The Planetary Society

THE PLANETARY REPORT

SEPTEMBER EQUINOX 2021

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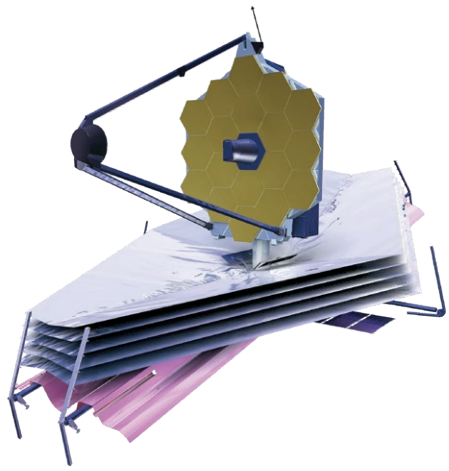
READY FOR LAUNCH

THE JAMES WEBB SPACE TELESCOPE



A FEW REFLECTIONS ON MIGHTY REFLECTORS

Looking forward to the next great space observatory

by Bill Nye

EVER SINCE GALILEO built his telescopes and observed the heavens, telescopes have empowered us to know more of the cosmos and our place within it. Along with the night sky, I hope you and your family have marveled at the breathtaking views from NASA's Hubble Space Telescope and the European Space Agency's Planck and Herschel telescopes, among others. Along with the sheer beauty of what they record, they've taught us much about the early universe and the leftover effects of the Big Bang.

After many delays, the James Webb Space Telescope is finally complete. As I write, it just has one final more or less routine launch-vehicle delay to wait out, but before the end of the year, it may be in space and gathering light at last. I hope you trust me when I tell you that it is going to be well worth the wait.

With longer wavelength coverage and higher sensitivity, JWST will be the key that unlocks the next secrets of the cosmos. It makes me reflect (that's a telescope pun, everyone) on words I heard The Planetary Society's co-founder Bruce Murray say from time to time. When asked, "Why are you all building this telescope? What are you going to see?" his answer would be something like, "We don't know what we're going to see. That's why we built it!"

This issue of The Planetary Report takes a close look at JWST. We explore how people everywhere will benefit from its cosmic point of view and look forward to what we hope to discover with great anticipation. As always, we'll show you new ways you can get involved as a space advocate in the coming months, and we'll celebrate the amazing impact you've made as a Planetary Society member.

BILL NYE *is chief executive officer of The Planetary Society.*

ON THE COVER: After three decades of planning, construction and delays, NASA's James Webb Space Telescope is finally ready for launch. This artist's concept shows Webb at a special location in space called L2, located 1.5 million kilometers (932,000 miles) from Earth. There, the Sun and Earth's gravity balance in a way that allows Webb to permanently keep the Sun, Earth and the Moon at its back while it observes the cosmos. *Credit: NASA / Adriana Manrique Gutierrez*

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Sheehan is surrounded by her paintings inspired by Hubble images. You can find her work at www.barbarasheehan.com.

PHOTO COURTESY OF THE ARTIST

COSMIC INSPIRATION

by Barbara Fee Sheehan

I HAVE ALWAYS been in awe of the heavens. When I was a little girl, my bed was right under a window, and I would put my pillow on the windowsill to watch the night sky, waiting for a shooting star. I would go to sleep thinking of the vastness of the universe.

In January 2015 at age 71, I came across the Hubble Space Telescope's 25th-anniversary photo "Pillars of Creation." I was fascinated by the incandescent brilliance of that photo. Having painted and sculpted since childhood, I immediately felt that I needed to try my best to capture the translucency of the dust and gases by blending and glazing my paints.

Once I had completed several works, I entered online competitions for space art. The European Space Agency encouraged me to contact the International Association of Astronomical Artists. I did so and was accepted into this wonderful group of nearly 200 space artists worldwide. Their art includes oils, acrylics, watercolors, digital art, sculpture, fabric, quilting, glass, clay, jewelry, space hardware art and even music, all with a common goal — celebrating the beauty of space! Subsequently, I joined The Planetary Society, broadening my exposure and linking me to like-minded people who are mesmerized and stimulated by the beauty of the cosmos. Now, with the pending launch of the James Webb Space Telescope, space artists like myself will have a stupendous new source of inspiration.

BARBARA FEE SHEEHAN *is a Planetary Society member and the artist whose painting "Revealing a Newfound Galaxy" is featured on the back cover of this issue.*

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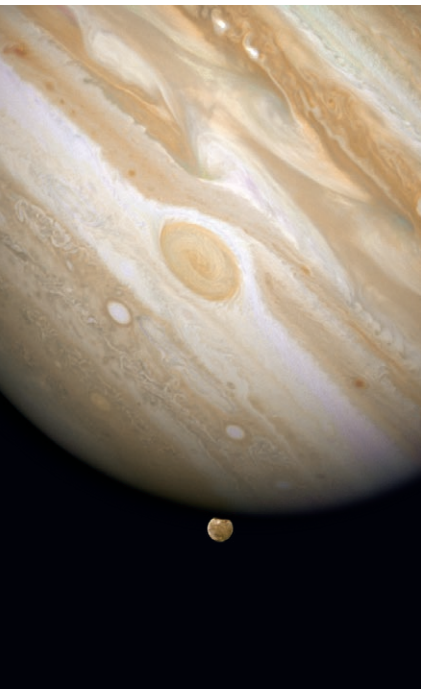
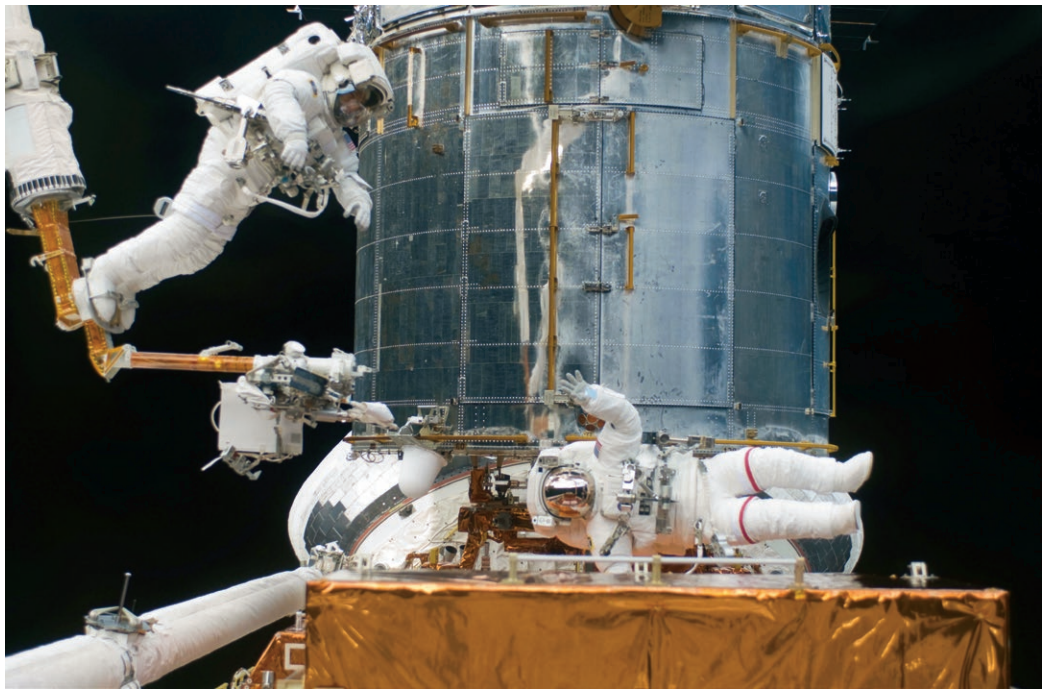




THE PEOPLE'S SPACE TELESCOPES

by Kate Howells

ABOVE LEFT *On April 9, 2007, Hubble caught Ganymede in the act of setting behind Jupiter. Ganymede is the largest moon in the solar system and is bigger than the planet Mercury.* NASA/ESA/E. KARKOSCHKA (UNIVERSITY OF ARIZONA)

ABOVE RIGHT *NASA astronauts servicing the Hubble Space Telescope in the 2009 mission made possible by public advocacy.* NASA

THEY SAY A PICTURE is worth a thousand words, but this doesn't even come close to the value of an image from a space telescope.

