Galactic Observer

John J. McCarthy Observatory

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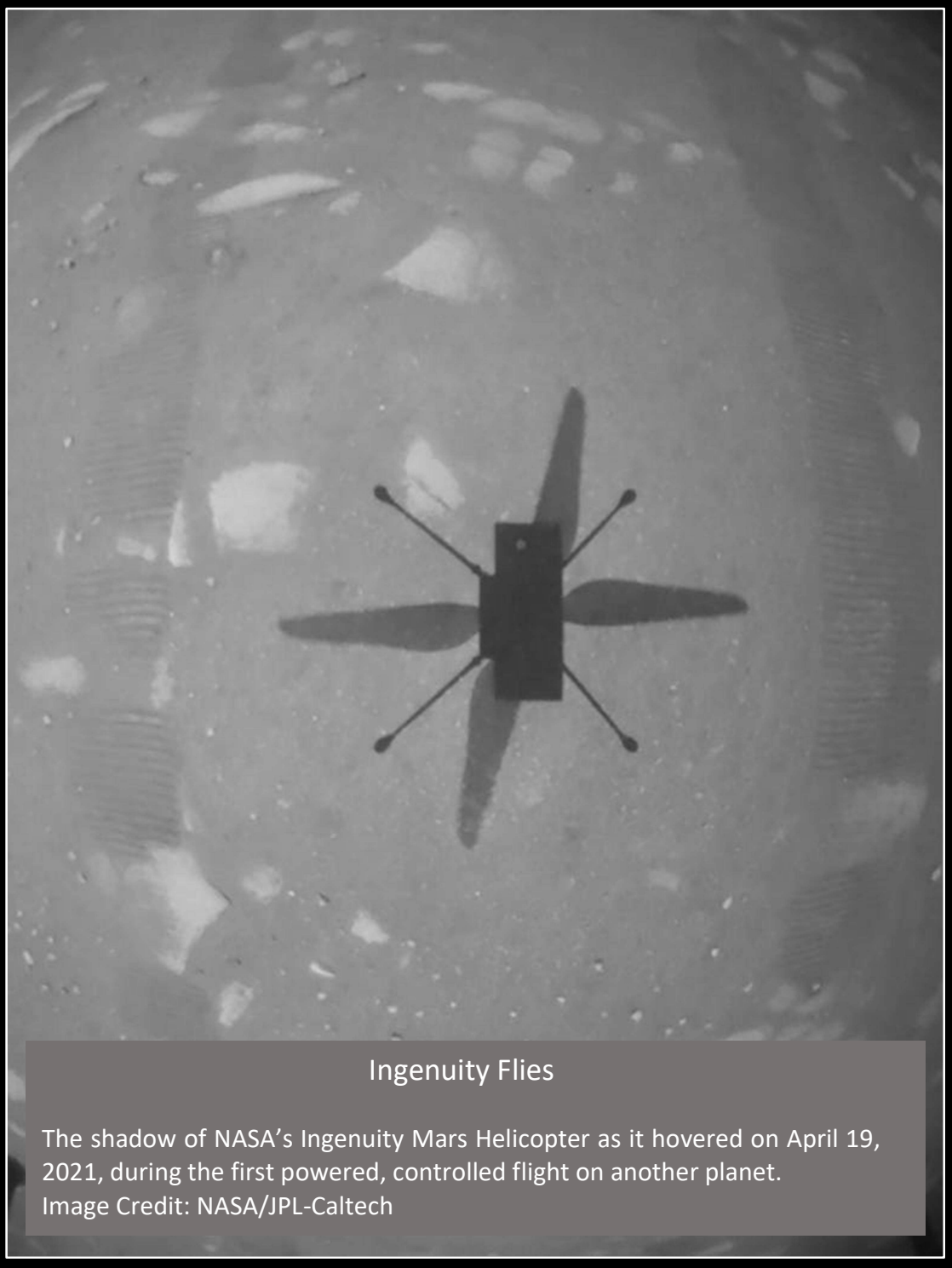
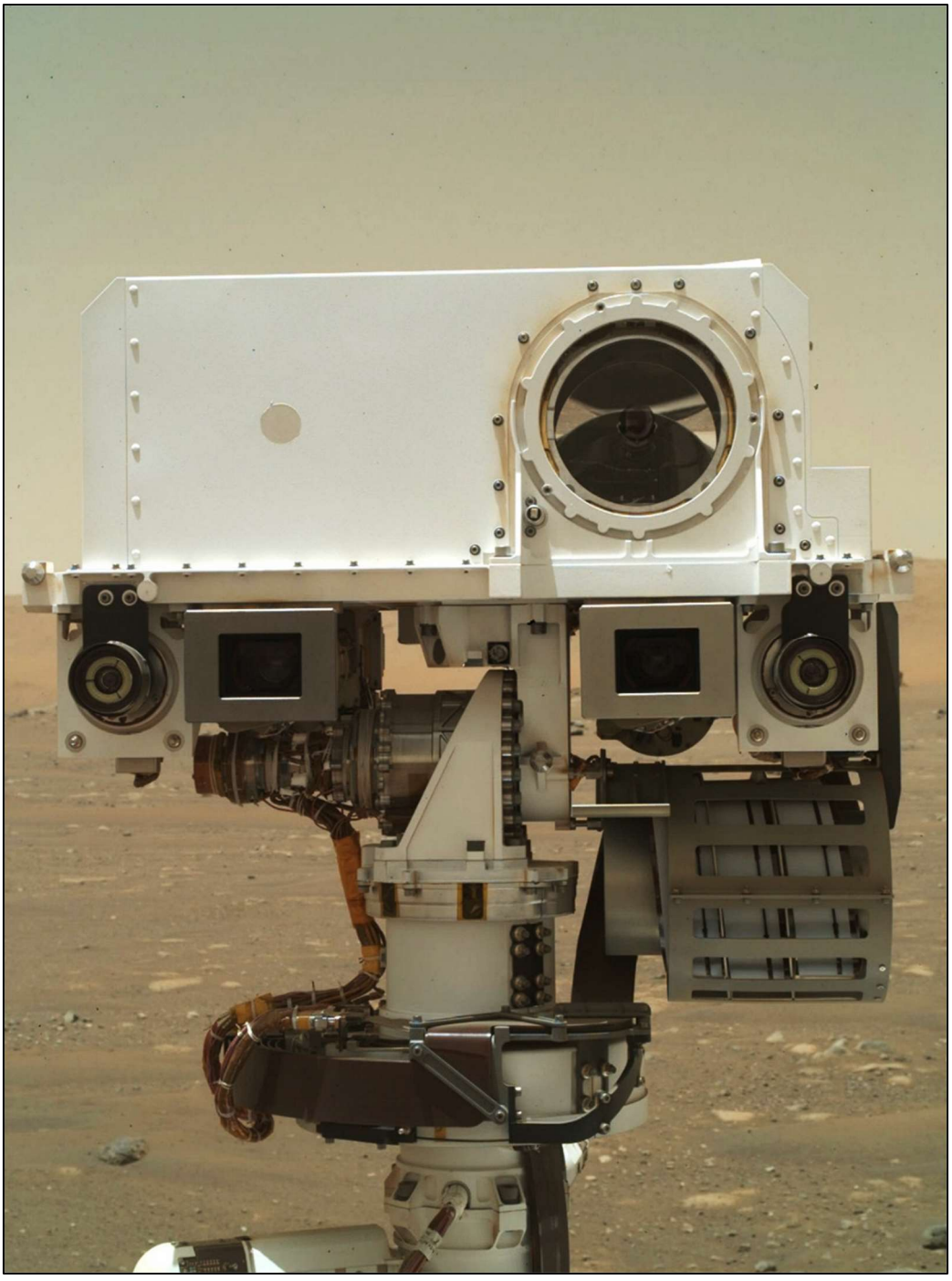


Ingenuity Flies

The shadow of NASA's Ingenuity Mars Helicopter as it hovered on April 19, 2021, during the first powered, controlled flight on another planet.
Image Credit: NASA/JPL-Caltech

May Astronomy Calendar and Space Exploration Almanac



The mast head of NASA's Mars Perseverance rover with its navigation cameras (left and right sides), zoom cameras (gray boxes), and the large, round SuperCam instrument on top. The image was acquired with the SHERLOC WATSON camera, located at the end of the rover's robotic arm on Sol 45 (April 6, 2021).

Image Credit: NASA/JPL-Caltech

In This Issue

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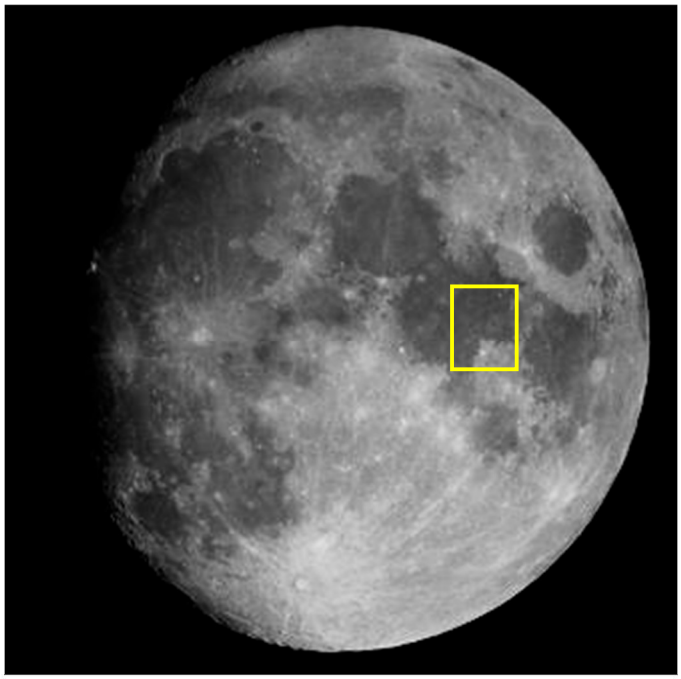
"Out the Window on Your Left"

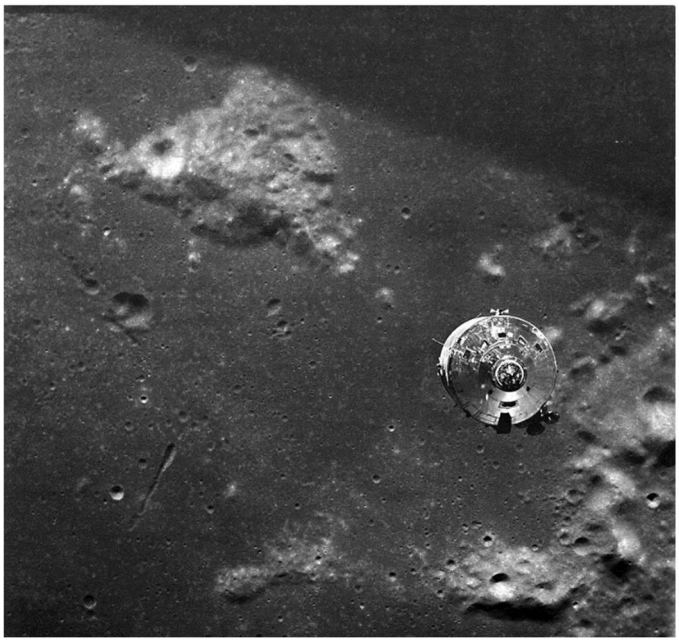
It's been almost 52 years since Neil Armstrong first stepped onto the moon's surface and more than 48 years since Gene Cernan left the last footprint. As a nation founded on exploration and the conquest of new frontiers, today's commitment to return to the moon has been as fleeting as the funding. But what if the average citizen had the means to visit our only natural satellite; what would they see out the window of their spacecraft as they entered orbit around the moon? This column may provide some thoughts to ponder when planning your visit (if only in your imagination).



Launched in May 1969, Apollo 10 was a dress rehearsal for Apollo 11, with astronauts Thomas Stafford and Eugene Cernan flying the Lunar Module to within 9 miles (14 km) of the surface. Along the way the Apollo 10 crew identified dozens of informal landmarks that could be used by Armstrong and Aldrin as waypoints to check their progress against the nominal descent timeline. The names appear on the charts used by the astronauts, in technical reports, and in the transcripts of communications between the astronauts and mission control.

