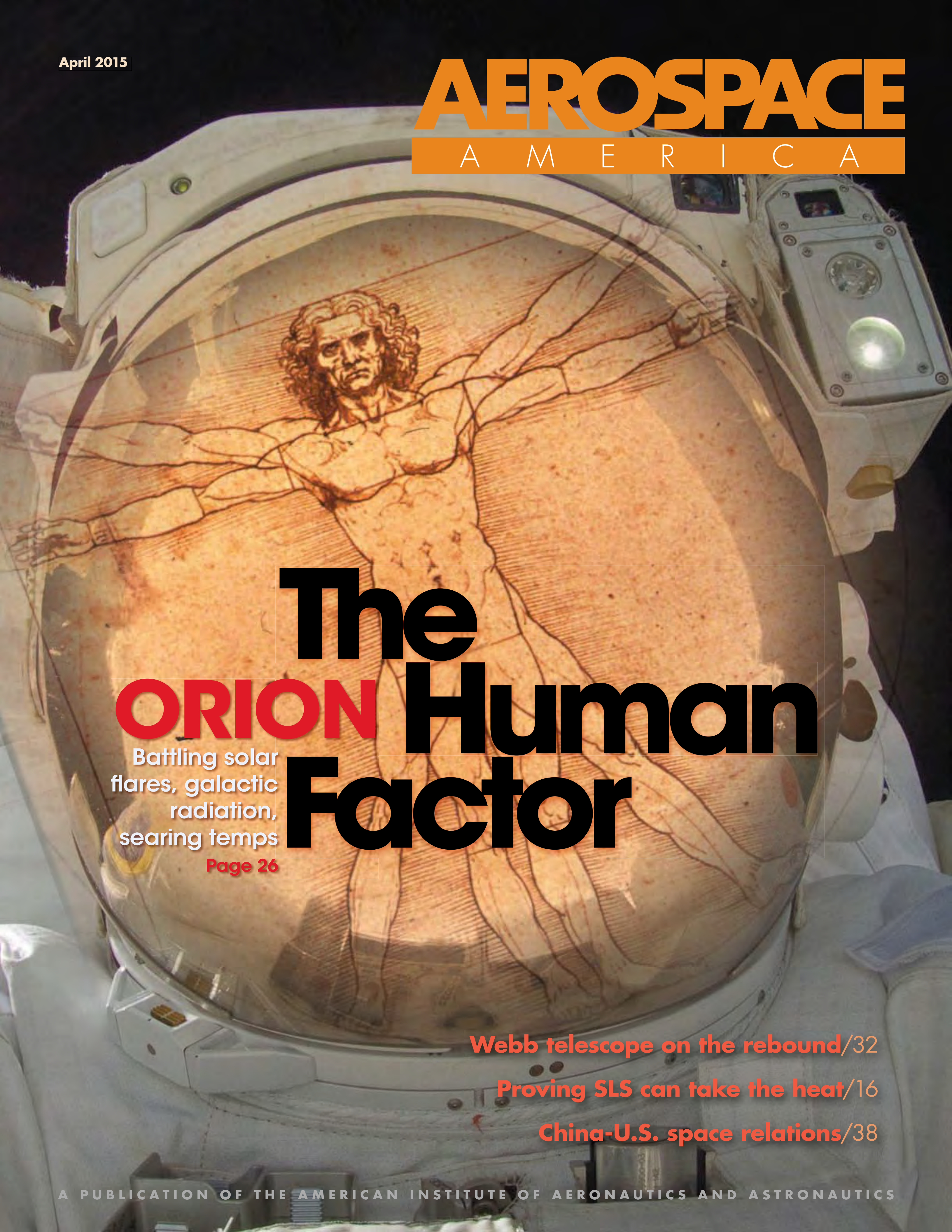
April 2015

AEROSPACE AMERICA



The Human Factor

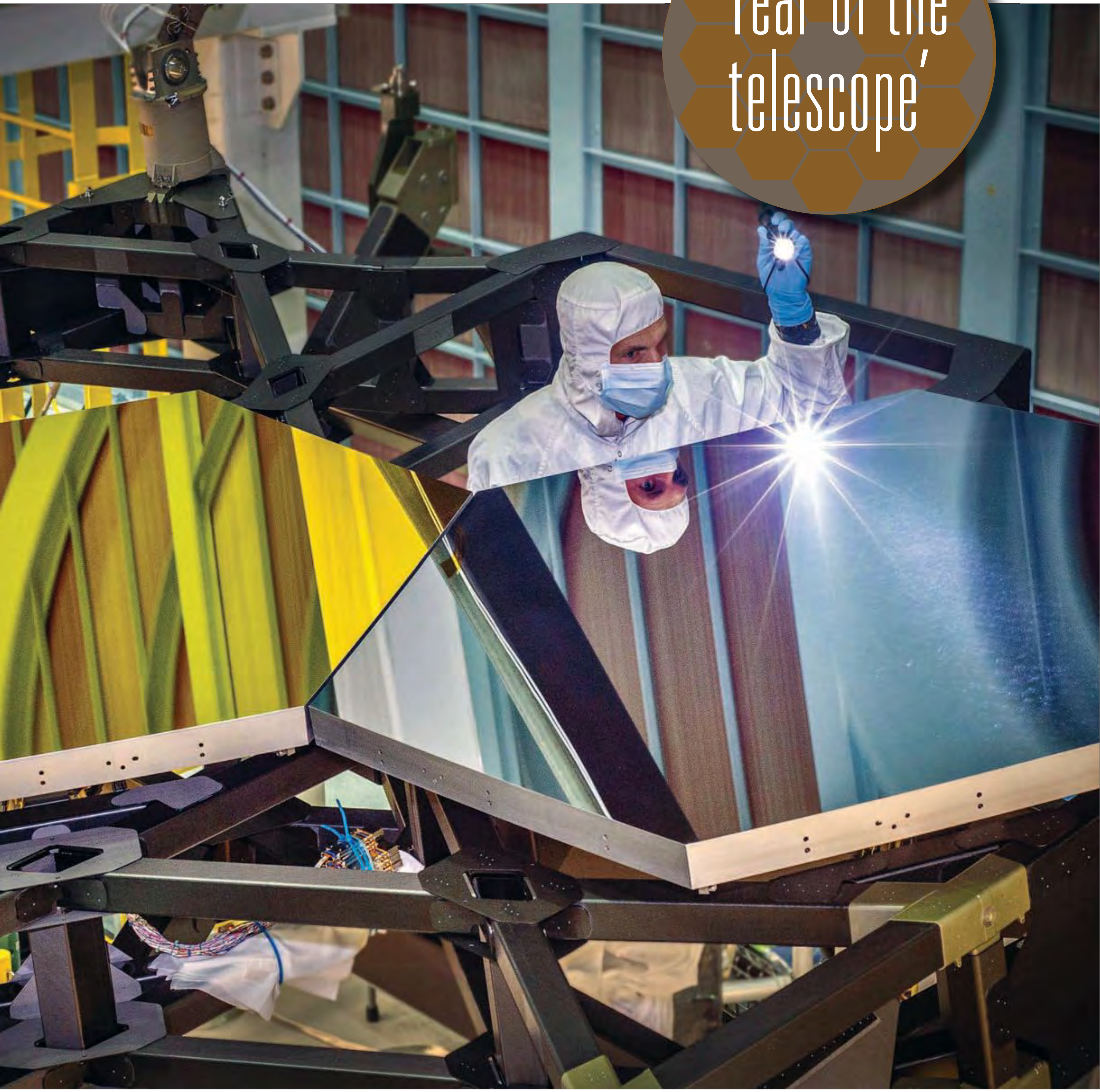
ORION

Battling solar flares, galactic radiation, searing temps

Page 26

A PUBLICATION OF THE AMERICAN INSTITUTE OF AERONAUTICS AND ASTRONAUTICS

‘Year of the telescope’



NASA

Pathfinder: An optical engineer at NASA’s Goddard Space Flight Center in Maryland examines two test mirror segments attached to a composite backplane like the one that will hold the 18 segments of the James Webb Space Telescope’s primary mirror. The Pathfinder telescope will be tested with the same equipment and processes as the flight telescope.

by Ben Iannotta

NASA is pushing development of the Webb telescope into a critical assembly and test phase at a time when investigators at the Government Accountability Office warn there is little room left for error. Ben Iannotta visited Goddard Space Flight Center to learn how NASA plans to surprise the doubters and get Webb into space with no further delays.

