Fact Sheet

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James Webb Space Telescope Thermal Test Program

Overview

To see the near and mid-infrared light from the first stars and galaxies, the James Webb Space Telescope (JWST) must operate at temperatures close to absolute zero. JWST will make use of the free cooling of deep space at the L2 point nearly 1 million miles from Earth. But this also presents a unique thermal challenge because passive cooling to cryogenic temperatures is very sensitive to design and material properties and small errors, or heat leaks, can have dramatic temperature effects. This is one reason why successful thermal testing is so important to the Observatory's reliability. Northrop Grumman is conducting two thermal tests: one on the "core" section of the Observatory, which has been completed; and another test on a 1/3 scale model of the sunshield, slated for fall, 2009.

Core Thermal Test

The core model built by Northrop Grumman is a hardware facsimile of the Webb Telescope's central region where the performance-critical thermal elements come together. The core model stands about two stories, or 17.5 feet and 17 feet wide. It consists of the top portion of the spacecraft bus, deployable tower, a truncated but fully tensioned five-layer sunshield, optical telescope element backplane support frame, integrated science instrument module (ISIM) compartment, deployable cable trays, thermal management systems, and ISIM electronics compartment.

The core region of the Observatory is where the dominant heat leaks can occur. A passive thermal management system composed of various shields, barriers, radiators, and multilayer insulations is used to control these heat leaks. Multi-layer insulation (MLI) covers nearly all the hardware and "black MLI" (carbon-filled Kapton cover sheets) is also heavily used in JWST. Black MLI prevents static electrical charge buildup that could damage electronic components. For this reason, much of the inner Observatory appears black.

The core thermal test, conducted in the largest thermal vacuum chamber at Northrop Grumman's Space Park facility, represents the first time the Observatory has been tested in a full temperature environment. The test chamber included a custom made gaseous helium-refrigerated shroud that enabled background operating temperatures as low as -435 degrees F (13K). This supporting refrigeration system was installed along with the core hardware assembly specifically for this and other JWST tests. Test data was collected every six minutes by 550 strategically placed diode and thermocouple temperature sensors, non-stop for nearly six weeks.

The core model was cooled to 30K for the coldest component and heat was added incrementally to individual subassemblies to isolate their heat impact on the system. At the end of these steps, all components were heated to their predicted levels and the first thermal balance point was measured. A thermal balance point is a steady state condition used to anchor models at the point when heat going in matches heat going out. To get a second thermal balance point, the heat levels are raised by about 20K to cover the expected flight operating point. The two thermal balance points become the database that provides correlation input to the model.

Sunshield Scale Model Thermal Test

The Webb Telescope's sunshield separates the observatory into a warm sun-facing side, and a cold side facing away from the sun. Serving as a radiation blocker, the sunshield is subjected to nearly 100,000 thermal watts of solar heat, and reduces that to one tenth of a watt on the cold side, a million to one reduction. The cold side, where the optical telescope element and science instrument module are located, will be cooled passively to as low as -414 degrees Fahrenheit (25 K, or slightly above absolute zero).

Sunshield scale model testing will take place in the same thermal vacuum chamber used for the core test. Between 300 and 400 strategically placed sensors will collect data every six minutes over the six-week testing period.

The test article consists of a one-third scale flight model, which includes the central region or core of the sunshield closest to the spacecraft. The test will use heaters to simulate changes in the angle of the spacecraft to the sun and measure the resulting thermal performance. Other heating conditions will also be tested. As a final step in the test, an actuator will collapse three of the membranes to 60 percent of their normal gap and then examine how the change of shape affects thermal and reflective properties.

Test Data and Model Correlation

The ultimate test purpose is two-fold: validate the model by demonstrating that a passive thermal facsimile used to design the Observatory accurately represents measured results; and carry forward lessons learned and align data to the larger sister flight model. The design model made various assumptions based on best available data and those assumptions can now be anchored by actual test data.

In this process, the model is corrected through a series of computer runs that more accurately reflect the complicated interactions between the components in the core thermal model. Once this is done, selective correlation results can be used to bring the flight model to a higher level of fidelity prior to the flight test. Although the data from the core thermal test will take from two to three months to fully analyze, a first look indicates a good match to thermal capability predictions for such a large and complicated test. More than three-fourths of the diode sensors were within 5K of the pre-test predictions and a significant fraction was less than 1K of pre-test predictions.

Since the full size sunshield cannot be tested in one g (standard gravity) and is larger than nearly every thermal vacuum test chamber in the world, its final performance is verified by analysis to a validated model and the model will be validated in the scale model thermal test. Over the next two months after the test, the sunshield test data will be correlated with model data to align predictions with test results. This will demonstrate not only the ability to predict its performance but also provide guidance for anchoring the flight model.

Both thermal tests go a long way in establishing early integrated model verification, well before the flight test. As a result, the fidelity of the master model is improved, which adds flight confidence and reduces technical risk. This is especially important because the Webb Telescope is the first Class A space hardware program to validate major functional areas by analytical model. This is due to its immense size, its need to have a zero-g environment to deploy, and a passive cryogenic design that will adequately perform only with an accurately represented deep space thermal environment.

The tests also expand the joint Northrop Grumman Aerospace Systems/NASA institutional knowledge for large JWST class cryogenic testing which will continue to the more complex flight article testing later in the program at NASA's Johnson Space Center.

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