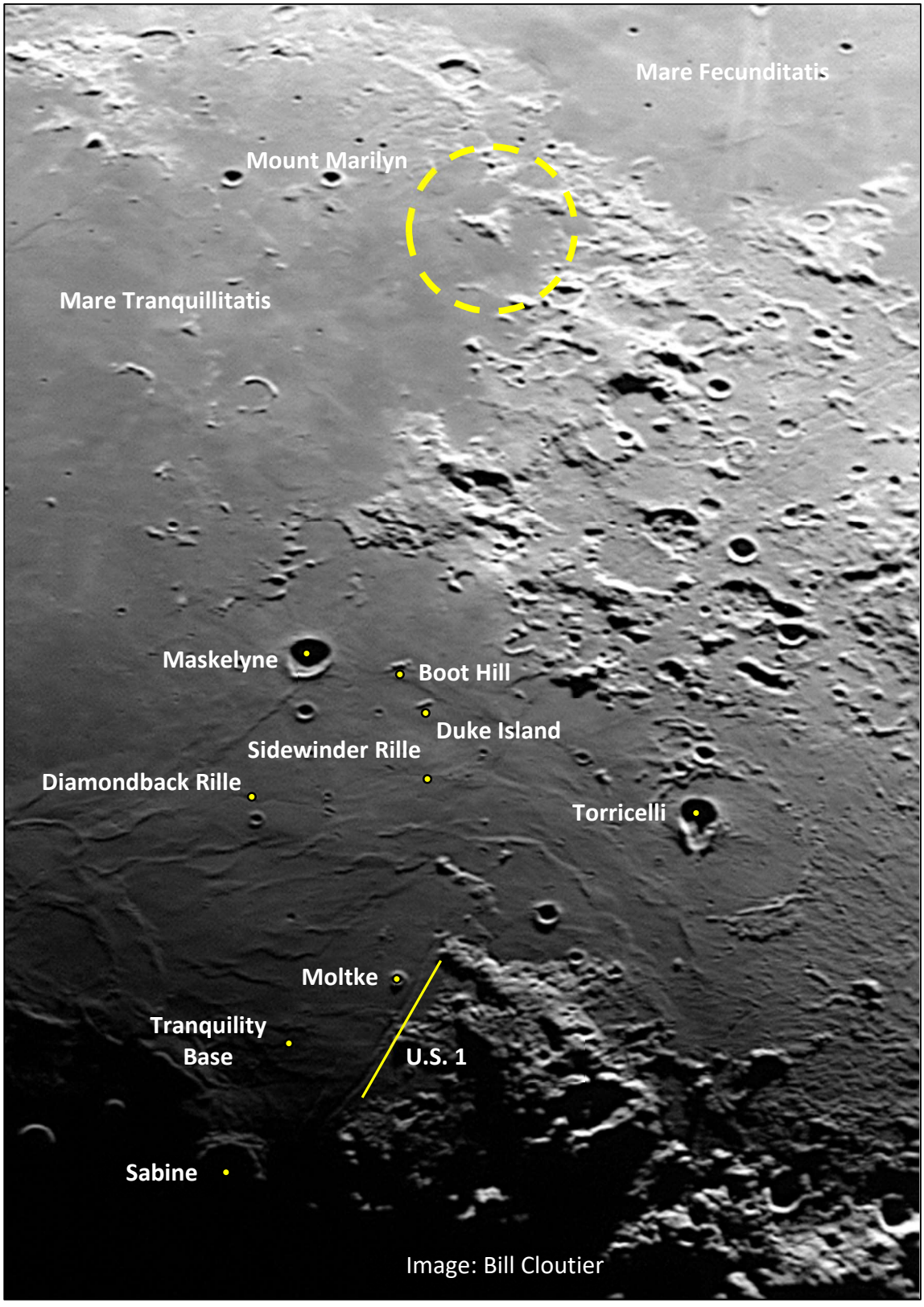
By February 1968, the Apollo Site Selection Board had identified five landing sites under consideration for the first moon landing. The sites were central to the near side and within five degrees of the lunar equator. Sites 1 and 2 were located in the Sea of Tranquility (Site 1 was eventually rejected as being too far east).

Sites appraised for the first landing (from ground-based telescope observations, robotic spacecraft photographs, and Apollo 10 astronaut assessments) were relatively flat, free of boulders and large craters, and level. NASA preferred to land shortly after dawn, approaching the target from the east so that the crew could view the terrain with the sun at their backs. This restricted the availability of a particular landing site to just one day in a lunar month. Launch delays would move the landing site west for more favorable lighting.



NASA Photo: Apollo 10 Command Module as seen from the Lunar Module with Mt. Marilyn visible in the background

The Approach



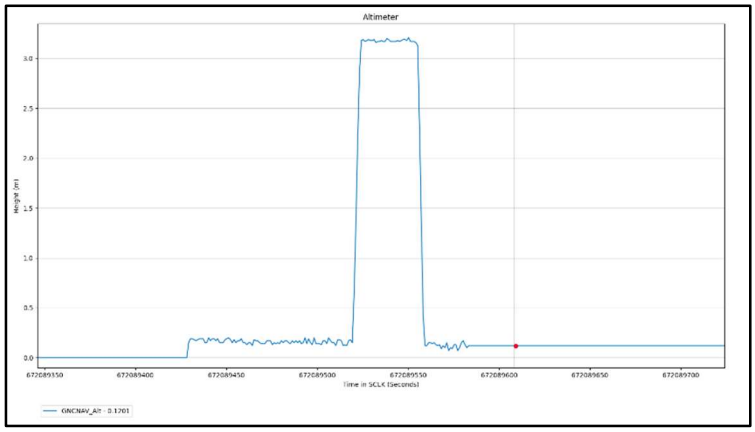
First Flight

NASA's Ingenuity Mars Helicopter made history on Monday, April 19 at 12:33 pm local Mars time, when it became the first aircraft to make a powered, controlled flight on another planet. The solar-powered helicopter executed a flawless flight plan, climbing to an altitude of about 10 feet (3 meters), where it hovered, turned 90 degrees, so that its color camera was pointed towards the Perseverance rover parked about 211 feet (64.3 meters) away, before descending and landing. NASA Associate Administrator for Science Thomas Zurbuchen subsequently announced that the Martian airfield where the test took place would now be known as Wright Brothers Field.

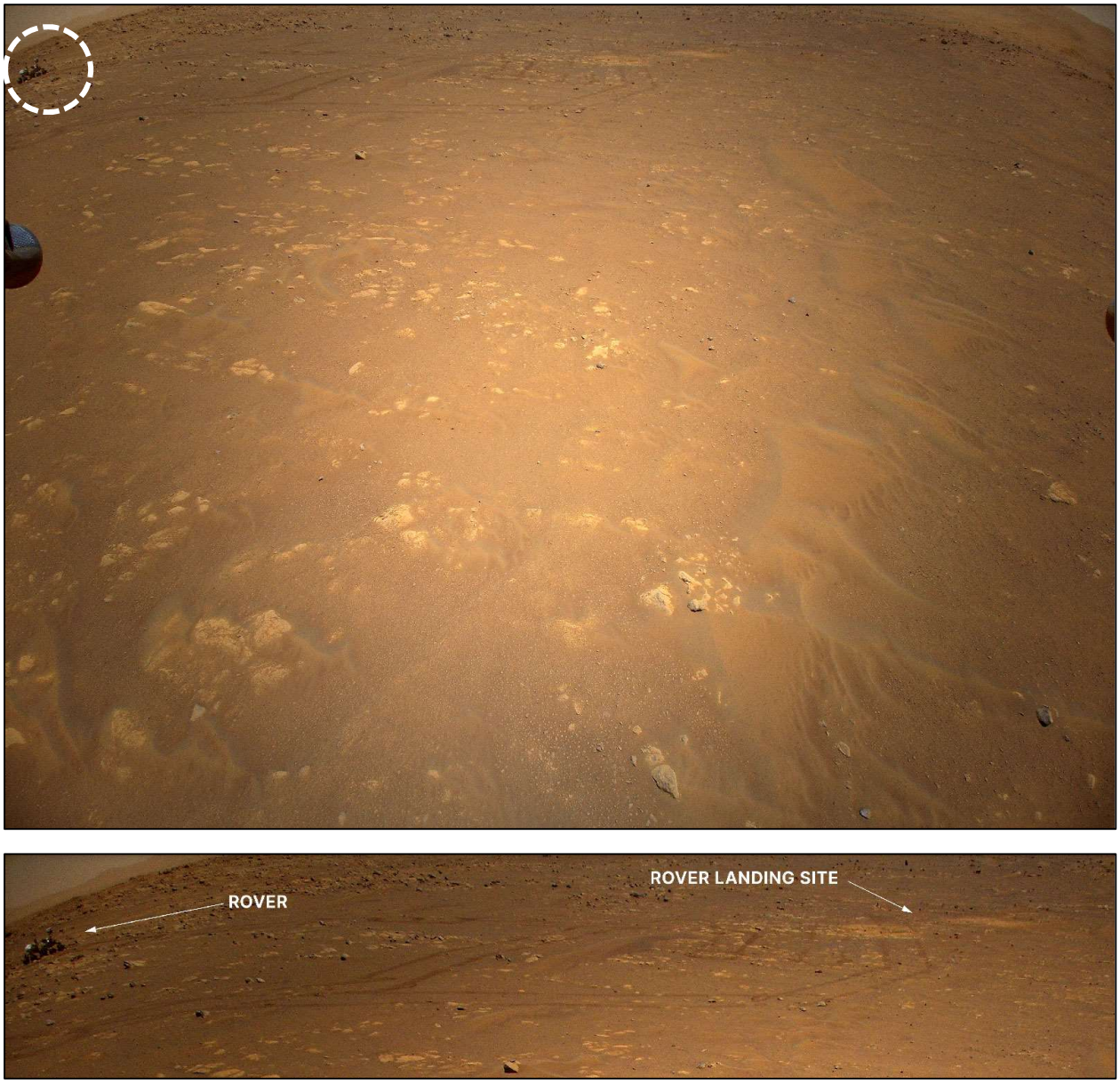
Ingenuity in Flight at Wright Brothers Field
Credit: NASA/JPL-Caltech/ASU/MSSS

Three days later, the 4-Earth-pound (1.8-kg) rotorcraft took to the air again, climbing to 16 feet (5 meters) before moving laterally 7 feet (2 meters). While the first flight lasted about 40 seconds, the second flight extended that duration to almost 52 seconds.

In the mission plan, NASA set aside 30-sols, or Martian days, for flight-testing the helicopter (which would have expired in early May). On April 30th, after three successful flights, NASA announced a 30-sol extension and a transition from testing to operations. The project team intends to fly the helicopter to a new staging area on flight 5, and integrate its flight plan with the rover's exploration goals. While NASA has not ruled out an even longer operating campaign, the diminutive aircraft will have to survive the harsh Martian environment and more rugged terrain being considered for future excursions.