Like high-tech eggs waiting to hatch, two rows of metallic silver containers are perched on a mezzanine at NASA's Goddard Space Flight Center in Maryland. The containers overlook the same cleanroom where more than two decades ago the Hubble Space Telescope's corrective optics were prepared. The containers hold an equally precious cargo: mirror segments due for assembly this year into the optical element of the James Webb Space Telescope.

Once Webb reaches space, these 18 segments must automatically align themselves to form a 6.5-meter diameter primary mirror smooth to 100 nanometers, or about a thousandth of the width of a human hair, says NASA's Lee Feinberg, manager of Webb's Optical Telescope Element.

That's just one feat in what will be a weeks-long series of automated set-up procedures as Webb coasts to its orbit beyond the moon. Feinberg has agreed to brief me about the turning point his team has reached in development of Webb telescope and show me around Goddard's Building 29, where he has worked since the run-up to the 1993 Hubble repair mission.

The Government Accountability Office describes Webb as "one of the most complex projects in the National Aeronautics and Space Administration's history," and the GAO's characterization is not an overstatement.

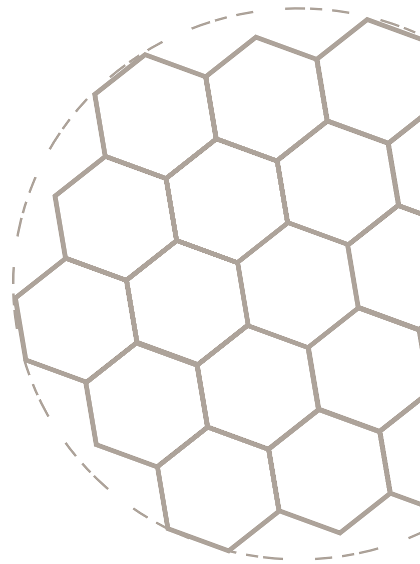
Webb looks nothing like Hubble or any other telescope, because it's meant to do something that's never been done before: Look back in time 13.5 billion years toward the first light of the universe to see the birth of stars and formation of planets. That means detecting light that's been stretched to infrared wavelengths by the expanding universe. Most of Webb's technical challenges spring from the need to keep the optics and science instruments cold, so that those infrared waves aren't swamped by warmth from Webb. A tennis court-sized sunshield must keep the optics at minus 370 degrees Fahrenheit. That's cold, but not as chilly as required by Webb's Mid-Infrared Instrument, one of the four science instruments that will be attached in a module behind Webb's primary mirror. The MIRI instrument will need a helium cooling system to keep it at minus 449 degrees, just 10 degrees shy of absolute zero, so it can detect mid-infrared wavelengths.

Building Webb has turned out to be a lot harder and time-consuming than expected. Today's projected cost of $8.8 billion is nearly double a 2009 estimate, and GAO says the cost has actually ballooned by a factor of nine if one looks at the original cost estimates of astronomers. Webb was going to be launched in 2014, but NASA now plans to launch it in October 2018 on an Ariane 5 rocket contributed by the European Space Agency.

Over the next three years, Feinberg and managers at NASA's Jet Propulsion Lab, Johnson Space Center, Northrop Grumman and Exelis must do more than assemble and rigorously test all elements of a unique space telescope. They must orchestrate a story of redemption, one that could convince future presidents and skeptical lawmakers that this first-of-a-kind telescope should not be the last of its kind. Within decades, astronomers want to launch an even more fantastic telescope with a mirror diameter three times that of Webb's for a range of astronomy, including possibly photographing an Earthlike exoplanet for the first time.

