Fact Sheet

One Space Park
Redondo Beach, CA 90278

NORTHROP GRUMMAN

For more information, contact:

Sally Koris
310.812.4721 (o)
310.567.5279 (m)
sally.koris@ngc.com

James Webb Space Telescope Sunshield Test

Webb's 1/3-scale and full-scale model sunshields stand up to rigorous thermal and deployment tests

It's complicated, it's huge, it's strong and it's very sensitive to all kinds of heat, vibration and pressure, from launch to deployment. How do we know that the James Webb Space Telescope's five-layered, tennis court-sized sunshield will unfurl perfectly in space and keep solar heat away from the mirrors and science instruments?

It sounds simple: test, re-test, verify and re-verify using a variety of measurement instruments and methods. But the reality is that it's a very time-consuming, meticulous task to ensure that the world's largest space telescope performs exactly as it was designed.

Keeping an infrared telescope at very cold operating temperatures isn't an option – it's an absolute necessity. For the Webb telescope to see the traces of infrared light generated by stars and galaxies billions of light years away, it must be kept at cryogenic temperatures of under 50°K (-370°F). Otherwise, sunlight would warm the telescope and the heat from the telescope itself will swamp the very faint astronomical signals, effectively blinding the telescope's eye. The job of the sunshield is to keep that from happening.

Serving as a radiation blocker, the sunshield is subjected to nearly 100,000 thermal watts of solar heat, and reduces that to 0.6 watts on the cold side, about 1/8th the heat of a night light. But how do you test a complicated structure of this huge size? There isn't a cryogenic chamber on the planet big enough, and building one doesn't make sense from a budget and practical standpoint. So Webb engineers from Northrop Grumman Aerospace Systems and NASA have constructed a 1/3-scale model and a test facility to perform the critical thermal test of the sunshield system.

The thermal test had two main goals:

- verify that the sunshield design can actually block and redirect the sun's energy before it reaches the telescope and
- verify the accuracy of computer thermal models used to predict how the full-size sunshield will perform.

"The flight sunshield will be deployed and visually inspected prior to flight, but only a computer simulation of its thermal performance will be used to determine if it's ready to launch," explains Keith Parrish, Webb Telescope Sunshield Manager at NASA's Goddard Space Flight Center, Greenbelt, Md.

"This is very similar to wind tunnel testing of large aircraft," he notes. "Most aircraft, especially large commercial airliners, are simply too large to undergo full-size testing. Computer models, which extrapolate the test data from smaller scale model wind tunnel tests, are used to verify final design and predict the full size aircraft's performance. Our Webb sunshield 1/3-scale model test is a very similar approach."

Simulating the sun's heat

In space, the sunshield will be heated by the sun. For ground testing, the 1/3-scale model was placed in a thermal vacuum test chamber at Northrop Grumman Aerospace Systems' Space Park facilities in Redondo Beach, Calif. The sun's heat was simulated by electrical heater plates placed very close to, but not touching layer 1, the warm, sun-facing layer. Power to the heaters was steadily increased until layer 1 reached similar temperatures as those expected in flight, well over 100 degrees C (212°F, the boiling point of water at sea level).

Measuring how the sunshield reacts

Approximately 400 temperature sensors were placed all over the sunshield. "We also keep an eye on the chamber's gaseous helium-refrigerated shroud temperatures and liquid helium cooling plates," adds Parrish. "The cooling plates simulate the cold background temperature of space at the orbit of Webb, which is around 7 Kelvin (-446.8°F). We can't get these plates all the way down to 7K, which is pretty close to absolute zero. The plates typically get down to the 15 to 25°K (-434.4°F. to -414.4°F) temperature range, so exact knowledge of their temperature is critical to understanding the sunshield's performance. "

The engineering team used the 1/3-scale tests for a trial run of a device called a radiometer. Hung or mounted around the sunshield, these devices measure the heat radiation that is bouncing around and between the sunshield, the cold plates and the chamber walls. Since this kind of effect doesn't occur in space, it's important to understand how this heat bouncing impacts the test results. When the flight instruments and observatory are tested at Goddard and Johnson Space Center, these devices need to be working well.