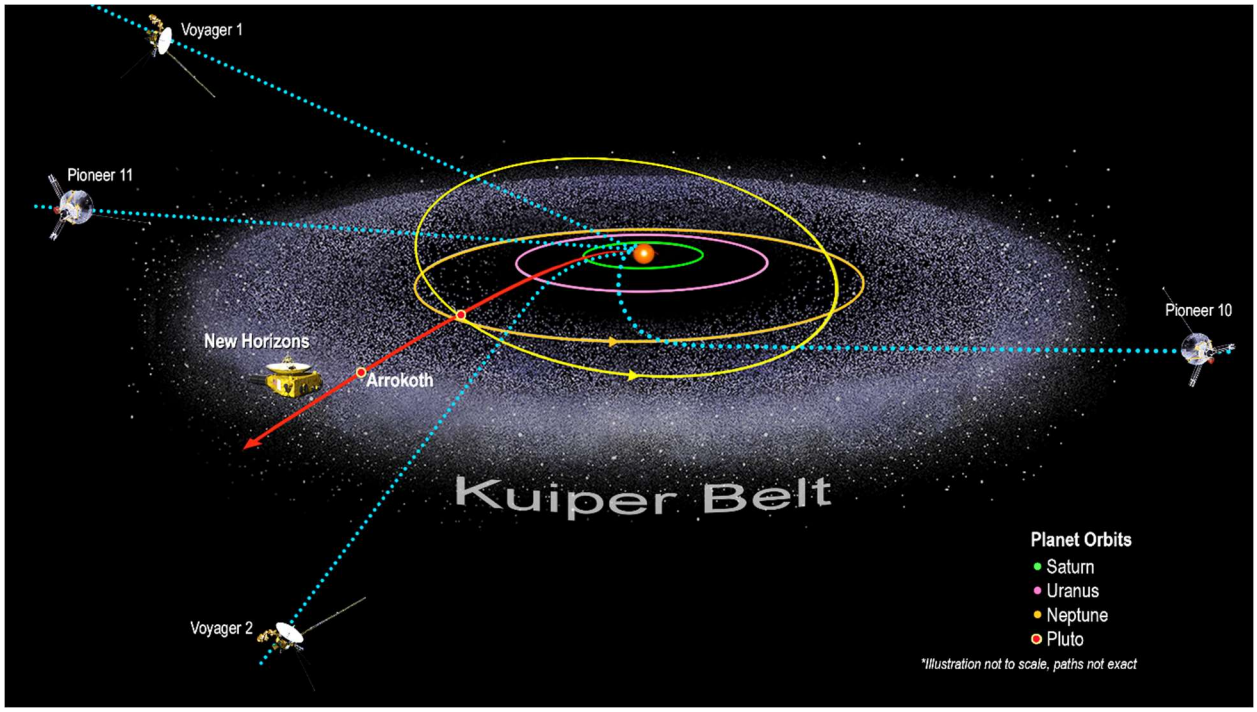
First flight profile
Credit: NASA/JPL-Caltech



An image taken by NASA's Ingenuity Mars Helicopter's color camera during its third flight on April 25 captured the Perseverance rover in the distance (upper left corner). At the time the image was taken, the helicopter was flying at an altitude of 16 feet (5 meters) and was about 279 feet (85 meters) from Perseverance. The rover's landing site is also visible in the image, as well as the areas cleared (lighter patches) by the Descent Stage's rocket motors on either side.

Credits: NASA/JPL-Caltech

New Horizons Milestone



Relative locations of the five spacecraft in the outer solar system, Pluto and Charon, and Arrokoth
Credit: NASA/JHUAPL/SwRI

On April 17 (EDT), NASA's New Horizons spacecraft became only the fifth spacecraft to reach a distance of 50 au (astronomical units) from the Sun. An "au" is the distance between the Earth and Sun, or approximately 93 million miles (150 million km), or 8 light-minutes. At 50 au, spacecraft communications (at the speed of light) take almost 7 hours – one way.

The New Horizons spacecraft was launched on January 19, 2006 from the Cape Canaveral Air Force Station in Florida. With a gravity assist from Jupiter, the spacecraft executed a close flyby of Pluto on July 14, 2015, passing within 7,750 miles (12,500 kilometers) of the one-time ninth planet.

Three and a half years later, on New Year's Day, New Horizons flew by a small Kuiper Belt object. Arrokoth, as it would be named, was about 4 billion miles (6.6 billion km) from the Sun at the time of the encounter.

New Horizons will join Voyagers 1 and 2 in interstellar space sometime in the 2040s. Voyager 1 was the first spacecraft to leave the solar system and is currently more than 152 au or 14.1 billion miles (22.9 billion km) from the Sun.

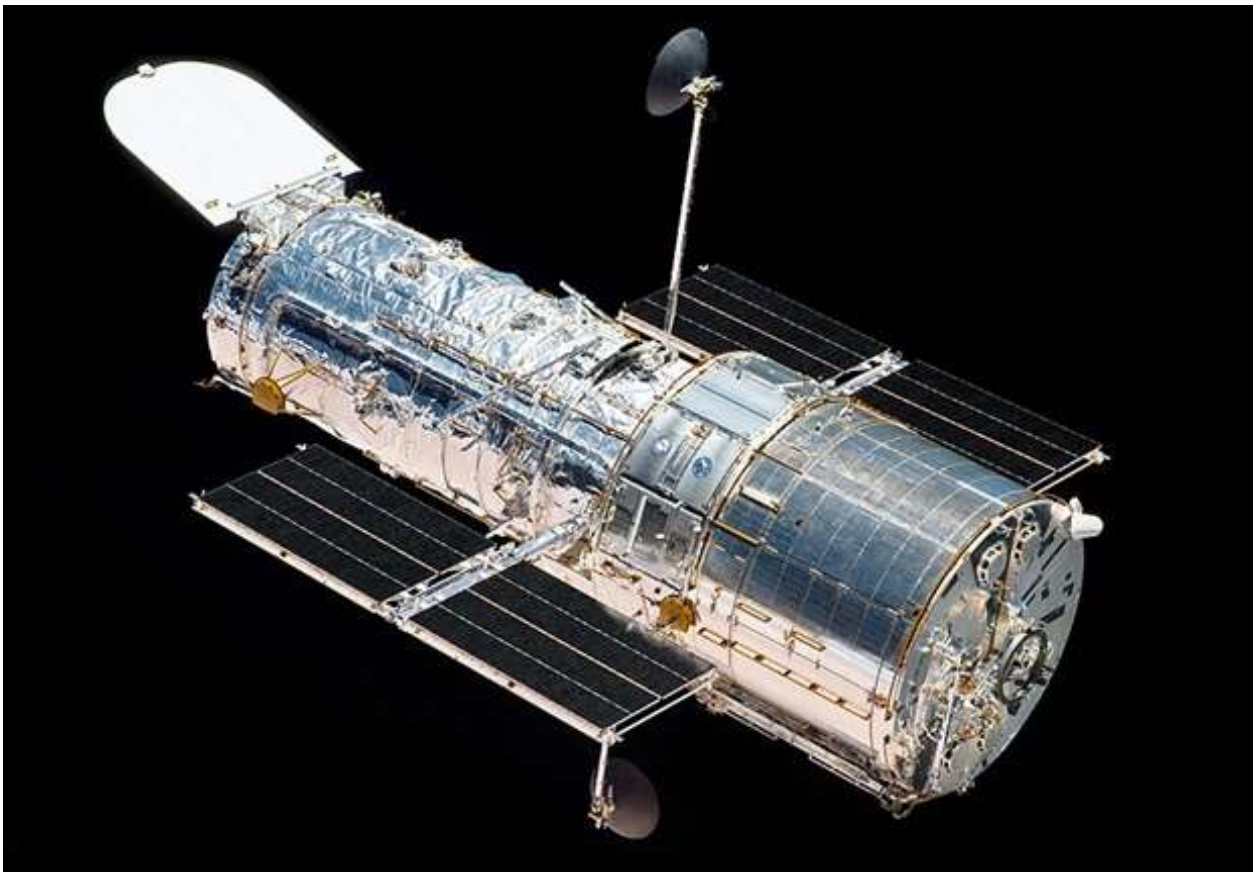
Otherworldly

Martian Clouds

Autumn on Mount Sharp (currently being explored by NASA's Curiosity rover) is also the beginning of the cloudy season. The rover recently photographed the high clouds that are visible at twilight in Mars' thin atmosphere against the silhouette of Mount Mercou (in the foreground). Scientists are using the Curiosity's cameras to observe and analyze the clouds and cloud formation.

Image Credit: NASA/JPL-Caltech

Thirty Plus



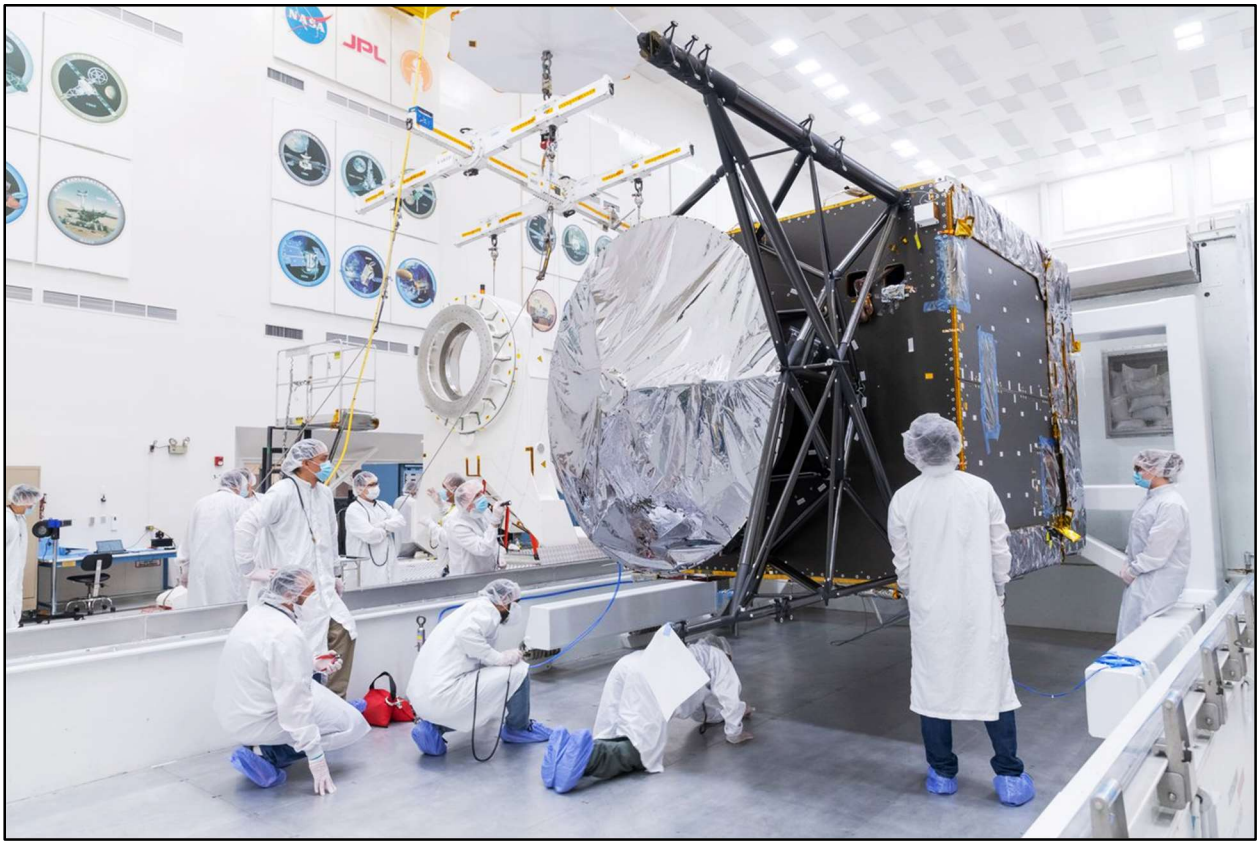
View of the orbiting observatory from the space shuttle Atlantis in May 2009, during the fifth servicing mission to the telescope Credits: NASA

On April 24, the Hubble Space Telescope (HST) celebrated thirty-one years since it was launched into orbit on the space shuttle Discovery in 1990. Being in low-Earth orbit, and accessible by the space shuttle (now retired), has contributed to the observatory's longevity and the science it has been able to return. While the shuttle fleet was active, HST was visited on five separate occasions, with astronauts changing out failed components, replacing computers, solar panels, batteries and stabilizing gyroscopes, and repairing instruments such as the Space Telescope Imaging Spectrograph, which had suffered a power supply failure, and the Advanced Camera for Surveys. Astronauts also upgraded older instruments, such as the Wide Field Camera, with the latest generation, and more capable imagers.

After thirty-one years, the telescope is beginning to show its age, with minor degradations in its detectors, cosmic rays causing periodic computer resets, and general wear and tear on the hardware from thermal cycling and other environmental factors. In March, the telescope's door failed to close when the observatory entered a safe-mode caused by a software anomaly. Engineers were able to engage a backup motor for the task, but in returning to operations the Wide Field Camera 3 failed to reboot, likely caused by an aging power supply and low temperatures. Camera operations were subsequently restored and HST has since resumed science operations. While additional servicing mission are unlikely, expectations are that the observatory can still return ground-breaking science for many more years.