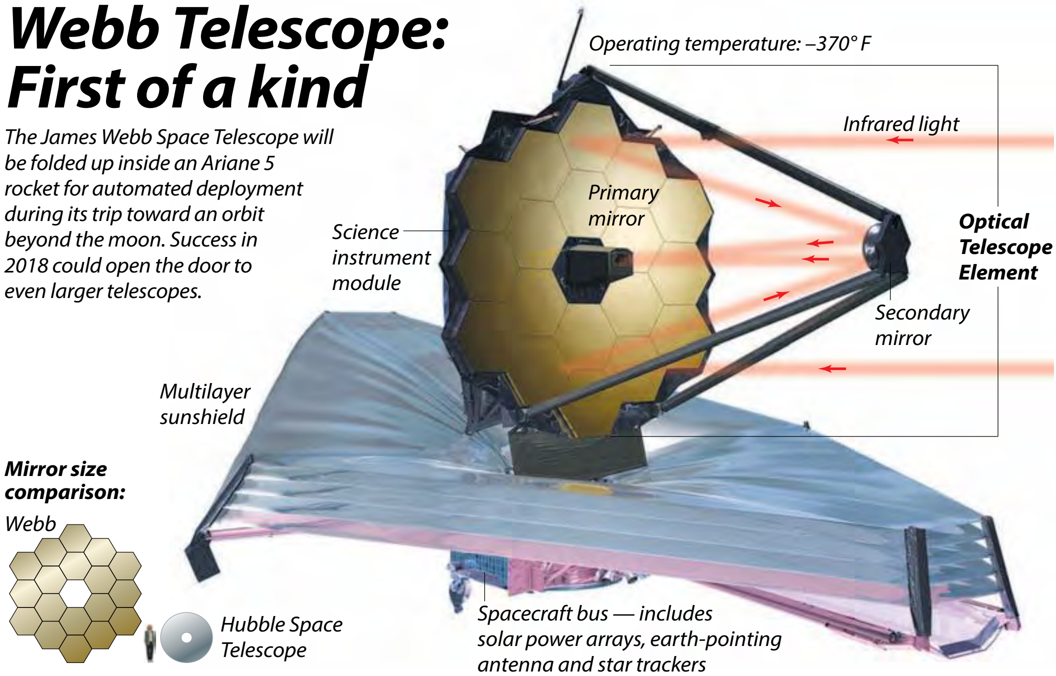
"If the country was smart and NASA wants to do it, we could leverage all this [Webb] stuff to build future bigger telescopes," says Feinberg.

But first, things are about to get busy in Building 29.



Webb Telescope: First of a kind

The James Webb Space Telescope will be folded up inside an Ariane 5 rocket for automated deployment during its trip toward an orbit beyond the moon. Success in 2018 could open the door to even larger telescopes.



Source: NASA

Graphic by John Bretschneider

“There’s this amazing race going on between ISIM, the Integrated Science Instrument Module, team and the Optical Telescope Element team,” Feinberg says. ISIM needs to be ready for installation on the telescope early next year.

Concurrent work is the name of the game even within Feinberg’s portion of the program. While assembly of the flight mirror is underway at Goddard, a Pathfinder telescope consisting of a backplane with two mirror segments will be tested inside Vacuum Chamber A at Johnson Space Center. It was trucked from Goddard late one night to Joint Base Andrews in Maryland and flown to Houston on an Air Force C-5C cargo plane. The idea of the Pathfinder is to iron out any assembly or test issues. Chamber A is the same chamber where NASA tested the Apollo hardware, but NASA had to upgrade the chamber to simulate the incredibly cold operating conditions for Webb. Engineers want to put the Pathfinder through it before they fly the flight telescope to Houston and roll it into the chamber in 2016.

Webb managers are confident that no Hubble-scale flaw — a primary mirror manufactured to the wrong prescription — lurks in their mirrors. The mirrors were tested multiple times during years of manufacturing at Ball Aerospace in Colorado, at Tinsley Lab and at NASA’s X-Ray and Cryogenics Facility in Huntsville, Alabama. In Chamber A, the team will be “turning the temperature down on [the Pathfinder], getting it cold, not just making sure that we can put light through it, but that the chamber’s working,” explains Scott Willoughby, Northrop’s program manager for Webb.

Testing everything, even the test equipment, is a key part of the Webb strategy. “You don’t want to build, build, build…and then test at the end,” Willoughby says. “For a program like Webb, you do a lot of additional testing at each step of the way because that’s the best place to find anything you need to resolve.”

‘Year of the telescope’

Technicians will soon take the mirror containers down from the mezzanine and open them for the first time since 2012, and four years since L-3’s Tinsley Lab in Richmond, California, finished polishing the mirror segments.

“We’re going to have a telescope in a little under a year from now,” Feinberg says. “A full, built-up flight telescope, right in this clean room.” Eric Smith, Webb’s program scientist and acting program director at NASA headquarters, has dubbed 2015 “the year of the telescope.”

