The James Webb Space Telescope

After many years the James Webb Space Telescope is well on its way to becoming a worthy successor to the Hubble Space Telescope.

By Jonathan P. Gardner and Heidi B. Hammel

Artist's concept of the completed James Webb Space Telescope. Webb will be 100 times more powerful than the HST, and its science will range from studying cold objects in our own solar system to studying the first light that formed in the universe. Spacecraft illustration: NASA. Background (Helix Nebula): NASA, NOAO, ESA, the Hubble Helix Nebula Team, STScI, and NRAO.
Editor’s note: The ASP continues its inside look at the James Webb Space Telescope (JWST) with this Mercury feature by two scientists who have been intimately involved in the project for many years. JWST Senior Project Scientist John Mather described the early history of the project in issue #110 of Astronomy Beat; he provides a detailed current status report on the project in Astronomy Beat #111 (May 14, 2013).

Jonathan: I started working at NASA's Goddard Space Flight Center (GSFC) in 1996. I was excited about the upcoming installation of an infrared camera on the Hubble Space Telescope (HST) which I wanted to use to study galaxy evolution with deep surveys. Not long after I started work, I ran into one of my new colleagues, who told me about a new telescope that was going to be the successor to the Hubble — larger and optimized for the infrared. One of its main science goals was to do deep surveys for galaxy evolution. I realized right away that if NASA was going to build a space telescope designed for my research interests, then I needed to get involved! Fast-forward 16 years. The mission is the James Webb Space Telescope, currently under construction, and I am the Deputy Senior Project Scientist for the mission at Goddard.

Heidi: My experience with space telescopes literally started with a bang, when the fragments of Comet Shoemaker-Levy 9 plowed into Jupiter in 1994. I was head of the Hubble Team that imaged Jupiter in response to the impacts. I was pretty young, and had nothing to do with the creation of the HST, but I recognized that it was an incredible tool. Some years later, I was asked to participate in an ad hoc science working group to study a new type of space telescope. The telescope was later named for James Webb, the architect of NASA's Apollo Moon landings and also a staunch advocate for space science. I jumped at the chance to work on building a telescope for the next generation of young scientists, and a few years later I was
officially selected to be one of the six Interdisciplinary Scientists for the program. That was more than a decade ago, so it has been a pretty long, strange trip.

**Mirror, Mirror**

**Jonathan:** A telescope requires mirrors, and the good news about Webb’s mirrors is that they are all finished. The primary mirror consists of 18 segments, each made of beryllium and coated with a microscopically thin layer of gold. Beryllium was selected because of its very stable thermal properties, and the coating is gold because that has the best reflective properties in the infrared. The gold coating is so thin that it comes to a little more than the mass of a dime for each mirror segment. All 18 mirrors work together as a single optical surface and are adjustable. The back of each mirror segment is supported with actuators, mechanisms arranged so that we can move the segment in many different ways. There is an additional actuator that pokes the middle of the mirror segment to adjust its curvature. We plan to re-align the mirrors every two weeks through the lifetime of the mission.

**Heidi:** Most of the primary mirror segments are still at Ball Aerospace in Colorado where they were made, but several have been shipped to the Goddard Space Flight Center. The mirrors will be installed onto the main framework of the telescope using a robotic arm on a huge structure called the Ambient Optical Assembly Stand (AOAS). The AOAS is 100,000 kilograms of welded steel built within the largest class-10,000 clean room in the world at Goddard. (A class-10,000 clean room has less than 10,000 particles larger than 0.5 micrometers per cubic foot. In comparison, normal room air has one million particles, so a class-10,000 clean room is 100 times cleaner than a normal room.) Goddard’s clean room has a [webcam](#).
which updates live images of the activity every 60 seconds, so you can watch Webb being built.

Jonathan: To see the first galaxies that formed in the early universe, we need to go fainter than Hubble can and see further into the infrared. So Webb’s mirror is larger than Hubble’s — 6.5 meters in diameter compared to Hubble’s 2.4 meters — and it will be cold, operating near 50 kelvin or -370°F. To keep the temperatures down, the Webb telescope itself will be shielded from sunlight by a multi-layer sunshield the size of a tennis court. The sunshield consists of five layers of Kapton, a flexible plastic material. Heat escapes between each of the five layers (each about one foot away from the next), so every layer is colder than the next. If we wanted to give the “Sun Protection Factor” of Webb’s sunshield, it would have an SPF of 1,000,000!

Instrumentation

Heidi: Webb will have four main science instruments, a mix of imaging systems and spectrographs. The imagers will provide amazing pictures, just like Hubble. The spectrographs will allow us to analyze the light from distant planets, stars, and galaxies to determine their chemical make-up, temperatures, pressures, distances, and many other properties. Two of the instruments are already at Goddard. The Mid-Infrared Instrument (MIRI, pictured on the previous page), which has a mixture of imaging and spectrographic capabilities, arrived from Europe last year. Soon after, the Canadian Space Agency delivered the Fine Guidance Sensor, which also has a Near-Infrared
Imager and Slitless Spectrograph sub-system (FGS/NIRISS).

Jonathan: The remaining two instruments should be completed this year. The main camera will be the Near-Infrared Camera, or NIRCam. The European Space Agency, in addition to providing the Ariane V rocket on which Webb will launch, also contributed a Near-Infrared Spectrograph (NIRSpec).
On to Launch

Heidi: Since both the primary mirror and the sunshield are larger than the Ariane 5 rocket’s five-meter-diameter cargo area, they will be folded up and stowed for launch. Unfurling the sunshield just after launch will be one of the most exciting parts of the mission.

Jonathan: Webb will be launched in 2018. Although we have many of the pieces nearly complete, the big task of putting it all together remains; we call this process “integration.” We also need to make sure it is all going to work when it gets into orbit. That means a lot of testing. The instruments will be tested at Goddard while the mirror is being assembled in the clean room. But to test
them together, we have to use a giant vacuum chamber at the Johnson Space Center. The full end-to-end optical test of the telescope and instruments together on the ground will ensure that it all works correctly after launch.

Heidi: This telescope is big, and so shipping it around the country is not trivial. Its penultimate trip will be from the US to the launch pad in French Guyana. NASA has built a giant transport carrier to keep the telescope safe during its travels.

Jonathan: Like Hubble, Webb is a general-purpose observatory and will address nearly every aspect of astronomy. Much of the amazing science to come from Webb will be things that we — the scientists who are helping to building this incredible machine — have not even thought of yet. One of the most important lessons we learned from Hubble was to expect the unexpected: fully half of the most amazing results were never even considered when Hubble was being built. Therefore, each year scientists from around the world will submit proposals to use Webb and a review committee will select the best ideas. We expect a lot of competition among scientists to use this powerful telescope. Hubble is awesome, and Webb will be better.

Heidi. Better than awesome? That’s NASA! 🌟

HEIDI B. HAMMEL is a planetary astronomer and one of the six Interdisciplinary Scientists for the James Webb Space Telescope. She is currently the executive Vice President of the Association of Universities for Research in Astronomy (AURA, Inc.) in Washington DC. Heidi is best known for using the Hubble Space Telescope to study giant planets and impacts on Jupiter, as well as for her award-winning public outreach.

JONATHAN P. GARDNER is the Chief of the Observational Cosmology Laboratory and the Deputy Senior Project Scientist for the James Webb Space Telescope at NASA’s Goddard Space Flight Center. He studies galaxy evolution using the Hubble Ultra-Deep Field and other galaxy surveys and looks forward to the day when Webb will find the first galaxies that formed in the early universe.