Taking Shape

Maxar Technologies has delivered the Solar Electric Propulsion (SEP) Chassis to NASA's Jet Propulsion Laboratory in Southern California for the Psyche spacecraft. The chassis provides the mounting structure for the project hardware and instruments, the propulsion system, the thermal system, guidance and navigation sensors and actuators, and the high-gain antenna.



Psyche's SEP Chassis being brought into High Bay 1 of JPL's Spacecraft Assembly Facility
Image Credit: NASA/JPL-Caltech

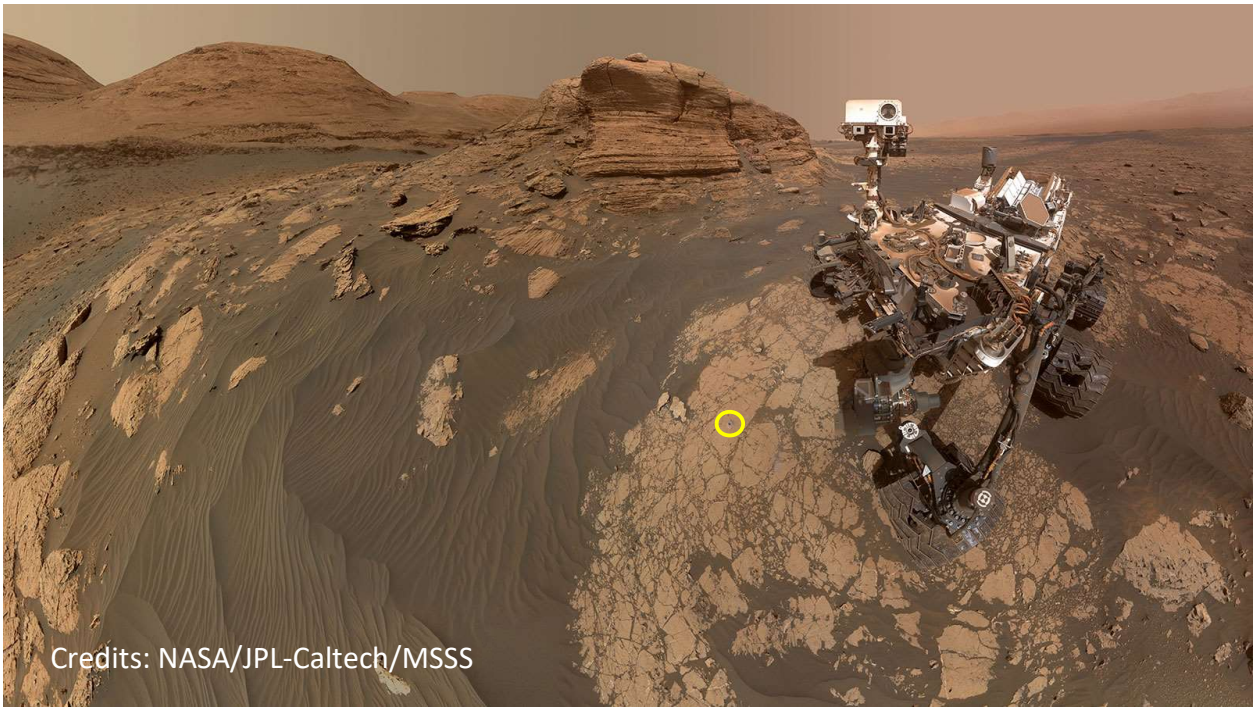
The Chassis represents 80 percent of the mass of the spacecraft. Over the next year, additional hardware will be added to the spacecraft, including the command and data handling system, a power distribution assembly, the X-band telecommunications hardware suite, three science instruments (two imagers, two magnetometers, and a Gamma Ray Neutron Spectrometer), and a deep space optical communications technology demonstrator.

The spacecraft is scheduled to launch from the Kennedy Space Center in August 2022. Launch services to the main asteroid belt will be provided by SpaceX's Falcon Heavy rocket. The Psyche spacecraft is expected to arrive at the Psyche asteroid in January 2026 (with a gravitation assist from Mars). During its primary mission of 21 months, the spacecraft will investigate the unique and metal-rich asteroid, suspected of being the exposed core of an early protoplanet, from four staging orbits, which become successively closer over time.

The Falcon Heavy will also carry a secondary payload – Janus, a pair of smallsats, which will visit two binary asteroids.

NASA's Other Rover

Approximately 2,300 miles (3,700 km) from where the Perseverance rover was monitoring Ingenuity's flight text, NASA's other rover (Curiosity) is continuing to work its way up the 3-mile-tall (5-kilometer-tall) Mount Sharp. Along the way, Curiosity used two of its cameras (one on the robotic arm and the other on the rover's mast) to create a panorama, including a selfie in front of a 20-foot-tall (6 meter) outcrop of bedded sedimentary rock called Mont Mercou (named for a mountain in France). The complete panorama was assembled from 71 images.



Curiosity has also been sampling the rock unit around Mont Mercou, feeding a portion of the material from the newly drilled hole into its internal chemistry laboratory (its thirtieth sample).

The rover has been climbing Mount Sharp, located in the middle of the 96-mile-wide (154 kilometer-wide) Gale Crater for the past seven years. It is currently exploring a transition zone on the mountain, between the lower "clay-bearing unit" and higher "sulfate-bearing unit." The drill hole is visible to the left of the rover and in a rock nicknamed "Nontron," after a region around a village in southwestern France.

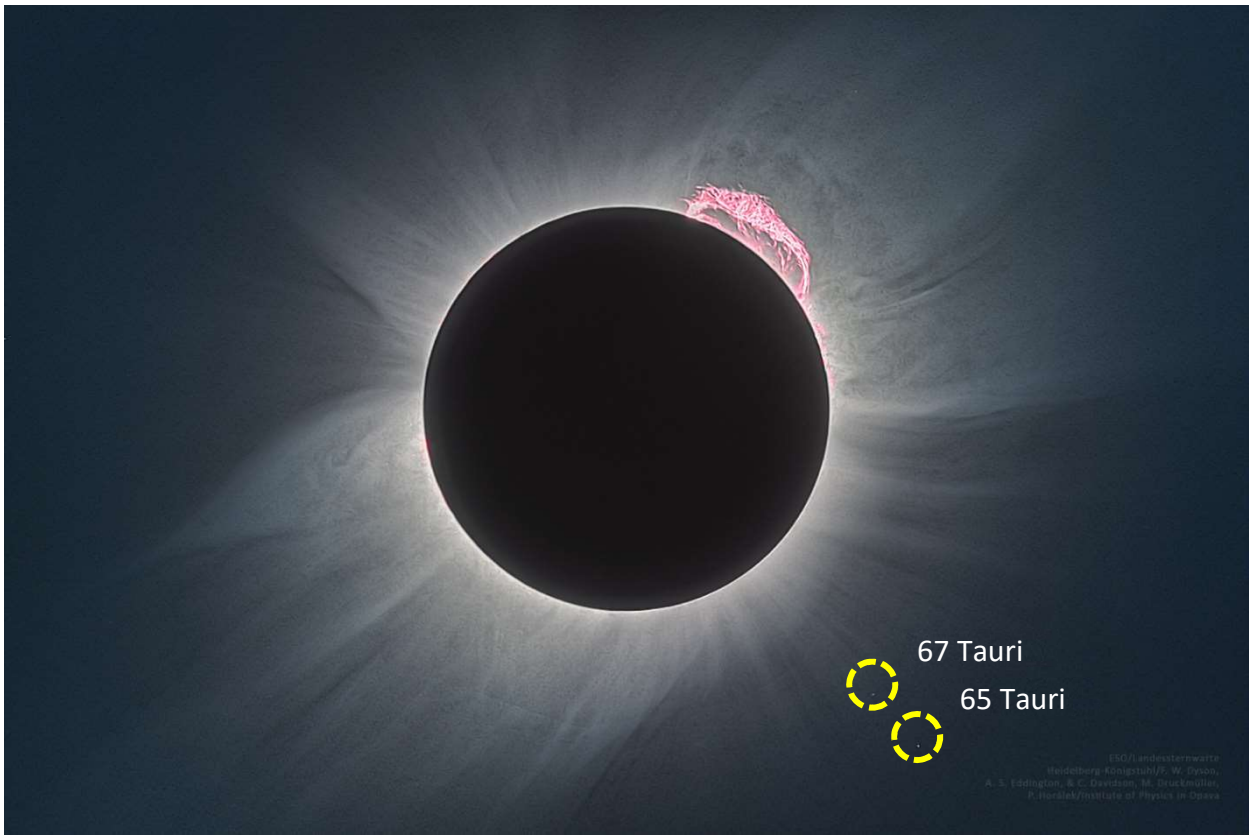
The transition zone may contain clues to the climatic changes that transformed Mars from a world with rivers, lakes and shallow oceans, billions of years ago, to the cold desert being explored by NASA's two rovers today. (A research article published in the April issue of "Geology" describes a cycle of alternating wet and dry times before the surface water completely disappeared around three billion years ago.)

The Curiosity rover has traveled 15.50 miles (24.94 km) since landing in Gale crater in August 2012 (it reached the base of Mount Sharp in September 2014). The rover has found definitive evidence of standing and running water in the rock layers laid down over time and in the mineral content left behind in the sediment. Over 3,100 Sols, Curiosity's cameras have also captured more than 783,000 images of the Martian landscape.

Einstein Image Restored

The total solar eclipse of 1919 provided astronomers an opportunity to test Albert Einstein's theory of general relativity, which had been published four years earlier. In the theory, Einstein determined that massive objects caused a distortion in space-time, and that the Sun was massive enough to bend the light from stars that passed close to it. Totality, when the solar disk is completely hidden by the Moon, is the only time when stars are not hidden by the Sun's glare in the daytime sky.

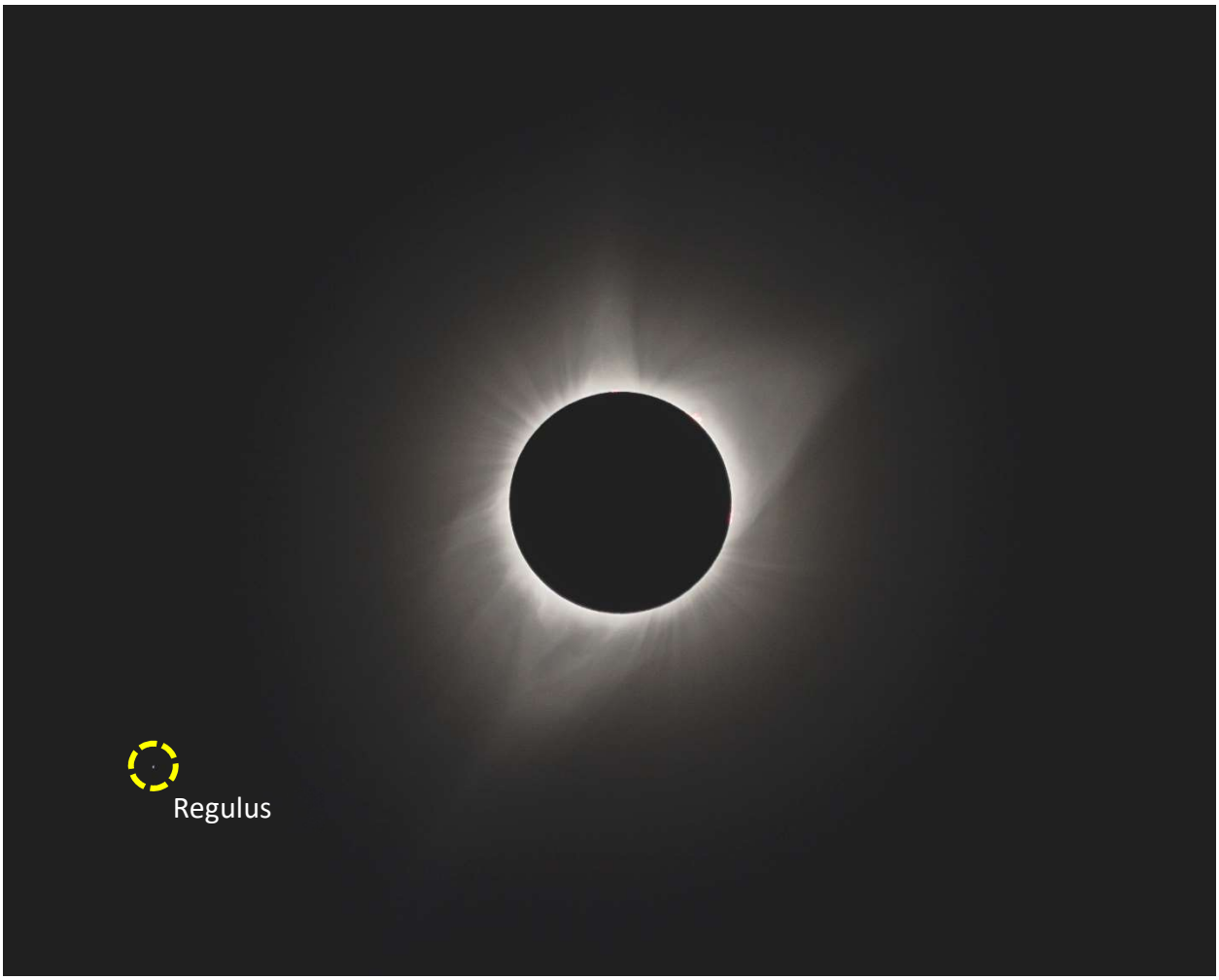
Two teams of British astronomers, headed by Frank Dyson and Arthur Eddington, sailed off to the Brazilian town of Sobral and the West African island of Príncipe, respectively, to record the eclipse and measure the gravitational deflection of starlight passing near the Sun. The slight offset in the positions of the stars recorded on the photographic plates during the eclipse (the Sun was passing through a bright cluster of stars in Taurus called the Hyades at the time), as compared with later images of the same star field without the Sun, were in close agreement with Einstein's predictions. The amount of the deflection was also greater for the stars closer to the Sun than those further away (by the amount predicted by general relativity and twice the amount predicted by Newtonian theory). Einstein became an instant celebrity and his theory gained world-wide recognition. However, despite Eddington's work, the Nobel committee refused to acknowledge his ground-breaking work, claiming it to be unproven (a Nobel prize was never awarded for relatively).