So much of what we know about the universe has to be appreciated abstractly, such as the past habitability of Venus and Mars, the inside of a black hole and the subsurface oceans of Europa. In many cases, you need context to understand an amazing new discovery, like briny liquid water on Mars or geysers on Enceladus. But when you see an image captured by a space telescope, the splendor is right there in front of you.

Planetary Society co-founder Bruce Murray was one of the earliest advocates for equipping planetary spacecraft with cameras when he worked on NASA's Mariner fleet of spacecraft that flew to Mercury, Venus and Mars in the 1960s. Mission scientists and engineers were skeptical, but Murray insisted that the public engagement value alone would make it worthwhile. Ultimately, the decision to take photos of other worlds proved hugely important for both science and engineering and for inviting the public into the adventure of exploration.

Science missions yield data that are meaningful and important to scientists, but not every mission impacts the general public in the same way. For the average person, an image can offer insights about the universe that you don't need a Ph.D. to appreciate. This accessibility is one of the reasons missions like NASA's Hubble Space Telescope have such enduring popularity with the general public.

In 2004, NASA announced that the final servicing mission to the Hubble Space Telescope would be canceled, meaning the telescope would no longer be maintained. After nearly 15 years in space, during which Hubble had produced hundreds of thousands of spectacular images, the telescope's batteries were running down, and some of its instruments were failing. Previous repairs had

been conducted by astronauts, but with the horrific Space Shuttle Columbia disaster of 2003 still fresh in everyone's memories, the then-administrator of NASA, Sean O'Keefe, deemed another Hubble repair mission too risky to be worthwhile.

This decision triggered intense opposition from scientists and citizens alike. Planetary Society members sent letters to Congress urging their representatives in government to save the mission, and around the world, other advocacy campaigns popped up online, collecting signatures in support of saving Hubble. The message all around was loud and clear: Hubble was too important to give up.

Congress listened and pressed NASA to reverse its earlier decision. In May 2009, the STS-125 Shuttle crew successfully carried out the servicing mission. Hubble lives on to this day and continues to open our eyes to the wonders of the cosmos.

The story of grassroots advocacy saving Hubble serves as an important reminder that publicly funded missions like this are ultimately for the benefit of the people who fund them. Scientific discoveries serve us all in many ways, but there is a special value to missions that yield something that is tangible and accessible to ordinary people.

The James Webb Space Telescope, set to launch after October 31, is the exciting successor to Hubble. Its advanced imaging capabilities will lead to groundbreaking new discoveries and images, and it will no doubt become a mission the public will treasure for many years to come.

ABOVE *This image of the Orion nebula was created using data from the Hubble and Spitzer Space Telescopes. Hubble sees in ultraviolet and visible light, while Spitzer sees in infrared light. When combined, these views produce a richer view of the nebula than what human eyes can see.* NASA/JPL-CALTECH/STSCI

KATE HOWELLS *is a communications strategy and Canadian space policy adviser for The Planetary Society.*

READY FOR LAUNCH

The James Webb Space Telescope is set to revolutionize our understanding of the cosmos

by Nancy Atkinson

A **SPACE TELESCOPE** three decades in the making is almost ready for launch. Scheduled to blast off later this year, the much anticipated James Webb Space Telescope is the largest, most powerful, most complex and most expensive space telescope ever built. As the revolutionary successor to the Hubble Space Telescope, Webb will reveal the universe's first stars and galaxies, zoom in on objects in our own solar system and examine exoplanet atmospheres for signs of life.

Named for NASA's second administrator, James Webb, the telescope is an international collaboration between the United States, European and Canadian space agencies. It features groundbreaking technology, including an enormous folding sunshade, a segmented mirror 6.5 meters (21 feet) wide and four science instruments to collect data that may fundamentally change our understanding of our universe.

"The discovery capability of Webb is limited only by our own imaginations," says Eric Smith, a Webb program scientist at NASA headquarters. "Scientists around the world will soon be using this general-purpose observatory to take us places we've only dreamed of going before."

Webb's innovations have also brought delays and ballooning budgets. As originally conceived in the 1990s, Webb was supposed to cost $500 million and launch in 2007. Over the years, progress slowed for redesigns, the fixing of various flaws, and testing — exacerbated over the past year and a half by the COVID-19 pandemic. The telescope's development cost has reached $8.8 billion, and it is prepped for liftoff atop an Ariane 5 rocket that will blast off from the European Space Agency's launch site in Kourou, French Guiana.

OPPOSITE
Technicians examine the James Webb Space Telescope in 2016 after a test to precisely measure the curvature and shape of the observatory's main mirror.
NASA/CHRIS GUNN

"It's been a long haul," says Heidi Hammel, an interdisciplinary scientist for the project and the vice president of The Planetary Society's board of directors. "I started working on this project 20 years ago before my youngest son was born, and now he is halfway through college. But now we are so close, and I'm very excited about all the things Webb will be able to do."

SEEING THE FIRST STARS AND GALAXIES

For 10 days in 1995, the Hubble Space Telescope squinted at an ordinary blank spot of space, seemingly devoid of objects. The result, known as the Hubble Deep Field, resembled a jewel box filled with galaxies of all shapes, sizes and colors.

While these galaxies were among the youngest and most distant ever seen, they were not, as astronomers had hoped, the first galaxies to form after the Big Bang. Not even subsequent deeper-field Hubble images could pick them out.

As the universe expands and the older and most distant galaxies speed away from us, their light gets redshifted farther into the infrared, making them dimmer and harder to see, says Massimo Stiavelli, head of the Webb telescope mission office at the Space Telescope Science Institute in Baltimore, Maryland.

"We realized there was a whole universe of light, so to speak, becoming invisible to Hubble because of cosmological redshifting," Stiavelli says. "We would need a new infrared telescope with a larger mirror to see it."

The answer became Webb. Whereas the youngest galaxy Hubble has ever seen was 400,000 years old, Webb will be able to see galaxies that are just 250,000 years old.

6 THINGS WE LOVE ABOUT THE JAMES WEBB SPACE TELESCOPE

1. **Exoplanets:** Webb will scan the atmospheres of Earth-like exoplanets, searching for gases associated with life as we know it.

2. **Outer planets:** Webb will monitor Jupiter, Saturn, Uranus, and Neptune to see how their atmospheres change over time.

3. **Small worlds:** From the asteroid belt to the Kuiper belt, Webb will determine what makes up some of our solar system's smallest objects.

4. **Early universe:** Webb will allow us to see galaxies that formed just 100 million years after the Big Bang.

5. **Stunning images:** The pictures Webb takes will help excite the public about space exploration.

6. **International collaboration:** Europe and Canada's space agencies contributed to Webb's four science instruments and Europe provided the rocket.

Since the chemical elements of life were produced in those first generations of galaxies, we owe our very existence to them. Webb will help scientists understand how and when the first stars turned on as well as where the very atoms that make up our bodies came from, answering some of the most important and fundamental questions ever posed.