The mirrors will be rigorously inspected and installed by Exelis onto a graphite composite backplane structure that’s due to arrive in August from Northrop Grumman. Three thousands miles away, managers at NASA JPL in Pasadena, California, will be shepherding the Northrop-supplied cryocooler for the Mid-Infrared Instrument to completion. On top of that, replacement detectors for Webb’s near-infrared instruments still need to be fully tested in a cryogenic vacuum chamber at Goddard, after a flaw was discovered in 2010 with the first batch. The Integrated Science Instrument Module, which will carry Webb’s science instruments behind the optics, is due for a third test later this year.

Mystery of the yellow flakes

Here at Goddard, Feinberg shows me an example of the kinds of problems that can be caught by running a Pathfinder through the same processes and facilities that the flight telescope will go through, right down to the elevator the mirror segments will ride in and the hallway they'll be wheeled down. We're deep in the bowels of Building 29, peering into to a cleanroom called the C-I-A-F, for Calibration, Integration and Alignment Facility. Each flight mirror segment will go through this room to make sure its shape has been maintained before it is assembled onto the backplane.

When the pathfinder mirrors were in the C-I-A-F, a technician spotted yellow particles on them. The flakes turned out to be bits of paint from a new crane and cabling installed in the room. The crane was painted incorrectly, "so when the crane operated, it generated yellow particles," Feinberg explains. "We figured out a way to cover the mirrors during Pathfinder, and said 'OK, once Pathfinder's done, we'll go back, we'll pull the cable off. We'll clean it up.' "

If the crane problem had come up with the flight mirrors this year, in theory it could have eaten up some of Webb's schedule reserve, the extra time that NASA requires program managers to distribute throughout construction timelines for large projects like Webb. GAO, which now reviews Webb's status annually on orders of congressional appropriators, warned in December that this reserve is down to 11 months, with critical work left, including fully testing the new detectors and finishing the cryocooler for the Mid-Infrared Instrument.

Much of the Webb plan involves testing, and Feinberg says managers carefully weighed the need for so much of it when they conceived the program. Hot on their minds was that a Hubble-style repair mission would be out of the question for Webb, which will coast beyond the moon to an orbit around the second Lagrange point, one of the locations in space where a spacecraft can orbit with relatively little energy. L2 is behind Earth relative to the sun, so Webb will be able to avoid warmth and stray light from the Earth and sun. NASA wants to get human explorers into deep space, and technologists say astronauts might someday help assemble a giant telescope. None of that could be ready in time to help a wounded Webb.

The mirrors of the James Webb Space Telescope shown in their shipping canisters at NASA's Goddard Space Flight Center in Maryland. Each of the 18 primary mirror segments is made of beryllium, which was selected mostly for its stability at cold temperatures.

As an example of Webb's complexity, Feinberg tells me to consider the motorized actuators attached to the mirror mounts on the back of each segment. Six on each segment will control the segment's position relative to the others. A seventh in the center will impart a force to keep the segment correctly curved, so the segments perform like a giant monolithic mirror. An electric motor and gears in the actuators must adjust the positions in steps of just 10 nanometers, which works out to one ten-thousandth of the width of a human hair. That's how the mirrors will be aligned to an accuracy of a thousandth of the width of human hair.

"Could you have imagined if we'd gotten to L2, we deployed the mirrors and we didn't have enough actuator stroke to get the system aligned?" Feinberg says.