Restored photo from the 1919 eclipse (taken from Sobral, Brazil)
Credit: Petr Horálek (ESO Photo Ambassador, Institute of Physics in Opava) and Miloslav Druckmüller (Brno University of Technology)

An image captured of the Sun from Brazil on May 29, 1919 has now been restored, including the spectacular prominence that would have been visible to the eye. Scratches and specks of dust were manually removed from the image. It was then sharpened and colorized to create an image as natural as possible and as close to what would have been seen on that day.

There were also several attempts to recreate the Dyson-Eddington experiment during the 2017 total solar eclipse - with limited success, in part, because there were so few bright stars near the limb of the Sun. The bright star Regulus, in the constellation Leo, was visible in the sky during totality, but so far from the Sun's limb that the deflection was minimal. According to NASA, light from Regulus was deflected by only one-third of an arcsecond (an arcsecond is an angular measurement equal to 1/3600 of a degree).

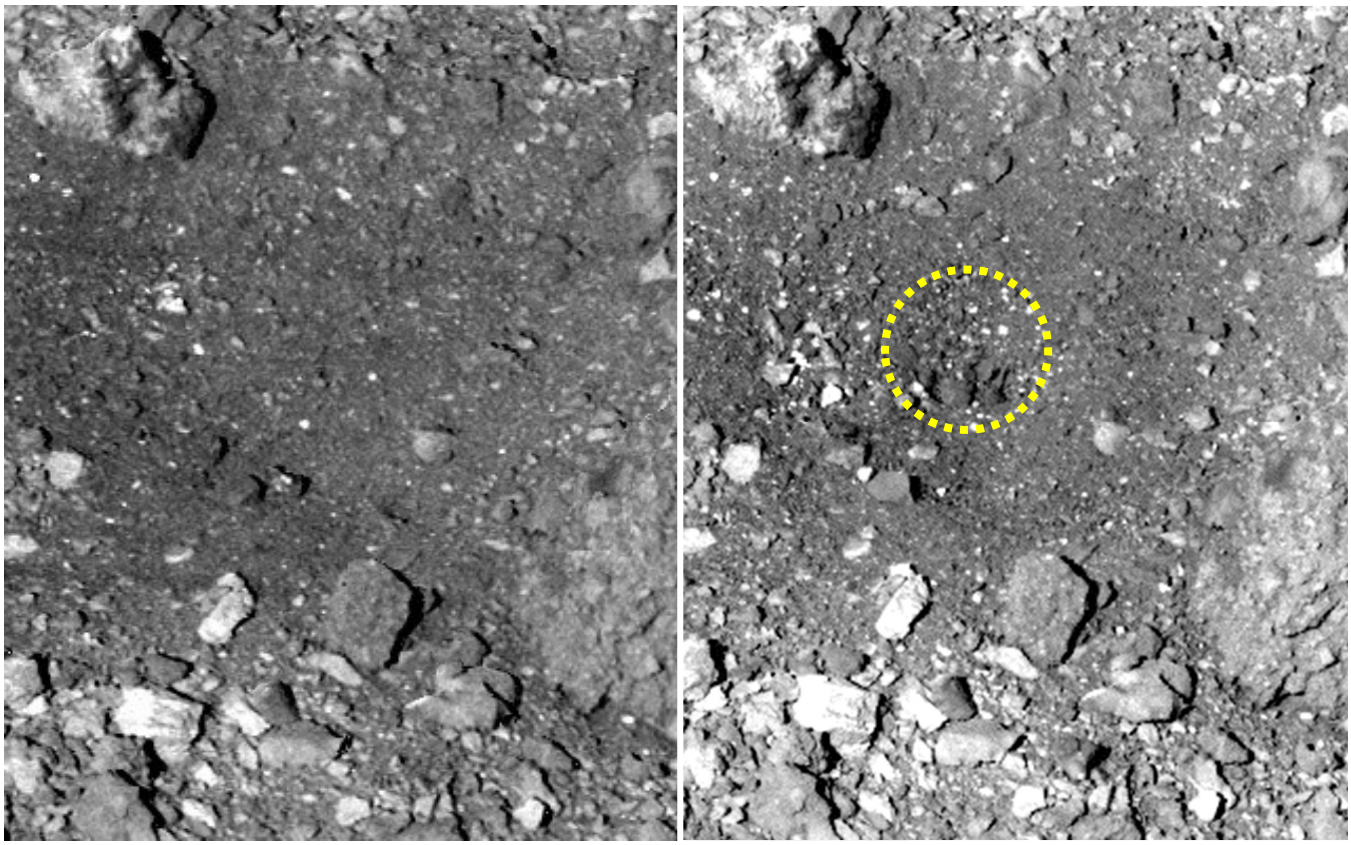


The star Regulus visible during the August 21, 2017 Total Solar Eclipse from Rexburg, Idaho
Photo: Bill Cloutier

On April 8, 2024, a total solar eclipse will be visible along a narrow path that will cross thirteen U.S. states, from Texas to Maine. In April, the Sun will be in the constellation Pisces and, similar to the 2017 eclipse, there will be relatively few bright stars near the solar disk. However, Venus and Jupiter will flank the Sun, with Saturn and Mars nearby, if you dare divert your gaze from the eclipsed Sun.

Farewell Tour

NASA's OSIRIS-REx spacecraft conducted its final flyby of the asteroid Bennu on April 7, coming within 2.3 miles (3.7 km) of the rocky surface – the closest since its sample collection run on October 20, 2020. One of the objectives of the flyby was to observe the sampling site for a final time and the disruption of the surface from the sampling activity.



Images of the Nightingale site on Bennu before (left) and after (right) contact by the OSIRIS-REx spacecraft's sampling system
Credits: NASA/Goddard/University of Arizona

The spacecraft's Touch-And-Go Sample Acquisition Mechanism consisted of a sampler head on an articulated arm. Once contact was made with the surface, a burst of nitrogen gas pushed the asteroid's regolith into the sampler head's chamber (the mission team confirmed that the system had collected more than enough material). The spacecraft spent 5-6 seconds in contact with Bennu's surface with the sampler head, appearing to crush the porous material underneath it, and sink into the rocky matrix (it appears that the sampling head sunk 1.6 feet (48.8 cm) into the asteroid's surface). After the sample was acquired, the spacecraft fired its thrusters to back away from Bennu.

The sampling activity created a small depression, with the nitrogen gas and the spacecraft's thrusters exposing rocks that had been covered with a fine-grain regolith and tossing others across the surface. OSIRIS-REx leaves for home on May 10. A two-year journey will conclude with a sample return capsule, carrying its Bennu cargo, entering the Earth's atmosphere and landing, under parachute, at the Utah Test and Training Range on September 24, 2023.

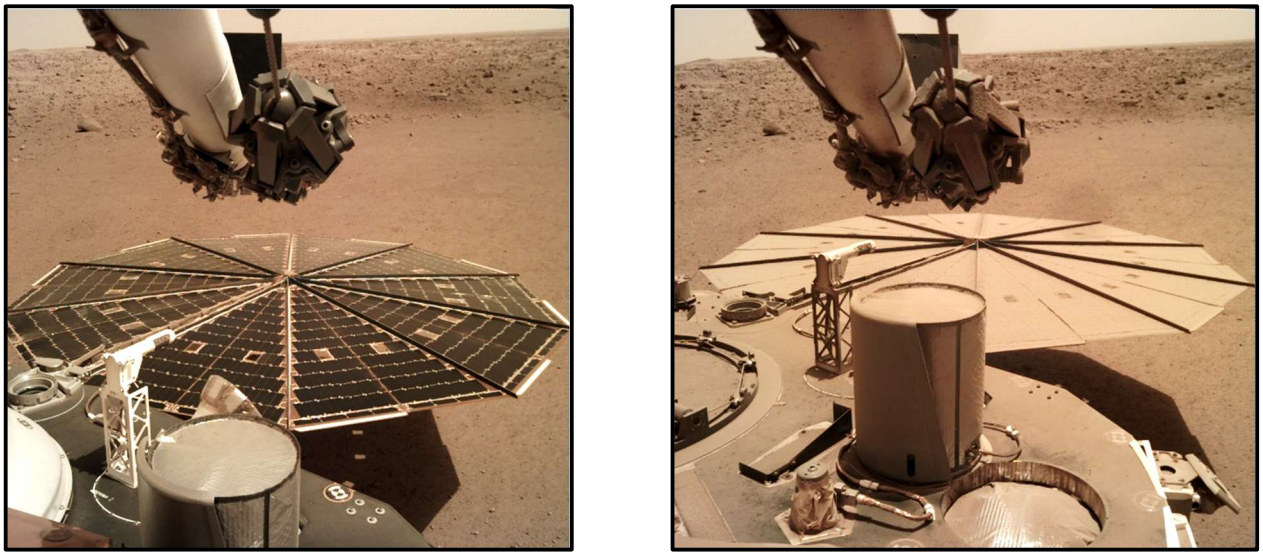
Wanted: Martian with a Squeegee

NASA's Mars InSight lander set down on Elysium Planitia on November 26, 2018. Power for the lander, its robotic arm, heaters, and its suite of instruments is provided by two large solar panels - deployed shortly after touchdown. InSight's two-year prime mission (which ended in November 2020) was extended another two years; however, power may be the limiting factor to operations.

Mars is a dusty environment and NASA expected a gradual loss of performance over time as dust accumulates on the flat solar panels. NASA's Mars Exploration Rovers were also solar powered. They far exceeded their original 90-day missions, in large part due to periodic dust-cleaning events from wind gusts and dust devils. While InSight has detected hundreds of passing dust devils, none have been close enough to clean the arrays. With winter approaching, the windy season coming to an end, and with Mars continuing to move further away from the Sun, the mission team is taking measures to conserve power until the situation improves (the solar arrays are currently producing only 27% of their dust-free capacity).

InSight is the first mission dedicated to investigating the interior of the planet. Its primary tool is an ultra-sensitive seismometer called SEIS that can detect surface movements smaller than a hydrogen atom. While the winds haven't been strong enough to remove the dust from the solar arrays, they do induce vibrations that obscure some marquakes. NASA has been using the scoop on the end of InSight's robotic arm since March to cover the cable connecting SEIS to the lander with soil in an effort to insulate it from the wind and extreme cold.