THE TWO MIRACLES

It's one thing to realize you need a large, infrared telescope to peer back into the early universe. Building it is another matter.

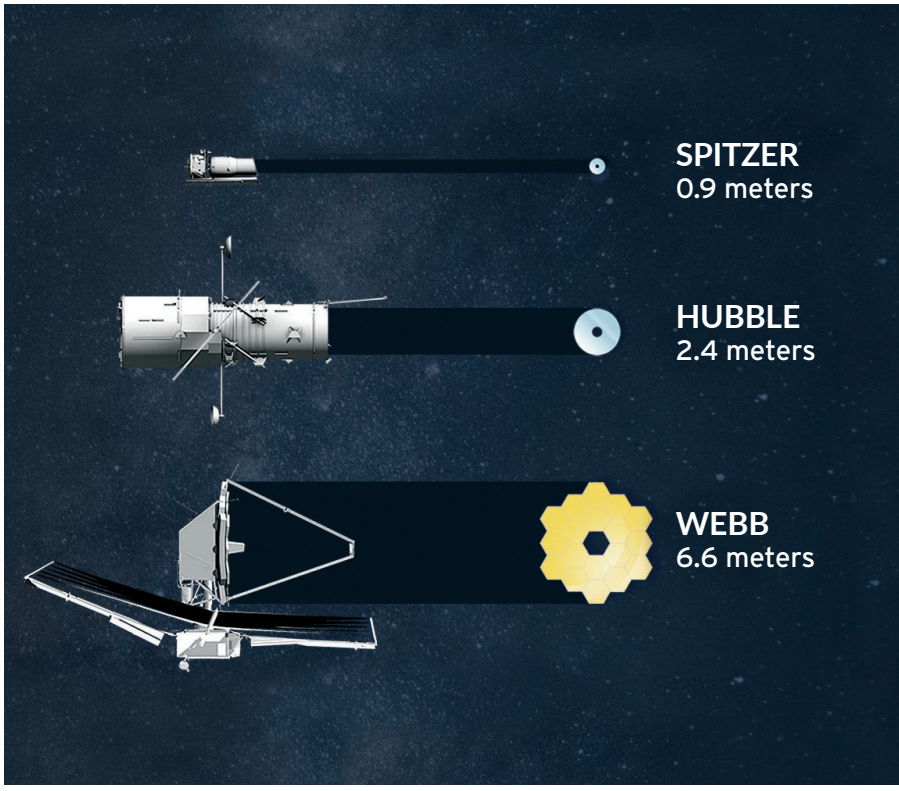
Webb required major advances in 10 major technologies, including optics, detectors and thermal control systems. The biggest challenge was developing the telescope's mirror and sunshield, which Stiavelli calls "the two miracles."

With a diameter of 6.5 meters (21 feet), Webb's mirror is more than 2 ½ times wider than Hubble's, yet it is still light enough and small enough to launch on a rocket. After 12 different design contracts, engineers settled on a lightweight beryllium mirror divided into 18 hexagonal segments arranged like a honeycomb. Three segments on each side fold back for launch so the entire mirror can fit inside the Ariane 5's payload fairing.

Webb's infrared detectors must be very cold to pick up the faint infrared signatures of distant cosmic objects. Stray heat from either the telescope itself or the Sun, Earth and the Moon could overwhelm its sensitive instruments and throw off the telescope's precisely aligned optics.

To stay cool, Webb will deploy a tennis-court-sized, five-layer sunshield made of heat-resistant Kapton. This will keep the telescope chilled to -233 degrees Celsius (-388 degrees Fahrenheit). For launch, the sunshade folds and rolls into a tight bundle but relies on a multistep, multiday process for unfolding in space. Its design has caused the Webb team considerable consternation over the years.

But even the sunshield isn't enough to stay cool. Webb will travel 1.5 million kilometers (932,000 miles) away from Earth to a special spot in space called the second Lagrangian point, or L2, where the Sun and Earth's gravity balance in a way that allows Webb to permanently keep the Sun, Earth and the Moon at its back while it looks outward at the cosmos.



The fact that Webb will be so far from Earth means it cannot be serviced like the Hubble Space Telescope, which had initial mirror problems and received several upgrades and fixes over the years.

"With a complex telescope like Webb, there are myriad ways that things could go wrong," says Hammel, noting that over the past 20 years — and especially over the past five years — Webb's team has tested and retested the telescope in every way imaginable: shaking it, cycling it through heat and cold and putting it inside vacuum chambers.

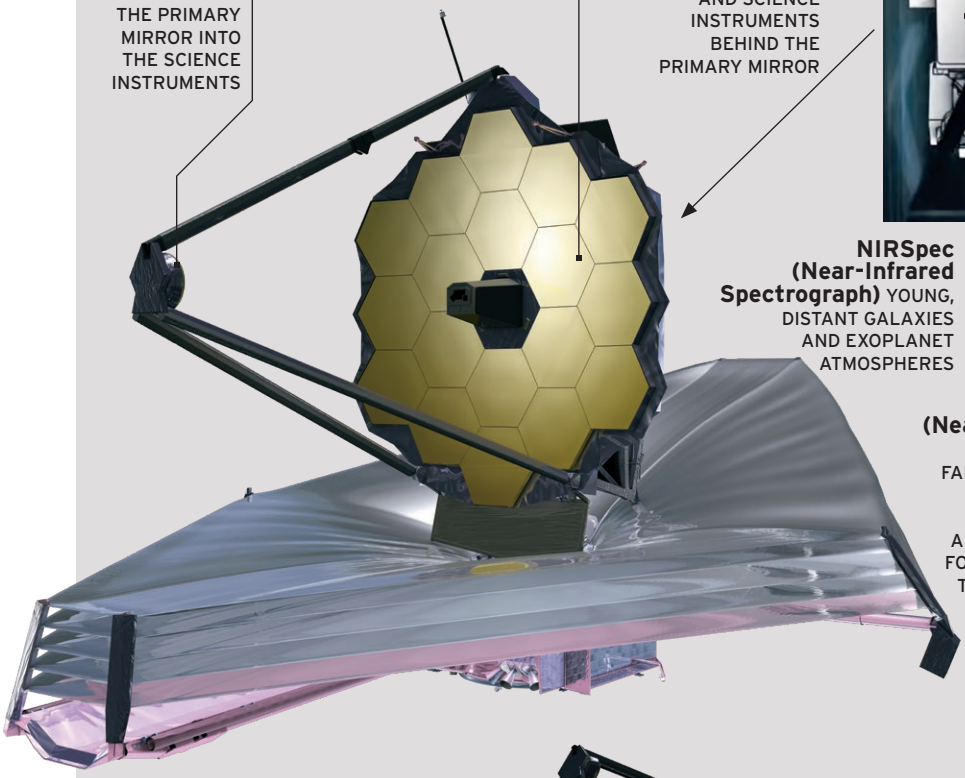
"That's been part of the cost of this expensive mission — making sure we've done everything we can to ensure success," she says.

PLANETARY SCIENCE

Webb is armed with four science instruments to process the light captured by its gold-coated mirrors. They are optimized for infrared light but can also see a slice of the visible spectrum that includes red, orange and gold.

