifetime (as compared to Hubble)—a five-year requirement on the mission lifetime and a ten-year goal—has driven a number of discussions about how to maximize the science return of Webb. Based on experience with other observatories, it is clear that getting on-orbit data into the hands of astronomers quickly is key to realizing the full scientific potential of the instruments and the observatory. The JWST Advisory Committee to the Institute director has advocated for an open-access early release science program to demonstrate the key observing modes of Webb’s instruments. The planning of the early release science program will be an open process, involving community members, and was announced at the town-hall meeting in Seattle.

To engage unique parts of our future user base, we have established a presence at more specialized, regularly occurring meetings. The goal is to seek new perspectives and feedback regarding observing capabilities. In this spirit, we attended the 45th Lunar and Planetary Science Conference (LPSC) in The Woodlands, Texas, in March, where the Hubble and Webb projects hosted a joint town hall. We apprised the solar-system community of the status of these two observatories and invited their interest and involvement. We reviewed the status of previous recommendations regarding solar-system observations with Hubble, and solicited further input. Our presence at the 46th Division of Planetary Science (DPS) meeting in November in Tucson, Arizona included a topical session focusing on reports from ten community-based groups in a joint town-hall meeting. The white papers being prepared by these groups will describe prospective case studies of different types of solar-system science investigations with Webb. The joint town-hall meeting held at DPS was recorded; the presentations and a recording of the session can be found at http://www.stsci.edu/jwst/science/jwst-solar-system-meetings-docs.

A booth provided an additional point for interaction between Webb project members and the solar-system community.

Informing the community about data analysis software being developed for Webb is an important component of preparing the astronomy community to do science with Webb. The tools to be used for data exploration will be written in the PYTHON programming language, and packaged as part of the ASTROPY software toolkit (Robitaille et al. 2013, A&A volume 558, page A33). We are initiating a series of events which will familiarize future Webb users with ASTROPY and tools being developed specifically for Webb science analysis. The Seattle AAS meeting featured a Sunday morning ASTROPY tutorial for those seeking more information on how to use the ASTROPY software and a description of recent developments. From May 6–8, 2015, the Institute will host a User Training in JWST Data Analysis meeting (http://www.stsci.edu/institute/conference/ut_jwst_da/). The 2½ day meeting will introduce data analysis tools to the Webb user community. It will serve to familiarize novice PYTHON users with ASTROPY, and follow the workflows of several example data analysis use cases. There will be a heavy emphasis on hands-on use of the tools available, as well as opportunities for feedback and suggestions for improvement. Both the AAS ASTROPY tutorial and User Training event will become annual occurrences.