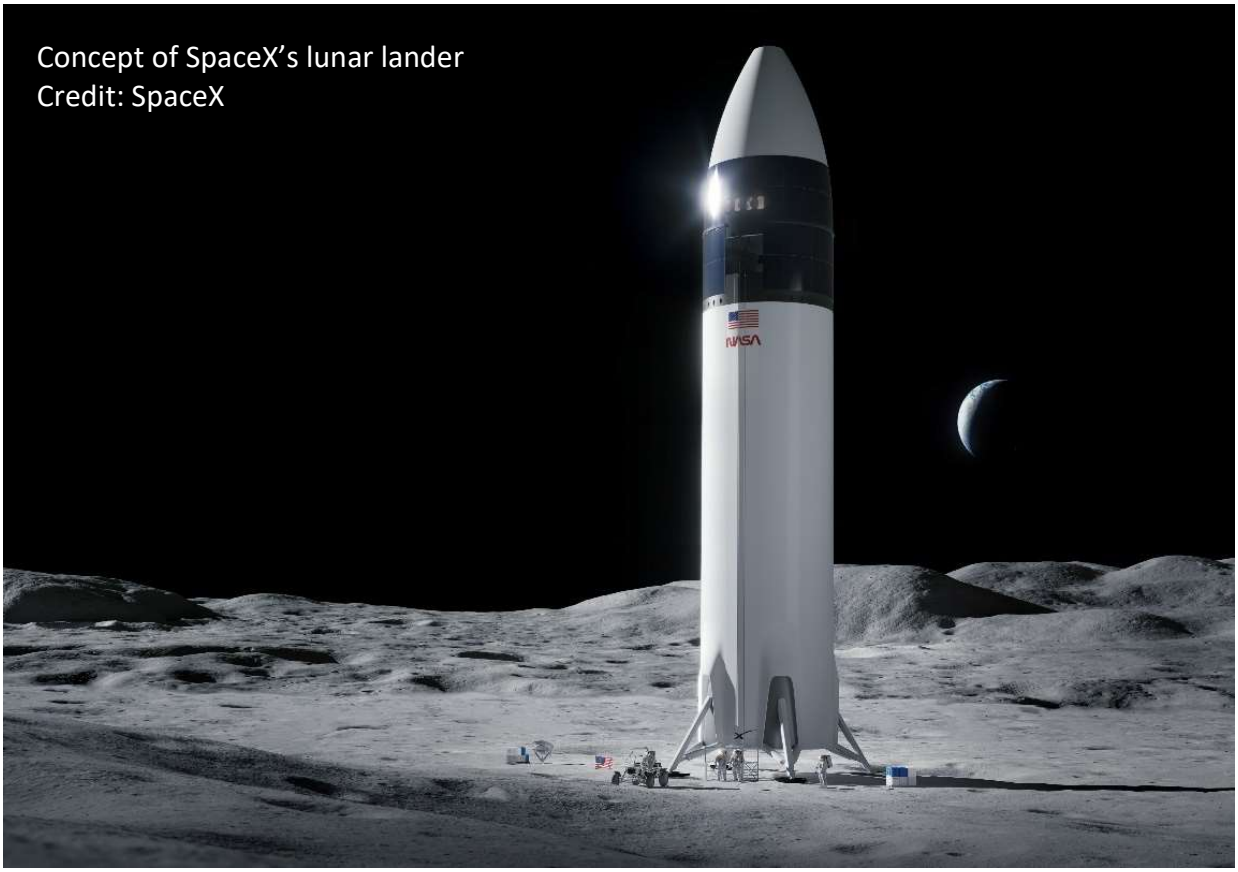
Over the next few months, instruments and sensors will be temporarily shut down and other energy-intensive activities curtailed so that the available power can be channeled to the lander's heaters and other critical operations. This may include SEIS, which has detected over 500 quakes to date, including two recent strong events that are believed to originate from a region called Cerberus Fossae – suggest that it may still be volcanically active.



One of the lander's two solar panels, each spanning 7 feet (2 meters), on Sol 10 (December 7, 2018) and on Sol 789 (February 14, 2021) showing the accumulation of power-killing dust
Image Credit: NASA/JPL-Caltech

SpaceX Moon Lander

NASA's Artemis program is intended to return astronauts to the Moon in preparation for the future exploration of Mars. The program, named for the sister of Apollo, includes the Space Launch System (SLS) rocket, the Orion spacecraft, which can accommodate up to four astronauts on deep space missions, an orbiting lunar outpost (called Gateway), and the human landing system, which will transport two astronauts from orbit, or the Gateway, down to the Moon's surface and back.



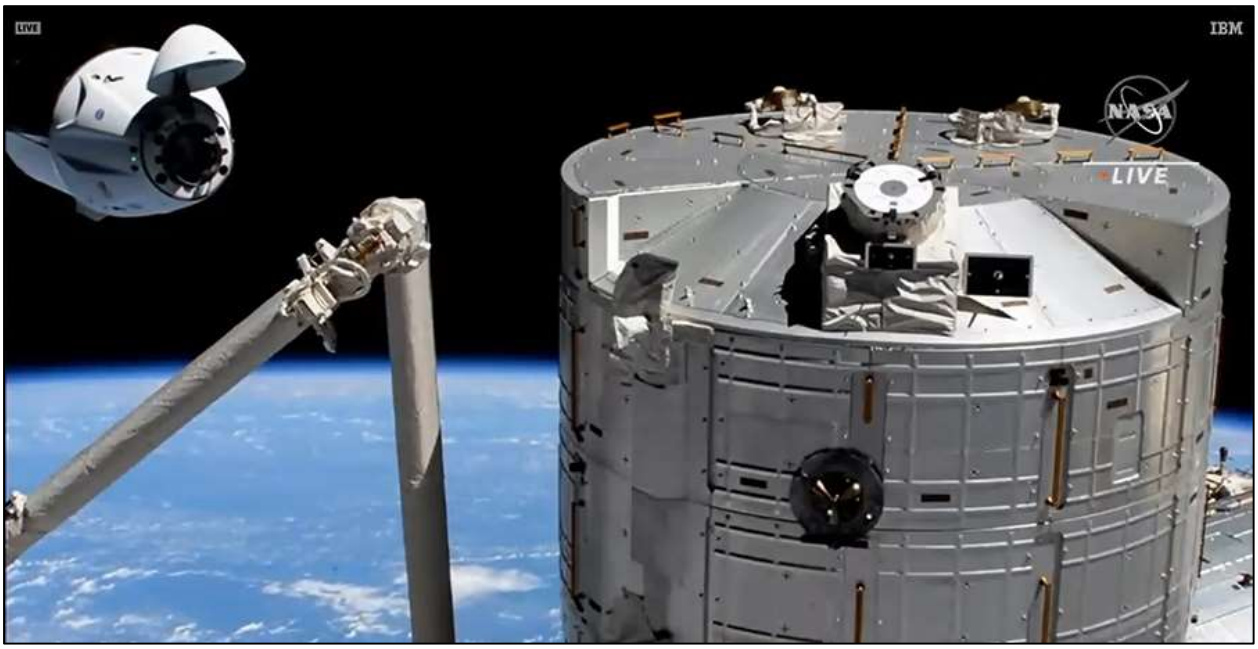
In 2020, NASA awarded contracts to three commercial companies (SpaceX, Blue Origin and Dynetics) for the development of an innovative lunar landing system. It was expected that the agency would select two of the companies to further develop their concepts, but on April 16, NASA announced that they would proceed with only one - SpaceX.

SpaceX's firm fixed price ($2.9 billion) to build the Artemis lunar lander (a variation on its Starship) is significantly lower than Blue Origin's, the second most highly rated offer. While the proposal evaluator found SpaceX's approach complex and relatively high-risk, for example, requiring in-flight spacecraft refueling, the company was able to allay such concerns by proposing to conduct critical activities in low-Earth orbit, prior to leaving for the Moon. If an issue develops, near-Earth operations provide SpaceX additional options not available in deep space and, if necessary, NASA would be able to delay its launch until resolution. SpaceX's proposal also provides NASA additional flexibility should issues arise with the SLS, with the Starship able to maintain station in lunar orbit for up to 100 days prior to a rendezvous with the Orion spacecraft.

The lunar version of the Starship is also able to accommodate large, bulky payloads that far exceed NASA's initial requirements, which could prove invaluable in the future as the mission evolves.

Dragon Swap

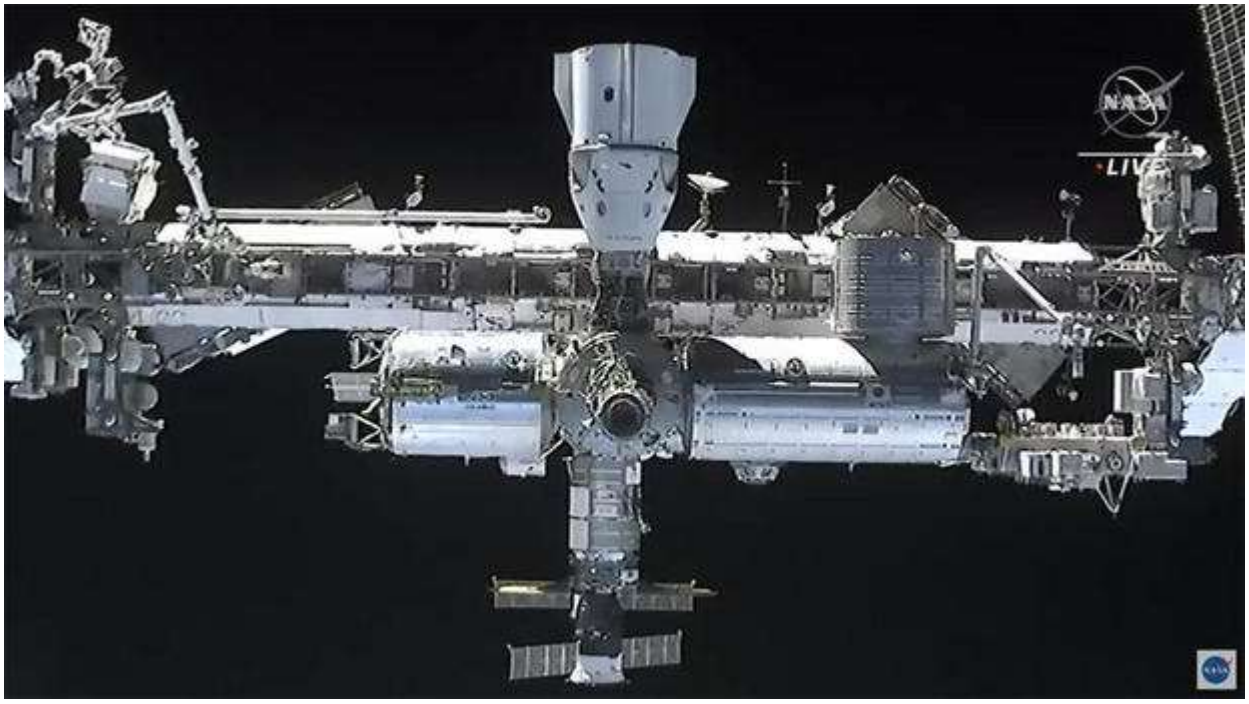
In the early morning of April 23, a SpaceX Falcon 9 rocket lifted off from Launch Complex 39A at the Kennedy Space Center in Florida. Aboard the Crew Dragon spacecraft were four astronauts destined for the International Space Station (ISS) - NASA astronauts Shane Kimbrough and Megan McArthur, Japan Aerospace Exploration Agency astronaut Akihiko Hoshide and European Space Agency astronaut Thomas Pesquet - for a six-month science mission. While this was the second crew rotation flight of a U.S. commercial spacecraft, the launch was also record setting for being the first time that a crew had been launched on a flight-proven booster (booster B1061 had been used to launch the Crew-1 mission in November 2020) and in a flight-proven spacecraft (Crew Dragon "Endeavour" flew the Demo-2 mission in May 2020, with NASA astronauts Doug Hurley and Bob Behnken). The booster was recovered after separating from the second stage, landing on a barge in the Atlantic Ocean.