The science instruments can be used separately or combined by investigators who want to study a

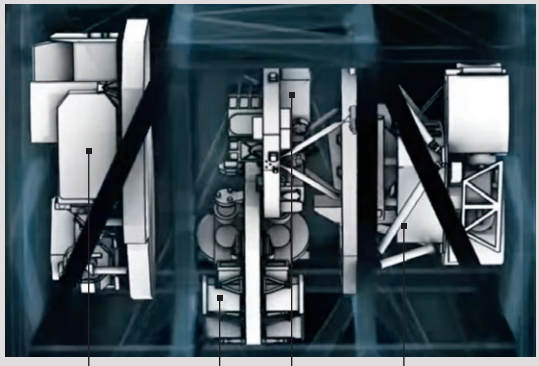
ABOVE *Webb's mirror is nearly three times larger than the Hubble Space Telescope's mirror and more than seven times larger than that of the Spitzer Space Telescope, which was retired in 2020.* NASA



SECONDARY MIRROR REFLECTS GATHERED LIGHT FROM THE PRIMARY MIRROR INTO THE SCIENCE INSTRUMENTS

PRIMARY MIRROR 18 HEXAGONAL SEGMENTS MADE OF METAL BERYLLIUM AND COATED WITH GOLD TO CAPTURE FAINT INFRARED LIGHT

INTEGRATED SCIENCE INSTRUMENT MODULE (ISIM) HOUSES ALL OF WEBB'S CAMERAS AND SCIENCE INSTRUMENTS BEHIND THE PRIMARY MIRROR

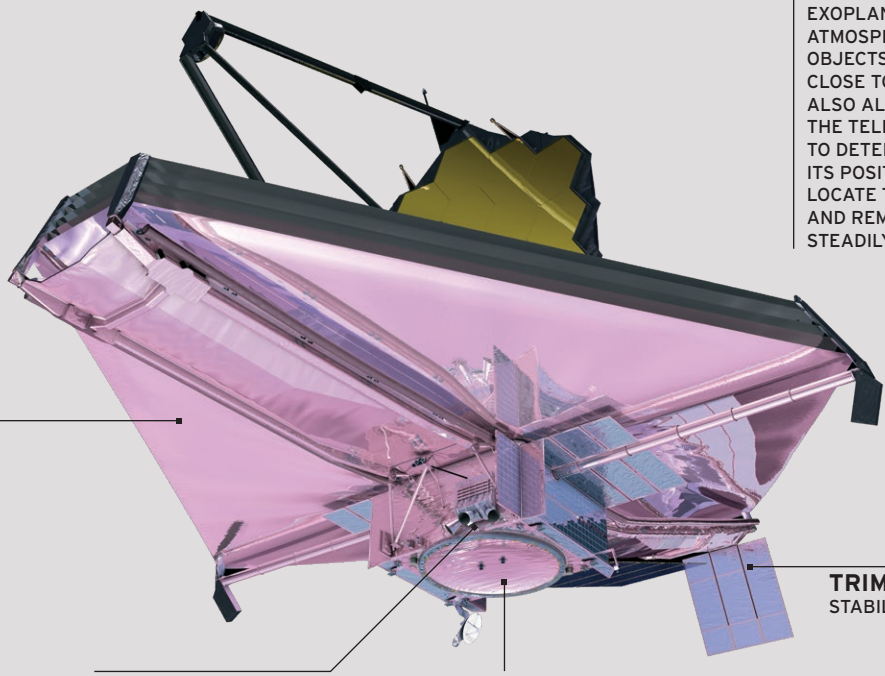


NIRSpec (Near-Infrared Spectrograph) YOUNG, DISTANT GALAXIES AND EXOPLANET ATMOSPHERES

NIRCam (Near-Infrared Camera) FAINT OBJECTS, INCLUDING FIRST STARS AND GALAXIES FORMED AFTER THE BIG BANG

MIRI (Mid-Infrared Instrument) DISTANT STELLAR CLUSTERS, AREAS OF INTENSE STAR FORMATION HIDDEN BEHIND THICK DUST, AND EXOPLANETS

FGSS/NIRISS (Fine Guidance System/Near-Infrared Imager and Slitless Spectrograph) DISTANT GALAXIES, EXOPLANET ATMOSPHERES AND OBJECTS THAT ARE CLOSE TOGETHER. ALSO ALLOWS THE TELESCOPE TO DETERMINE ITS POSITION, LOCATE TARGETS AND REMAIN STEADILY POINTED



MULTI-LAYER SUNSHIELD FIVE LAYERS SHIELD THE OBSERVATORY FROM THE LIGHT AND HEAT OF THE SUN AND EARTH

TRIM FLAP HELPS STABILIZE THE SATELLITE

STAR TRACKERS SMALL TELESCOPES THAT USE STAR PATTERNS TO TARGET THE OBSERVATORY

SPACECRAFT BUS CONTAINS MOST OF THE SPACECRAFT STEERING AND CONTROL MACHINERY, INCLUDING THE COMPUTER AND THE REACTION WHEELS

variety of objects, such as black holes, dark matter, gamma-ray bursts, gravitational waves, large-scale structures in the universe and even how liquid water is transported through space. In particular, Webb's infrared capabilities will allow it to peer through clouds of dust and gas to see stars and planets being formed.

Hammel is one of several scientists scheduled to use the telescope in its first year of operations, and she'll use it to look at objects in our own solar system. Given Webb's location and the fact that it can't point toward the Sun, it won't be able to look at the planets in the inner solar system. It can be used with caution to study Mars, the asteroid belt, Jupiter and Saturn, but its strength lies in looking farther out.

"Webb looks like it was perfectly designed to look at objects in the outer solar system, especially Uranus, Neptune and Kuiper belt objects," Hammel says. "It has the right sensitivity and exact fields of view with the different instruments."

When Webb was initially being designed, scientists had only found a few exoplanets — planets that orbit other stars. Today, there are more than 4,000, and one of Webb's major focuses will be to study the atmospheres of these distant worlds.

"With Webb, we can begin studying more systematically the chemical properties of the atmospheres of exoplanets," said Stiavelli. This includes looking for signatures of water, carbon dioxide and even methane, all of which could point to the possibility of life.

Webb carries several coronagraphs, which block the light from bright stars to reveal orbiting exoplanets. These worlds will only show up as mere points of light, but scientists will be able to analyze them to reveal a great deal of information, including color, rotation rates, seasons, weather and even the possible existence of plant life.

ELIMINATING BIAS

There is no shortage of scientists lining up to use the James Webb Space Telescope. Allocating time on the observatory falls to the Space Telescope Science Institute. STScI has operated the Hubble Space Telescope for decades and will apply that experience to Webb, overseeing flight operations, providing software for scientists to plan observations and to analyze their data and hosting all the data for future archival study.

In planning for observations, STScI organizes the selection process of reviewing and choosing proposals from scientists around the world. In recent years, some researchers noticed that certain biases had crept into the review and selection processes.

"The most obvious was consistent gender bias, where women were getting less observing time than men," says Neill Reid, head of the STScI science mission office. "Also, the proposals from younger investigators and people from smaller institutions were being chosen much less often than those from more established researchers coming from more well-known institutions."

Reid says the data showed that a reviewer's attitude toward a submission could be affected even unconsciously by knowing the identity of the lead author or principal investigator. Proposals were being chosen based on the merit of the person submitting the proposal, not on the merit of the proposal itself.

Over the past few years, Reid has worked with social scientists to institute a dual-anonymous peer-review process for both Hubble and Webb proposals. Under this system, neither proposers nor reviewers know each other's identity until after the proposals have been evaluated.

"The result is that we are now not only closer in the male-female ratio but we have many more proposals chosen from first-time principal investigators and more junior scientists in general for both Hubble and JWST," Reid says. The new process has worked so well that NASA has now instructed all other similar missions to use this same technique in their selection processes.