Experimenting with extremes

Seven different testing conditions were used to gather temperature data, and these test conditions were tailored so that engineers can study how the sunshield performs in space under a variety of conditions. Some test conditions exaggerated or increased temperatures and heat flows in specific areas of the sunshield. Even though these test conditions do not simulate flight conditions, they're designed to isolate and better define particular variables used in computer thermal simulations. "One specific test condition used a mechanism in the chamber to change or warp the sunshield's shape," Parrish explained. "Since proper shape is critical to the sunshield's performance, this test condition gave engineers important data so they could see if computer models can actually predict the thermal impact of shape changes."

Matching models to test data

After the temperature data was gathered, engineers ran computer models over and over again with small changes to mimic the actual test conditions. The goal is to better match the temperature data from the sensors on the sunshield to the computer models. "This is really the critical part in the whole testing process," says Parrish. "Gathering the test data was just the beginning. Understanding that data and how it applies to the flight sunshield's predicted thermal performance is the critical step."

To understand how the membrane shape affects thermal performance, a Light Detection And Ranging (LIDAR) laser device took highly accurate shape measurements on each of the five layers of the sunshield at room temperature. These measurements were used to validate the computer model predictions of each membrane under ambient conditions. The computer models were then used to predict the membrane shapes over the various test conditions.

Later this spring, the thermal chamber will be modified with a window so that the LIDAR device can see into the chamber and measure the shape of layer 5, the coldest layer, near its cryogenic operating temperature, approximately 77°K (-320.8°F). This test will allow the engineers to confirm if the computer model's prediction of shape at temperature is correct.

Analyze and verify

Careful planning and following rigorous procedures paid off – the test was very successful because all test objectives were met and engineers were able to collect the data they needed. That data is being carefully analyzed to see if the test temperatures accurately reflect the thermal performance of the flight sunshield. Data analysis and correlation is a lengthy process that is ongoing and expected to complete in May. The 1/3-scale tests go a long way in establishing model verification well in advance of the flight test. As a result, the fidelity of the master model is improved, which adds flight confidence and reduces technical risk. The 1/3-scale tests also validate the manufacturing techniques of the membranes themselves.

Testing how the layers unfurl

While thermal performance is critical, so is deployment: the sunshield must unfurl perfectly to do its job. Since no computer-aided design tools can predict the behavior of the thin Kapton membrane when it's folded up and then unfurled, Space Park's Webb engineers built a full-size model, called an integrated validation article (IVA), to design and validate various membrane management systems. Since the deployed sunshield is the size of a tennis court, details such as cabling tension, surface figure and folding methods require testing by model.

More than 100 containment devices or clamps hold the membrane in place in the stowed position during launch. The IVA tests how the sunshield can unfold from the clamps to a deployed state. "To contain billowing during launch, when air exits very rapidly from the launch vehicle, the stowed membranes must be vented, and containment devices must hold the membranes in place and then be able to release in repeatable ways when the sunshield deploys," explains Andy Cohen, Aerospace Systems' Webb Space Vehicle Manager. "We've completed verification of the first vent test of a partial membrane and are building a second test article to demonstrate venting of the core area."

The IVA will also be used to test the interactions and alignments between the Unitized Pallet Structure (UPS) shell and the sunshield membranes. The UPS consists of two large rectangular arms that contain the folded membranes. During deployment, the arms open up into a horizontal position and the membranes begin unfurling in highly orchestrated stages. "The UPS will be subject to 1g offload testing (one g is the average acceleration of gravity at the surface of the Earth) with simulated membranes first," said Andy Tao, Aerospace Systems' Chief Webb Sunshield Engineer. "The bare Kapton will be replaced by a flight-like membrane and a series of deployment tests will begin with five full flight-size models in late 2010."

A number of thermal deployment tests in flight configuration will be done for hinges and other components, as well as the five-segment telescoping mid boom sub-assemblies that pull out and tension the membranes. A development model of the mid boom has been fabricated and has completed deployment trials at ambient temperatures. The mid boom is the structure at the middle of the layered membranes just under the primary mirror.

Northrop Grumman Aerospace Systems is prime contractor on the Webb Telescope, which is managed by NASA's Goddard Space Flight Center in Greenbelt, Md. Expected to launch in 2014, the telescope is a joint project of NASA, the European Space Agency and the Canadian Space Agency.

###

April 2010