Crew Dragon Endeavour on approach, with the Kibo laboratory module in the foreground
Credit: NASA TV

Megan McArthur, the pilot of the Crew Dragon spacecraft, and second-in-command for the mission, sat in the same seat that her husband, Bob Behnken, occupied in his ride to the ISS last year on Endeavour (the first Crew Dragon to visit the ISS twice). McArthur was the mission specialist on STS-125 in 2009 when the space shuttle Atlantis visited the Hubble Space Telescope for the final servicing mission - but this is her first visit to the ISS.

With the arrival of Endeavour, the Crew Dragon joined another Space X spacecraft, the Crew Dragon Resilience which had arrived last November. Resilience departed the station in early May (after several weather delays at the landing zone), along with astronauts Michael Hopkins, Victor Glover, Shannon Walker and Japanese astronaut Soichi Noguchi, but for a time there were 11 astronauts on station, requiring several of the crew to sleep in their spacecraft. Resilience returned to Earth, splashing down in the Gulf of Mexico off the coast of Florida under four large, red and white parachutes.



Docking approach captured by Endeavour's nose camera, including a view of the Crew Dragon Resilience docked at the top-side port of the Harmony module and only a few feet away from the forward-facing port where Endeavour would park.
Credit: NASA TV

The 11 astronauts and cosmonauts aboard the ISS during the crew rotation period in late April - comprised of the personnel from Crew-1, Crew-2 and Expedition 64
Image credit: NASA TV

Harnessing the Atom for Spaceflight

Conceptual nuclear-powered spacecraft
Credit: DARPA

The Defense Advanced Research Projects Agency intends to demonstrate nuclear thermal propulsion (NTP) technology for space travel. It started the DRACO program in 2020 (DRACO is short for demonstration rocket for agile cislunar operations) with the goal of launching a spacecraft driven by nuclear thermal propulsion above low-Earth orbit in 2025.

DARPA had selected General Atomics, based in San Diego, California, to develop the nuclear reactor (a $22 million contract). The reactor, fueled by fissionable uranium, would heat a propellant (most likely hydrogen), which would be discharged through an engine nozzle to produce thrust. In theory, NTP can achieve high thrust-to-weights similar to chemical propulsion, but with the high propellent efficiency of electric systems.

DARPA believes that NTP can transform space travel, allowing spacecraft to travel huge distances quickly. If successful, transit times to Mars could be cut in half (mitigating some of the challenges of deep space travel, including the effects of weightlessness on the human body and the biological damage from exposure to solar and galactic radiation). The Pentagon also has expressed an interest in spacecraft that can be quickly repositioned in space.

In April, DARPA selected two contractors, Blue Origin and Lockheed Martin, to develop competing spacecraft concepts for the demonstration. DRACO would be conducted in Earth orbit and eventually in cislunar space (the space between the Earth and Moon). The first phase of the program is expected to last 18 month and will focus on reactor development and propulsion systems. Blue Origin and Lockheed Martin will be working, independently, in the second phase to develop conceptual spacecrafts that would incorporate General Atomics' NTP design.

DARPA is not the only agency with an interest in NTP. A National Academies committee recently issued a report that concluded that "NASA needs to pursue 'aggressive' development of space nuclear propulsion technologies if the agency wants to use them for human missions to Mars in the next two decades."

Apollo 10

Apollo 10 was the second mission to orbit the Moon (Apollo 8 being the first) and the first lunar mission to include the Lunar Module (LM). The Saturn V rocket, carrying the Command Module (CM) named Charlie Brown and LM, named Snoopy, was launched on May 18, 1969.

The Apollo 10 Saturn V and the mobile launch platform atop the crawler-transporter

Credit: NASA

Astronauts Thomas Stafford and Eugene Cernan flew the LM to within 47,000 feet (14,326 meters) of the lunar surface. The LM made two passes over the designated Apollo 11 landing site before jettisoning of the LM's descent stage (in preparation for the rendezvous with the CM). At that time, the ascent stage began to wildly gyrate and for three harrowing minutes, the spacecraft went into a near-fatal roll before Stafford could gain manual control. The cause was eventually traced to a switch being in the wrong position.

Public Astronomy

Eighty-five years ago, on May 14, 1935, the Griffith Observatory opened to the public and its ownership transferred to the City of Los Angeles. Located on the southern slope of Mount Hollywood in Griffith Park, the public facility is operated by the city's Department of Recreation and Parks, and has welcomed over 76 million visitors since opening.

A public observatory was the brainchild of Griffith J. Griffith, a Welsh immigrant who made his fortune in Mexican silver mines and California real estate. In 1896, he purchased and donated 3,015 acres to the city for a public park after visiting grand open spaces in Europe. In 1912, after a visit to the Mount Wilson observatory, Griffith offered the city $100,000 for a public observatory to be built on Mount Hollywood in Griffith Park. Griffith was quoted as saying "Man's sense of values ought to be revised. If all mankind could look through that telescope, it would change the world!"

Unfortunately, Griffith would not live to see his vision realized. Mired in political debate, work on the observatory didn't begin until 1933. However, guided by leading astronomers and scientists of the day, including astronomer George Ellery Hale, physicists Edward Kurth and Rudolph Langer, Adler Planetarium Director Philip Fox and Russell Porter, leader of the amateur telescope making movement, an observatory was constructed and dedicated two years later. The facility also included a planetarium. The planetarium was only the third of its kind in the United States; the technology was not even invented until four years after Griffith's death.

The Griffith Observatory is visible from many parts of Los Angeles, being located at an elevation of 1,134 feet above sea level. It is one of the most popular attractions in Southern California.

Space Shuttle History

The space shuttle Endeavour first arrived at the Kennedy Space Center on May 7, 1991 as a replacement for the lost Challenger. It was built out of spare parts from the construction of the Atlantis orbiter. Endeavour was first launched (STS-49) a year later on May 7, 1992. The orbiter's name was selected through a national competition among students and was named after the ship commanded by British explorer James Cook in his exploration of the South Pacific in 1768-71. Cook, among other accomplishments, observed the transit of the Sun by Venus from Tahiti in June 1769.

Endeavour flew its 25th and final mission (STS-134) in May 2011 (the next to last shuttle flight). Commander Mark Kelly was the last astronaut to disembark from the shuttle at the conclusion of the mission. In September 2012, the shuttle was flown to Los Angeles on top of a Boeing 747 for permanent display at the California Science Center. Endeavour is currently in temporary storage at the museum and will be displayed in a launch configuration (vertical) once construction of a new exhibition center is complete.

In May 2015, the Science Center announced that they had acquired the only flight-qualified external tank in existence. The tank had been built in 2000 for the Columbia shuttle but never flew (it was replaced by a lighter version before it was assigned to a flight). The External Tank (ET-94) is 28 feet in diameter, 154 feet long and weighs approximately 65,000 pounds.

The external tank left NASA's Michoud Assembly Facility in Louisiana for California on April 12, 2016. Traveling by barge, the tank passed through the Panama Canal and arrived in Marina del

Rey in late May. The tank was moved through the streets of Los Angeles to the Science Center following the route previously taken by Endeavour.

The Science Center has also acquired a pair of flight-worthy solid rocket boosters for the display. The 149-foot-tall (45 meter) solid rocket boosters were donated by Orbital ATK and NASA. The refurbished tank will be lifted into a vertical configuration to form the structural support for the Endeavour orbiter and the twin solid rockets for display in Samuel Oschin Air and Space Center, a 200,000 square foot exhibition center being added to the Science Center's main building.

May History

Vehicle Assembly Building
Photo: Bill Cloutier

On May 25, 1961, President Kennedy, in an address before a joint session of Congress, set forth a challenge to the American people: "I believe this nation should commit itself, before this decade is out, to landing a man on the Moon and returning him safely to the earth." With what started out as an attempt to reverse the political setbacks in Laos, the Congo, the Bay of Pigs in Cuba, and as a response to the first flight into space by cosmonaut Yuri Gagarin, Kennedy's speech set the gears of a technological revolution into motion. The post-Sputnik world of the 1960's would see two great nations compete to control the "high ground," the new frontier in the Cold War.

Lost in the political posturing and often overlooked is that, in less than 10 years, on May 20, 1969, the 456-foot-tall doors on the Vehicle Assembly Building at the Kennedy Space Center opened to reveal AS506, the official designation of the Saturn V rocket that would carry Apollo 11 to the moon. More than 20,000 private firms and hundreds of thousands of workers participated in this program, for a fraction of the cost of the Vietnam War. Not only did the United States reach the Moon, it built a national infrastructure of technology, manufacturing and education that has not been rivaled.

Final Servicing Mission

On May 11, 2009, the space shuttle Atlantis lifted off from Pad 29A at the Kennedy Space Center for its first visit to the Hubble Space Telescope and the telescope's last servicing mission. Atlantis ferried two new instruments to the telescope - the Cosmic Origins Spectrograph and the Wide Field Camera 3. The Atlantis crew repaired the Space Telescope Imaging Spectrograph (STIS) and the Advanced Camera for Surveys (ACS), replaced a Fine Guidance Sensor, six gyroscopes, and batteries. A new science computer was installed along with new insulation on three electronic bays. A soft-capture mechanism was added to the telescope's base to facilitate its de-orbiting at its end of operational life.

The space shuttle Atlantis, on Pad 39A at the Kennedy Space Center, being readied for the final Hubble Space Telescope servicing mission (STS-125), May 2009

Photo: Bill Cloutier

The Atlantis crew included three astronauts that had visited Hubble on previous repair missions - Scott Altman (STS-109), John Grunsfeld, (STS-103 and STS-109) and Mike Massimino (STS-109).

Construction began on NASA's fourth space shuttle in 1980 and, with lessons-learned from the construction and testing of the Enterprise, Columbia and Challenger, was completed with half the effort spent on the Columbia. Atlantis is named for a two-masted sailing ship that operated for the Woods Hole Oceanographic Institute in Massachusetts from 1930 to 1966. The shuttle was delivered to the Kennedy Space Center on April 9, 1985. Six months later, she carried a classified payload into orbit for the Department of Defense (STS-51J). Among Atlantis' many accomplishments were: flying the first mission to the Russian space station (Mir), providing on-orbit launch capabilities for the Magellan (Venus) and Galileo (Jupiter) planetary probes as well as the Compton Gamma Ray Observatory, delivering the U.S. laboratory module Destiny, Joint Airlock Quest and multiple sections of the International Space Station's Integrated Truss structure.

May Showers

The *Eta Aquarids* meteor shower peaks in the early mornings of the 5th and 6th. The dust producing the shooting stars is from *Comet Halley*. As with all meteor showers, the Aquarids are named for the constellation (Aquarius) from which they appear to radiate. Typically, you can expect to see up to 20 meteors per hour. A late rising, waning crescent moon should not interfere with viewing the shower this year.

Sunrise and Sunset (from New Milford, CT)

	Sunrise	Sunset
May 1st (EDT)	05:50	19:49
May 15th	05:34	20:02
May 31st	05:22	20:17

May Nights

For those who do their stargazing early in the evening, a myriad of spectacular objects appear out of the twilight, winking into view as the Earth turns away from the Sun. Leo dominates the southwestern sky with its reverse question mark arrangement of stars, punctuated by the star Regulus, forming the front of the lion, and a triangular arrangement of stars forming the back or tail of the creature. To the west of Leo is an open star cluster called the Beehive (M44) in the constellation Cancer. On a dark night it can be seen with the naked eye. East of Leo, towards the constellation Boötes is the globular cluster M3. Boötes is easily identified by its bright star Arcturus. Follow the arc in the handle of the Big Dipper to find Arcturus, at the base of the kite-shaped constellation. M3 is located further away than the center of our galaxy, the Milky Way, and is one of the many outstanding globular clusters that will grace the late spring and summer skies.