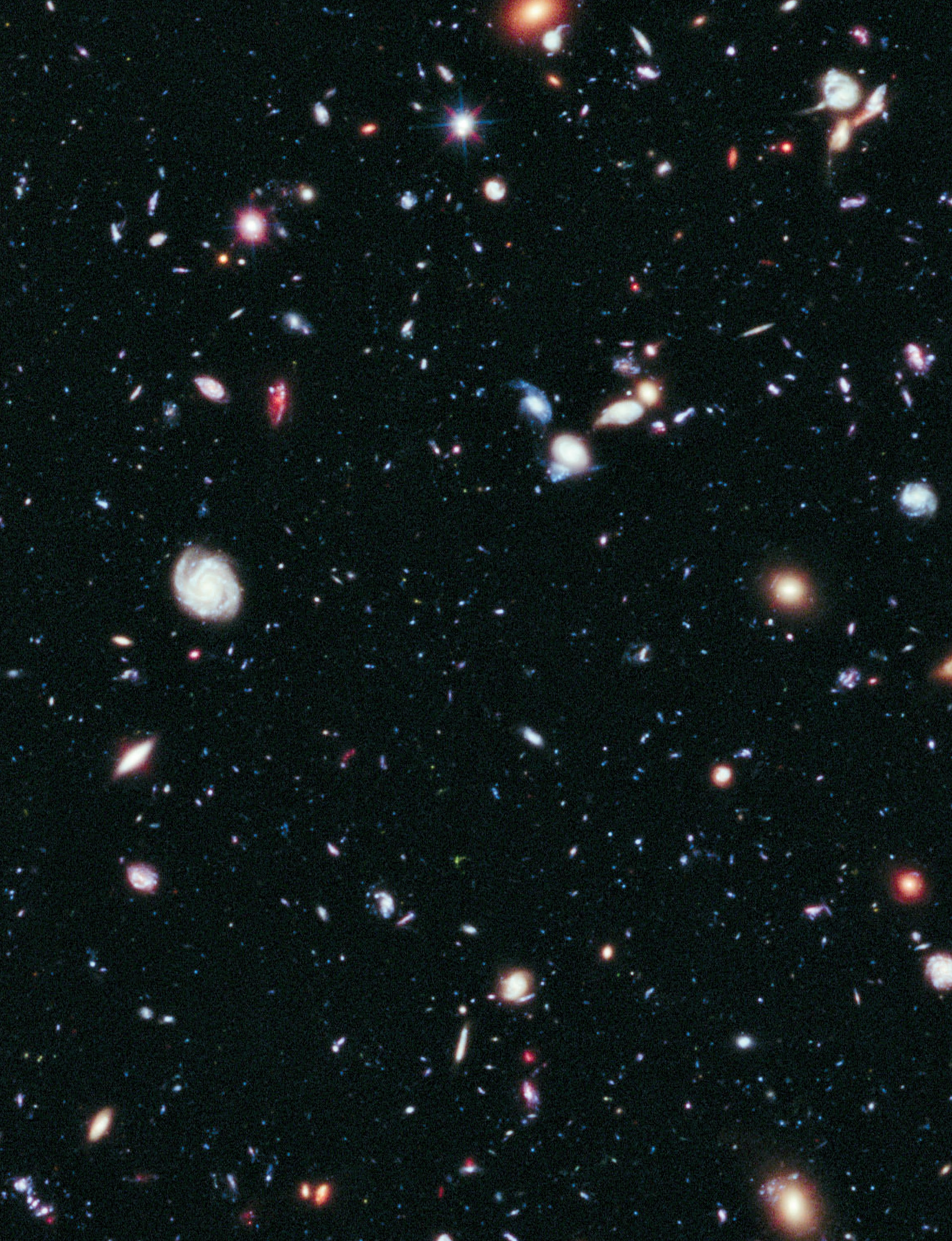
SIX MONTHS OF TERROR

After Webb launches, it will take roughly 180 days for the telescope to travel to its new home in space, unfold its sunshield and mirror, deploy its solar arrays, position its antenna and run through a long list of commissioning tasks before the science starts.

In homage to trepidation felt by Mars rover landing teams, Webb's team has referred to this process as "six months of terror."

For Stiavelli, launch day will be nerve-racking as he watches his life's work blast into space atop what's

OPPOSITE *The James Webb Space Telescope is composed of three main elements. The Integrated Science Instrument Module houses the science instruments, the Optical Telescope Element includes the mirrors and backplane and the Spacecraft Element consists of the spacecraft bus and sunshield.* NASA/STSCI/ LOREN A. ROBERTS

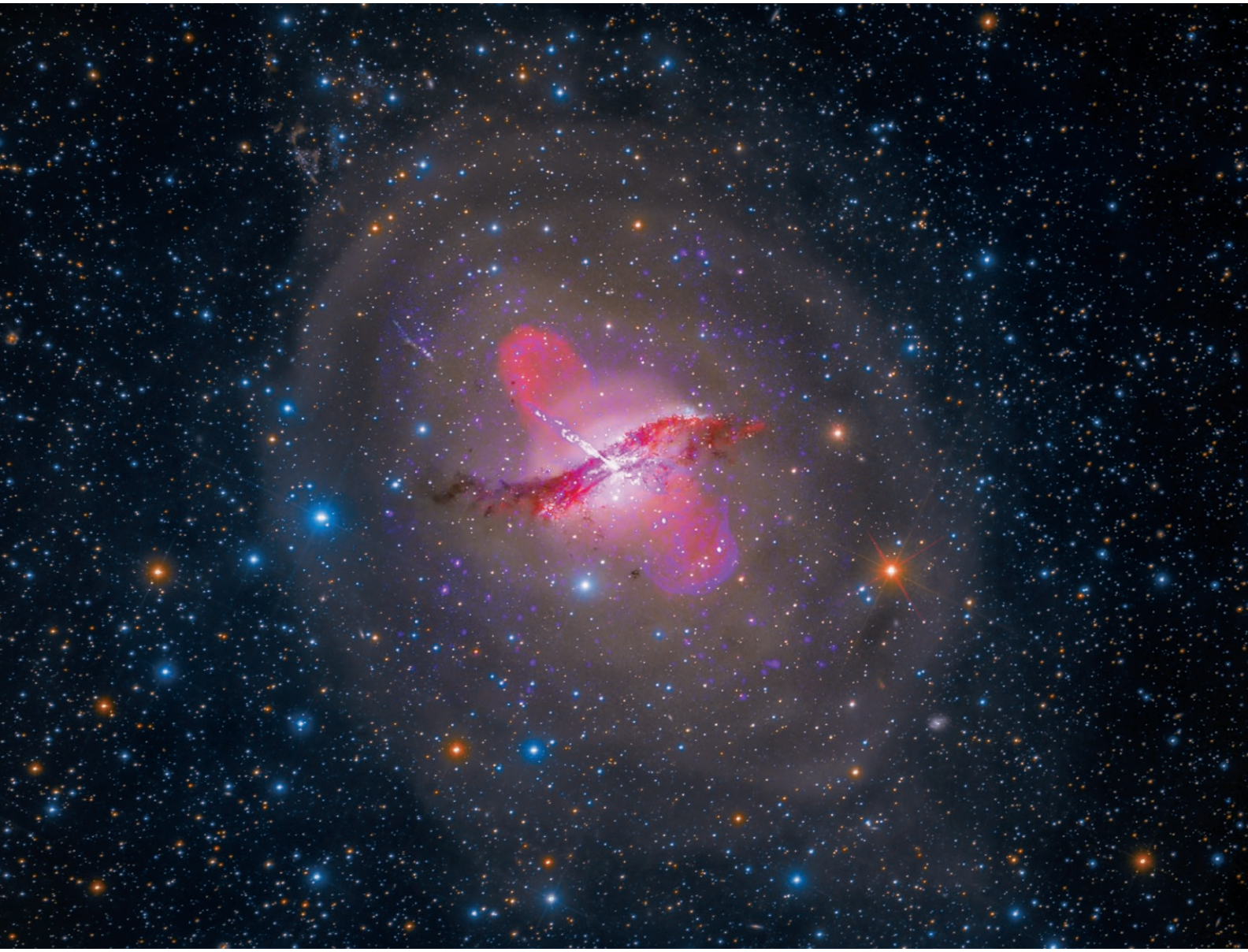


Since capturing the original Hubble Deep Field image in 1995, scientists have followed up with subsequent versions that reveal galaxies billions of times fainter than what unaided human eyes can see. This image shows part of the eXtreme Deep Field, or XDF, which was released in 2012 and combines 10 years of Hubble photos taken of a patch of sky at the center of a 2004 deep field picture. The full XDF contains about 5,500 galaxies.