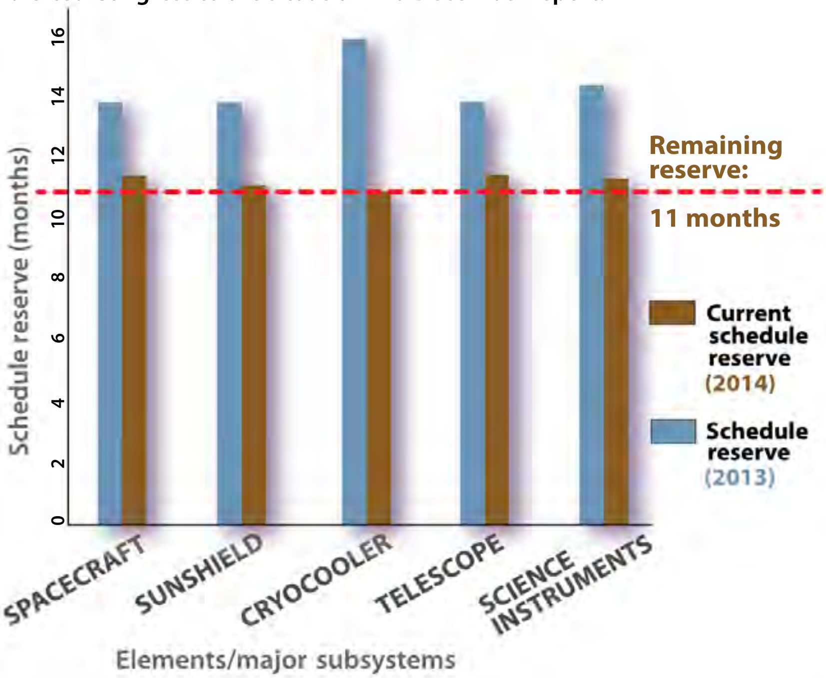
Tests, and lots of them, were put into the plan.

Ripple effects

Webb managers are still feeling the impact of a technical issue discovered with Webb's near-infrared detectors in 2010. These detectors, made of mercury cadmium telluride, convert infrared light into electricity and ultimately astronomical observations.

Shrinking Schedule Reserve

NASA requires managers of complex projects to program in time for the unexpected. Webb managers say they are dipping into this reserve at a reasonable pace. The Government Accountability Office nevertheless alerted Congress to the situation in a December report.



Source: GAO analysis of NASA data, GAO-15-100

They are at the heart of Webb's Near-Infrared Camera, Near-Infrared Spectrograph and Near-Infrared Imager and Slitless Spectrograh and the co-located Fine Guidance Sensor, the device that will keep Webb precisely pointed at its science targets.

The Defense Department was using the same kind of detectors in 2010, and it alerted NASA to a problem with them. "They were sensitive enough, but over time that sensitivity would degrade because of something in the way that the detectors were manufactured," says Smith, the acting Webb director.

NASA decided to stay with the manufacturer, Teledyne Imaging Sensors of Camarillo, California. "It was recognized [that] all they had to do was change their process in a small way, rather than [NASA] go out and get a whole other vendor," Smith says. Qualifying a new vendor's detector for flight would have been too time-consuming and "That would have been a much more costly route," Smith adds.

The rub was that it would take several years for Teledyne to produce new detectors. NASA couldn't risk waiting that long to begin testing the Integrated Science Instrument Module in a cryogenic vacuum chamber, so it conducted two tests without all of the required detectors and added a third test to the plan. CV3, as its known, will test the new detectors on all the instruments for the first time later this year.

The GAO is worried about the timing of all this, noting in its December report that the Integrated Science Instrument Module has burned through three months of schedule reserve out of the 7.5 months it had in 2013.

Another big challenge has been the cryocooler for the Mid-Infrared Instrument, or MIRI. A cryocooler consists of a compressor to pressurize helium and a cold head to chill the sensor with the helium. Northrop explains that conventional cryocoolers have compressors and cold heads "sitting right next to the instrument to be cooled."

That design was not possible with MIRI because of limited room in the instrument module and the need to minimize vibrations that could hurt the telescope's performance and insulate the instruments from warmth that could overwhelm the infrared light. Designers decided to put the compressor on the sunward side of the sunshield and push helium coolant through a line that will run through the shield and up the telescoping tower that holds the optical assembly above the sunshield, a distance of about 30 feet. Northrop says it had to develop new manufacturing techniques and test processes for the cooler.

"We've proven the physics, and now we're building and testing the flight hardware," Northrop says. All the flight equipment should be delivered "in the middle of 2015." NASA chimed in with a statement saying the cold head has been delivered and attached to the instrument module, and that all the electronics have been delivered. NASA is waiting for the compressor assembly to be delivered to JPL for testing.

What does all this mean? For believers like Feinberg it suggests that redemption could be within reach. "Before the first [Hubble] servicing mission, it was like NASA's credibility was on the line," he tells me. "But after that thing got up there and worked, it was like all the sudden there was a complete sea change. And I feel like that's what's going to happen here. Where else is there this level of exploration and discovery on our planet?"