NASA/ESA/G. ILLINGWORTH, D. MAGEE AND P. OESCH, UNIVERSITY OF CALIFORNIA, SANTA CRUZ/R. BOUWENS, LEIDEN UNIVERSITY/THE HUDF09 TEAM

BELOW *Centaurus A is the fifth-brightest galaxy in the sky and is only about 13 million light-years away from Earth, making it an ideal target for studying an active galactic nucleus – a supermassive black hole emitting jets and winds – with the James Webb Space Telescope.*

X-RAY: NASA/CXC/SAO; OPTICAL: ROLF OLSEN; INFRARED: NASA/JPL-CALTECH; RADIO: NRAO/AUI/NSF/UNIV.HERTFORDSHIRE/M.HARDCASTLE

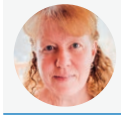


essentially a controlled explosion. But what really keeps him up at night is thinking about the thruster burns Webb must execute to arrive safely at L2.

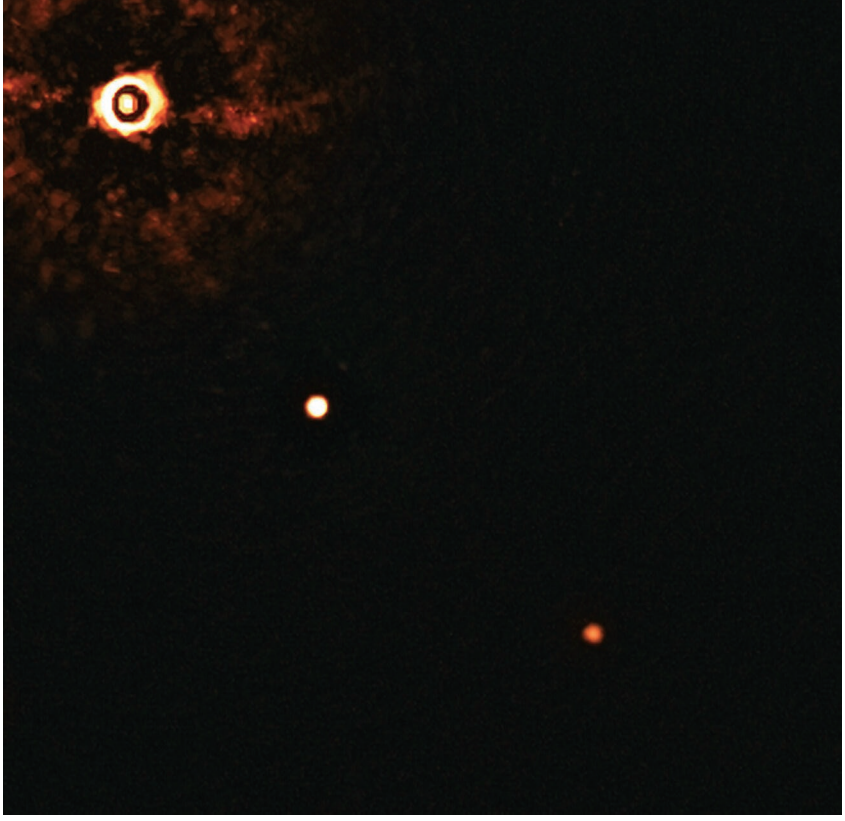
Hammel says her most terrifying moment will be the deployment of Webb's secondary mirror.

"If the sunshield doesn't fully deploy, it will really wreck our midinfrared observations, but maybe we can still do near-infrared. If the mirror doesn't fully open and you only have the center section, you lose sensitivity, but it could still function," she says. "However, if the secondary mirror doesn't deploy, you have no light through the telescope, and the mission is over. To me, that will be the most frightening moment."

But the anticipation of seeing Webb's first images and data supersedes all the fears and years of waiting. Webb scientists have been simulating and imagining what the data will look like for years. Receiving the real thing will be monumental, and they can't wait to share them with the world.



NANCY ATKINSON *is a space journalist and author with a passion for telling the stories of people involved in space exploration and astronomy.*



TOP *This image shows two planets orbiting a star called TYC 8998-760-1. The star is 300 light-years away from Earth. The planets are gas giants like Jupiter and Saturn, and the star is similar to our own at an earlier stage of evolution. The image was captured using the European Southern Observatory's Very Large Telescope in Chile.*
ESO/BOHN ET AL.

BELOW *This infrared view of the Pillars of Creation, a star-forming region inside the Eagle nebula, was taken by NASA's Hubble Space Telescope. In visible light, the clouds are opaque, but in infrared, the stars inside are able to shine through.*
NASA/ESA-HUBBLE/HUBBLE HERITAGE TEAM

Engineers examine a full-size test unit of the James Webb Space Telescope's sunshield following a successful deployment test in 2014.
NASA/CHRIS GUNN

MEMBERS STEP UP TO SAVE THE WORLD

In June 2021, The Planetary Society focused its attention on one goal: defending Earth from asteroid impacts. Members like you stepped up to help advance this important work in several key ways.

FUNDING ASTEROID HUNTERS

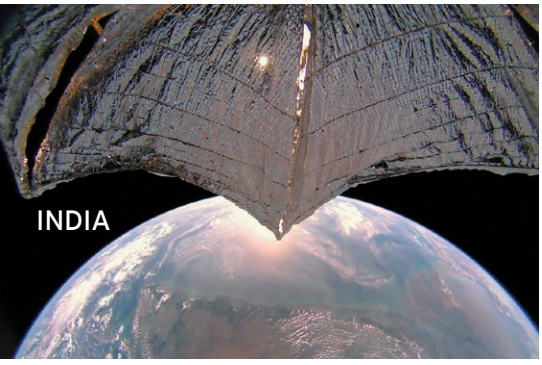
Members and donors around the world came together this year to support our Shoemaker Near-Earth Object Grant program. These grants fund astronomers who are scanning the sky for potentially dangerous asteroids. Through this crowdfunding effort, we were able to raise $91,000 for equipment upgrades for these planetary defenders who spend countless hours working to find, track and characterize near-Earth objects. The next round of Shoemaker grant applications is now in, and we're excited to announce new awardees in the coming months.

VOICING SUPPORT FOR PLANETARY DEFENSE

Planetary Society members and supporters sent more than a thousand messages to the United States Congress and the president this year in support of increased funding for NASA's planetary defense efforts. The petition specifically called for funding for NEO Surveyor, a dedicated, space-based telescope that would greatly accelerate the pace of hazardous asteroid detection and characterization. NASA's 2021 budget partially met that request; finally, in June 2021, the agency approved NEO Surveyor for further development.

CELEBRATING ASTEROID DAY

The Planetary Society was proud to partner with Asteroid Day, an annual celebration of all things asteroid. This year's virtual event featured a month-long online stream of videos about asteroid science and planetary defense. Asteroid Day takes a balanced approach to its subject matter, highlighting both the fascinating discoveries being made about the solar system's small bodies and the efforts that need to be taken to ensure that none of those bodies collide with our planet.



LIGHTSAIL SAILS ON

More than two years after launching, The Planetary Society's crowdfunded LightSail 2 spacecraft is still going strong in orbit. The operations team is working to improve performance and to learn more about solar sailing, the spacecraft and its evolution. LightSail 2 is still taking pictures, producing stunning images of the sail in front of Earth while gathering and sharing information about the evolution of the sail over time.

The mission has already taught us a lot, and the next step is to share these new insights with others in space engineering and with the public.

TALKING TECH

LightSail 2 mission team members have been presenting to and working with three future solar sail NASA missions (NEA Scout, ACS3 and Solar Cruiser) to share what we've learned and feed forward into the future of solar sailing.

This year, the peer-reviewed journal Advances in Space Research published an open-access paper about the LightSail 2 mission. The paper gives an overview of the spacecraft's hardware and software design, describes the mission's performance thus far and discusses some of the anomalies encountered during the mission.

Planetary Society Chief Scientist Bruce Betts also gave an invited presentation about the mission to NASA Goddard Space Flight Center's engineering colloquium, sharing solar sailing directly with another technical community.

Sharing the details of the LightSail 2 mission in academic and technical channels like these helps ensure that the knowledge this mission has enabled can be accessed by space agencies, companies and any others exploring the possibilities of solar sailing.

BRINGING LIGHTSAIL 2 TO YOU

We are excited to announce that LightSail 2 will be included in the FUTURES exhibition opening this November at the world-famous Smithsonian Institute's Arts and Industry building. A full-scale engineering model of the spacecraft will be on display as well as a quarter-scale model with sails deployed. A video will teach guests about this groundbreaking mission made possible by members like you.

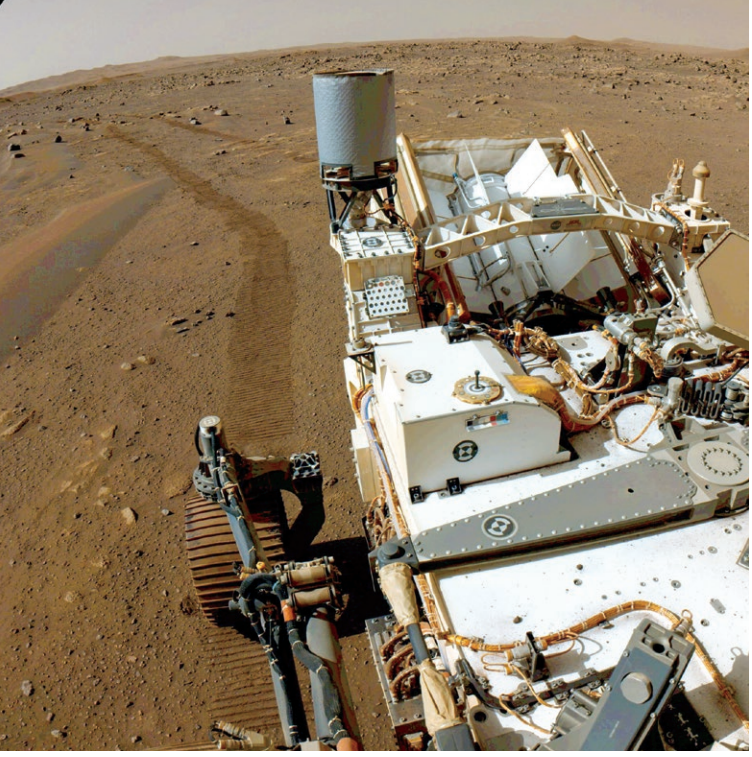
In August, we held a virtual premiere of "Sailing the Light," a 35-minute documentary film telling the story of our members' mighty achievement in crowdfunded spaceflight. The film shows the mission's development, the epic nighttime launch aboard a SpaceX Falcon Heavy rocket and what it means to all the people who made this historic advancement possible. You can watch "Sailing the Light" on demand on our YouTube channel and at **planetary.org/lightsail**.

JOIN THE EXTENDED MISSION TEAM

LightSail 2 is now on an extended mission to advance solar sailing! And we need your help to capture the science from this next phase and share its lasting impact with the world. Your support enables us to sustain daily operations, inform future solar sailing missions, and inspire the public through the creation of the LightSail exhibit at the Smithsonian's FUTURES exhibit this fall.

Give today and your gift will be matched up to $25,000! And if you make a gift of $100 or more you'll receive an official LightSail 2 Extended Mission stitched fabric patch to wear with pride.

Visit planetary.org/extended to make your gift today.



NASA's Perseverance Mars rover looks back toward its tracks on July 1, 2021, after driving autonomously for 109 meters (358 feet) — its longest autonomous drive to date.

NASA/JPL-CALTECH

IT'S ALWAYS A GOOD TIME TO GIVE THE GIFT OF SPACE

Whether you're planning ahead for holiday shopping or just looking to get someone else as excited about space exploration as you are, Planetary Society gift memberships are the way to go. Visit **planetary.org/gift** to share the passion, beauty and joy of space with someone you love.

"It was amazing talking directly to legislators and staff who make the decisions. I'll definitely come and volunteer again."

Planetary Society member Makayla Healy shows off her advocacy credentials during 2021's all-virtual Day of Action.

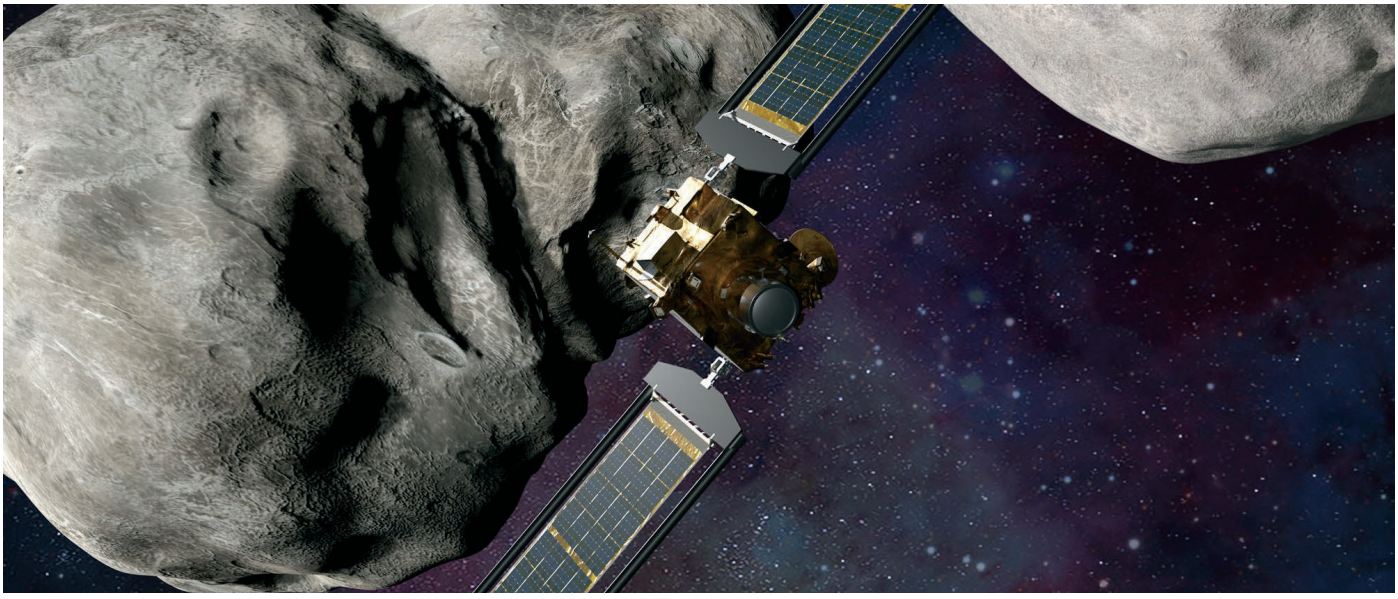
MAKAYLA HEALY

ADVOCATES, UNITE!

Planning for The Planetary Society's annual Day of Action is officially underway. Join your fellow members in speaking up in support of space science, exploration and planetary defense. U.S. citizens can sign up to receive training and join us in taking direct meetings with Congressional representatives to urge them to support strong investments in NASA. Wherever you live, learn how you can participate in this global advocacy effort at **planetary.org/dayofaction**.

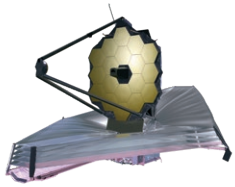
This artist's concept shows NASA's DART spacecraft approaching Dimorphos, the moon of asteroid Didymos.

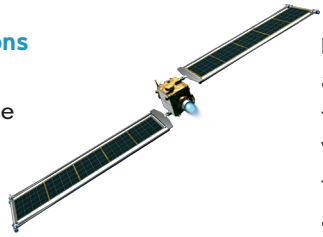
NASA/JOHNS HOPKINS APL/EDITED BY THE PLANETARY SOCIETY



LOCK IN YOUR LAUNCH PLANS

Several exciting missions are launching in the coming months, and there's nothing like a good launch party! Whether in person or remotely (since we're all pros at remote get-togethers now!), get your friends and family together to celebrate these exciting moments in space history. Brush up on your knowledge beforehand at **planetary.org/space-missions** and you'll have great conversation material as the countdown ticks away.





NASA's **Lucy** mission will be the first spacecraft to visit a group of asteroids called Trojans that share Jupiter's orbit around the Sun. Lucy will visit seven Trojan asteroids between 2027 and 2033 and will make a bonus visit to a main-belt asteroid in 2025. Lucy will launch from Cape Canaveral, Florida, on an Atlas V rocket, with a 21-day launch window opening on October 16, 2021.

The **James Webb Space Telescope** is currently slated for a November 2021 launch. This epic, $10 billion dollar observatory has been in development since 1996, so tensions will be high as it takes flight from French Guiana aboard an Ariane 5 rocket. Be sure to tune in to this momentous launch and make sure your popcorn is popped! It's going to be a real nail-biter.

NASA's **Double Asteroid Redirection Test (DART)** is a planetary defense mission to test the kinetic impactor technique to change the motion of an asteroid in space. While dates aren't yet finalized, the launch window for the mission begins November 24, 2021. DART will launch aboard a SpaceX Falcon 9 rocket from Vandenberg Air Force Base in California, and after more than a year of travel, it will intercept the asteroid Didymos' moonlet in late September 2022.

Stay tuned for launch date announcements and join us for live broadcasts of all these launches at **planetary.org/live**.

GEAR UP FOR THE GEMINIDS

IN THE SKY

Super-bright Venus is in the west in the early evening. Bright Jupiter and yellowish Saturn move toward Venus in the evening sky as the months pass until they make a compact line in the evening west throughout December. Mercury is visible low in the pre-dawn east from mid-October to mid-November and is close to dimmer reddish Mars on November 10 very low to the horizon as Mars begins getting higher in the east as weeks pass. A nearly total partial lunar eclipse occurs on November 18/19, visible from the Americas to the eastern Pacific. A total solar eclipse on December 4 is visible from portions of Antarctica and the southern Atlantic Ocean. The Geminids meteor shower peaks on December 13/14. The Geminids is usually the best shower of the year with 100+ meteors per hour from a dark site, but a gibbous Moon will wash out dimmer meteors this year. For more night sky tips, you can always check out **planetary.org/night-sky**.

RANDOM SPACE FACT

Even though the primary mirror of the James Webb Space Telescope has about six times the surface area of the primary mirror of the Hubble Space Telescope, the Webb mirror is much less massive — about 625 kilograms (1,375 pounds on Earth) compared to about 1,000 kilograms (2,200 pounds on Earth). Hubble's mirror is solid glass, whereas Webb's 18-segment primary mirror is made of lightweight beryllium with adjusters and a stiff frame.

TRIVIA CONTEST

Our March equinox contest winner is Dan Court of Dorset, UK. Congratulations! The question was: ***For more than five years, the Japanese Akatsuki spacecraft has been orbiting and studying Venus. What does "Akatsuki" mean in English?*** The answer: ***Dawn.***

Try to win a copy of "Super Cool Space Facts" by Bruce Betts and a Planetary Radio T-shirt by answering this question: ***What was the James Webb Space Telescope called before being named for former NASA Administrator James Webb?***

Email your answer to planetaryreport@planetary.org or mail your answer to The Planetary Report, 60 S. Los Robles Ave., Pasadena, CA 91101. Make sure you include the answer and your name, mailing address and email address (if you have one). By entering this contest, you are authorizing The Planetary Report to publish your name and hometown. Submissions must be received by December 1, 2021. The winner will be chosen in a random drawing from among all the correct entries received. For a weekly dose of "What's Up?" complete with humor, a weekly trivia contest and a range of significant space and science fiction guests, listen to Planetary Radio at planetary.org/radio.

***Please contact Terri or Taunya at Betchart Expeditions for brochures and updated information on COVID and travel. Call 1-800-252-4910 or go to* betchartexpeditions.com.**

There are wonderful travel adventures ahead for you in 2021 and 2022 with The Planetary Society! A magnificent eclipse awaits you in Antarctica. You can watch the aurora borealis dance across the Alaskan sky in March, and there are three fantastic lunar eclipse trips in 2022.

ALASKA AURORA BOREALIS
MARCH 10-16, 2022

Reserve your place now on this ever-popular winter-in-Alaska program, with dazzling evenings watching the aurora borealis.

TALL SHIP CARIBBEAN SAILING ADVENTURE
MARCH 19-26, 2022

Discover the night skies, history, and natural world of the Caribbean on one of the world's largest sailing vessels – the 4-masted Star Flyer.

GALAPAGOS ISLANDS TOTAL LUNAR ECLIPSE
MAY 11-20, 2022

There is nothing like a lunar eclipse over the Galapagos Islands. The whole sky will sparkle with starlight in this super dark-sky location! Join this fascinating trip with Dr. Tyler Nordgren.

HAWAII LUNAR ECLIPSE
NOVEMBER 6-14, 2022

See the total lunar eclipse on November 8 and explore the natural wonders of Hawaii, from active volcanoes to massive tree ferns to scientific observatories, with astronomer Dr. Tyler Nordgren.

The Planetary Society

60 SOUTH LOS ROBLES AVENUE
PASADENA CA 91101-2016 USA

Barbara Fee Sheehan, "Revealing a Newfound Galaxy"

This painting by Planetary Society member Barbara Fee Sheehan depicts the James Webb Space Telescope along with her interpretation of what the faraway GN-z11 galaxy might look like. Sheehan is hopeful that the JWST may be able to observe GN-z11, the oldest and most distant galaxy known to us. Studying this galaxy that is 32 billion light-years away from Earth would yield new insights about the early ages of the universe.

Do you want to see your artwork here? We love to feature our members throughout this magazine. Send your original, space-related artwork to *connect@planetary.org*.