Astronomical and Historical Events

1st Apollo Asteroid 2019 VT3 near-Earth flyby (0.031 AU)
1st Kuiper Belt Object *184314 Mbabamwanawaresa* at Opposition (39.563 AU)

Astronomical and Historical Events (continued)

1st History: Goddard Space Flight Center established (1959)
1st History: discovery of Saturn's moon *Daphnis* by the Cassini spacecraft (2005)
1st History: discovery of the Mars meteorite *Dar al Gani 476* (1998)
1st History: discovery of Neptune's moon *Nereid* by Gerard Kuiper (1949)
2nd Atira Asteroid 2013 JX28 closest approach to Earth (0.131 AU)
2nd Atira Asteroid 2020 HA10 closest approach to Earth (1.616 AU)
2nd History: discovery of the first binary star (Xi Ursae Majoris) by William Herschel (1780)
3rd Last Quarter Moon
4th Apollo Asteroid 2021 AF8 near-Earth flyby (0.023 AU)
4th History: launch of Lunar Orbiter 4 for photographic evaluation of Apollo and Surveyor landing sites (1967)
4th History: launch of the AQUA satellite to study precipitation, evaporation, and the cycling of Earth's water (2002)
4th History: launch of the Magellan/Venus radar mapping spacecraft and attached Inertial Upper Stage from the space shuttle Atlantis (STS-30) (1989)
5th *Eta Aquarids* meteor shower peak (best viewing: early morning on the 5th and 6th)
5th Apollo Asteroid 2018 JP near-Earth flyby (0.027 AU)
5th Amor Asteroid *5626 Melissabrucke*r closest approach to Earth (2.185 AU)
5th History: launch of NASA's InSight spacecraft (Mars lander) from the Vandenberg Air Force Base, California (2018)
5th History: launch of Freedom 7 and astronaut Alan Shepard aboard a Mercury-Redstone rocket, first American in space (1961)
6th Apollo Asteroid 2021 AE4 near-Earth flyby (0.048 AU)
6th Kuiper Belt Object *42355 Typhon* at Opposition (22.436 AU)
6th History: groundbreaking for the John J. McCarthy Observatory, a world-class observatory in New Milford, CT., with a mission to promote science literacy (2000)
8th **Second Saturday Stars - Open House at McCarthy Observatory**
8th Centaur Object *471143 Dziewanna* at Opposition (34.452 AU)
9th History: launch of MUSES-C (Hayabusa), Japanese sample return mission to asteroid *Itokawa* (2003)
9th History: first Earth-based laser aimed at the Moon: crater Albategnius (1962)
9th History: launch of first production model of the Project Mercury capsule from Wallops Island, Virginia to test the escape system (1960)
10th Apollo Asteroid *3752 Camillo* closest approach to Earth (1.695 AU)
10th OSIRIS-REx departs asteroid Bennu for Earth
10th History: President Truman signs Public Law 507, creating the National Science Foundation (1950)
10th History: Estherville Meteorite Shower: a 455-pound meteorite fell to earth in Emmet County, just north of Estherville, Iowa, where it buried itself 15 feet in the ground - largest meteorite known to have fallen in North America (1879)
11th New Moon
11th Moon at apogee (furthest distance from Earth)
11th Amor Asteroid *2202 Pele* closest approach to Earth (2.073 AU)
11th Centaur Object 144908 (2004 YH32) at Opposition (10.596 AU)
11th Kuiper Belt Object 2010 FX86 at Opposition (44.988 AU)

Astronomical and Historical Events (continued)

11th History: launch of the space shuttle Atlantis (STS-125), final Hubble Space Telescope servicing mission (2009)
12th History: first planetarium (Adler Planetarium in Chicago) opens in United States (1930)
13th Amor Asteroid *4957 Brucemurray* closest approach to Earth (0.977 AU)
13th History: launch of first Project Bumper rocket from White Sands, NM; the two stage rocket was a combination of a German V-2 and American WAC Corporal rocket (1948)
14th Apollo Asteroid 2015 KJ19 near-Earth flyby (0.039 AU)
14th Kuiper Belt Object *53311 Deucalion* at Opposition (41.598 AU)
14th History: Griffith Observatory, one of the first institutions in the U.S. dedicated to public science, opens in Los Angeles (1935)
14th History: launch of the Herschel infrared telescope and the Planck microwave observatory (2009)
14th History: launch of Skylab, the United States' first space station (1973)
14th History: the American Interplanetary Society (later renamed the American Rocket Society) launches its first liquid fueled (liquid oxygen and gasoline) rocket from Staten Island, N.Y. (1933)
14th History: German Society for Space Travel (Verein für Raumschiffahrt or VfR) launches the Repulsor-1, a liquid fueled (liquid oxygen and gasoline) rocket (1931)
14th History: Orgueil meteorite shower: large carbonaceous chondrite that disintegrated and fell in fragments near the French town of Orgueil; presence of organics renewed the debate on spontaneous generation as the origin of life; fragments analyzed by the French chemist Louise Pasteur for indigenous microorganisms (1864)
15th Kuiper Belt Object 65407 (2002 RP120) at Opposition (33.238 AU)
15th Kuiper Belt Object 90568 (2004 GV9) at Opposition (38.714 AU)
15th History: discovery of Pluto's moons *Nix* and *Hydra* by Hal Weaver, et al's (2005)
15th History: sixth docking of a space shuttle (Atlantis) with Russian space station Mir (1997)
15th History: launch of Faith 7 and astronaut Gordon Cooper aboard a Mercury-Atlas rocket, final Mercury mission (1963)
15th History: Soviet Union launches Sputnik IV containing a self-sustaining biological cabin and dummy astronaut (1960)
16th Amor Asteroid *452307 Manawydan* closest approach to Earth (1.138 AU)
16th Centaur Object *65489 Ceto* at Opposition (40.359 AU)
16th History: launch of the space shuttle Endeavor to the International Space Station on its final mission (2011)
16th History: Soviet spacecraft Venera 5 returns 53 minutes of data while descending by parachute through the atmosphere of Venus and before impacting the surface (1969)
17th Mercury at its Greatest Eastern Elongation (22°) – furthest distance from the Sun in the evening sky
17th History: Soviet spacecraft Venera 6 returns 51 minutes of data while descending by parachute through the atmosphere of Venus and before impacting the surface (1969)
17th History: discovery of Jupiter's cloud belts by Italian Jesuit, astronomer, and physicist Niccolo Zucchi (1630)
18th Apollo Asteroid 478784 (2012 UV136) near-Earth flyby (0.040 AU)
18th History: launch of Apollo 10 with astronauts John Young, Tom Stafford and Gene Cernan; the lunar module Snoopy was flown within 50,000 feet of the lunar surface while the command module Charlie Brown orbited the Moon (1969)

Astronomical and Historical Events (continued)

19th First Quarter Moon
19th Atira Asteroid 2018 JB3 closest approach to Earth (1.159 AU)
19th History: launch of the Mars 2 orbiter/lander (which subsequently crashed) (1971)
19th History: launch of the first Army Hermes A-1 rocket from White Sands, NM (1950)
19th History: oldest recorded meteorite fall, a 472-gram, ordinary chondrite, falls in Nogata, Japan (861 AD)
20th Atira Asteroid 418265 (2008 EA32) closest approach to Earth (0.597 AU)
20th Atira Asteroid 434326 (2004 JG6) closest approach to Earth (1.091 AU)
20th Kuiper Belt Object 2015 KH162 at Opposition (59.532 AU)
20th History: launch of the Japanese Venus Climate Orbiter Akatsuki or Planet-C spacecraft and the Ikaros solar sail (2010)
20th History: launch of the Pioneer Venus 1 spacecraft (1978)
21st Amor Asteroid *3553 Mera* closest approach to Earth (0.863 AU)
21st Kuiper Belt Object 2015 BP519 at Opposition (52.354 AU)
22nd History: launch of the GRACE Follow-On spacecraft from the Vandenberg Air Force Base, California. The tandem satellites tracking Earth's water movement and changes in sea level.
22nd History: launch (and recovery) of monkeys Patricia and Mike on an Aerobee rocket, reaching a record altitude of 30 miles (1952)
24th Atira Asteroid 2019 LF6 closest approach to Earth (0.890 AU)
24th History: discovery of Neptune's moon Larissa by Stephen Synnott, Harold Reitsema, and David Tholen (1981)
24th History: launch of Aurora 7 and astronaut Scott Carpenter aboard a Mercury-Atlas rocket; second American to orbit Earth (1962)
24th History: launch of Midas 2; first Experimental Infrared Surveillance Satellite (1960)
24th History: Russian civil engineer Ivan Yarkovsky born. Proposed idea that heat radiated from rotating bodies, such as asteroids, would generate a small force which over time could change the orbit (1844)
25th Moon at perigee (closest distance from Earth)
25th Apollo Asteroid 478784 (2012 UV136) near-Earth flyby (0.010 AU)
25th Amor Asteroid *2061 Anza* closest approach to Earth (1.618 AU)
25th History: Phoenix spacecraft lands in the Martian arctic (2008)
25th History: launch of first Skylab crew; astronauts Pete Conrad, Paul Weitz and Joseph Kerwin (1973)
25th History: President John F. Kennedy's Moon goal speech to Congress (1961)
25th History: science fiction writer and futurist Arthur C. Clark proposes communication satellites in geosynchronous orbit (1945)
25th History: first recorded perihelion passage of comet Halley by Chinese astronomers (240 BC)
26th Full Moon (Full Flower Moon)
26th History: launch of the first "Navaho Missile," a pilotless aircraft consisting of a missile and a booster; program goal was to determine the feasibility of an intercontinental missile (1948)
28th Mercury Passes 0.4° from Venus, low in the northwest sky shortly after sunset
28th Apollo Asteroid *101955 Bennu* closest approach to Earth (1.907 AU)

Astronomical and Historical Events (continued)

28th History: launch of Mars 3 (USSR) lander and rover; lander became the first spacecraft to attain soft landing on Mars, although transmissions ceased after 15 seconds (1971)
28th History: launch of an Army Jupiter missile carrying two primates (Able and Baker) to an altitude of 300 miles; monkeys survived the flight (1959)
28th History: Frank Drake born - radio astronomer devised the "Drake Equation" as an attempt to estimate the number of worlds in our galaxy that might harbor intelligent life (1930)
29th Binary Apollo Asteroid *69230 Hermes* closest approach to Earth (0.947 AU)
29th Apollo Asteroid *11311 Peleus* closest approach to Earth (1.475 AU)
29th Amor Asteroid *16064 Davidharvey* closest approach to Earth (3.429 AU)
29th History: Solar Eclipse observations (specifically, positions of stars in the vicinity of the Sun) used to confirm Einstein's General Theory of Relativity (1919)
29th History: launch of Luna 22 (USSR), lunar orbiter mission that included imaging as well as studying the Moon's magnetic field, the composition of lunar surface rocks, and the gravitational field (1974)
29th History: measurements during solar eclipse agree with predictions based on Einstein's General Relativity theory (1919)
30th History: launch of SpaceX's Crew Dragon with astronauts Doug Hurley and Bob Behnken to the International Space Station from the Kennedy Space Center. Designated Demo 2, it was the first launch of the spacecraft with astronauts aboard. (2020)
30th History: launch of Mariner 9, Mars orbiter and first artificial satellite of Mars; mapped Martian surface and imaged moons *Phobos* and *Deimos* (1971)
30th History: launch of Surveyor 1, Moon lander; transmitted over 11,000 images from Oceanus Procellarum (1966)
31st Apollo Asteroid *66391 Moshup* closest approach to Earth (0.296 AU)
31st Atira Asteroid 2010 XB11 closest approach to Earth (0.694 AU)
31st Plutino 469987 (2006 HJ123) at Opposition (32.158 AU)
31st History: European Space Agency's birthday (1975)

Commonly Used Terms

- Apollo: a group of near-Earth asteroids whose orbits also cross Earth's orbit; Apollo asteroids spend most of their time outside Earth orbit.
- Aten: a group of near-Earth asteroids whose orbits also cross Earth's orbit, but unlike Apollos, Atens spend most of their time inside Earth orbit.
- Atira: a group of near-Earth asteroids whose orbits are entirely within Earth's orbit
- Centaur: icy planetesimals with characteristics of both asteroids and comets
- Kuiper Belt: region of the solar system beyond the orbit of Neptune (30 AUs to 50 AUs) with a vast population of small bodies orbiting the Sun
- Opposition: celestial bodies on opposite sides of the sky, typically as viewed from Earth

- Plutino: an asteroid-sized body that orbits the Sun in a 2:3 resonance with Neptune
- Trojan: asteroids orbiting in the 4th and 5th Lagrange points (leading and trailing) of major planets in the Solar System

References on Distances

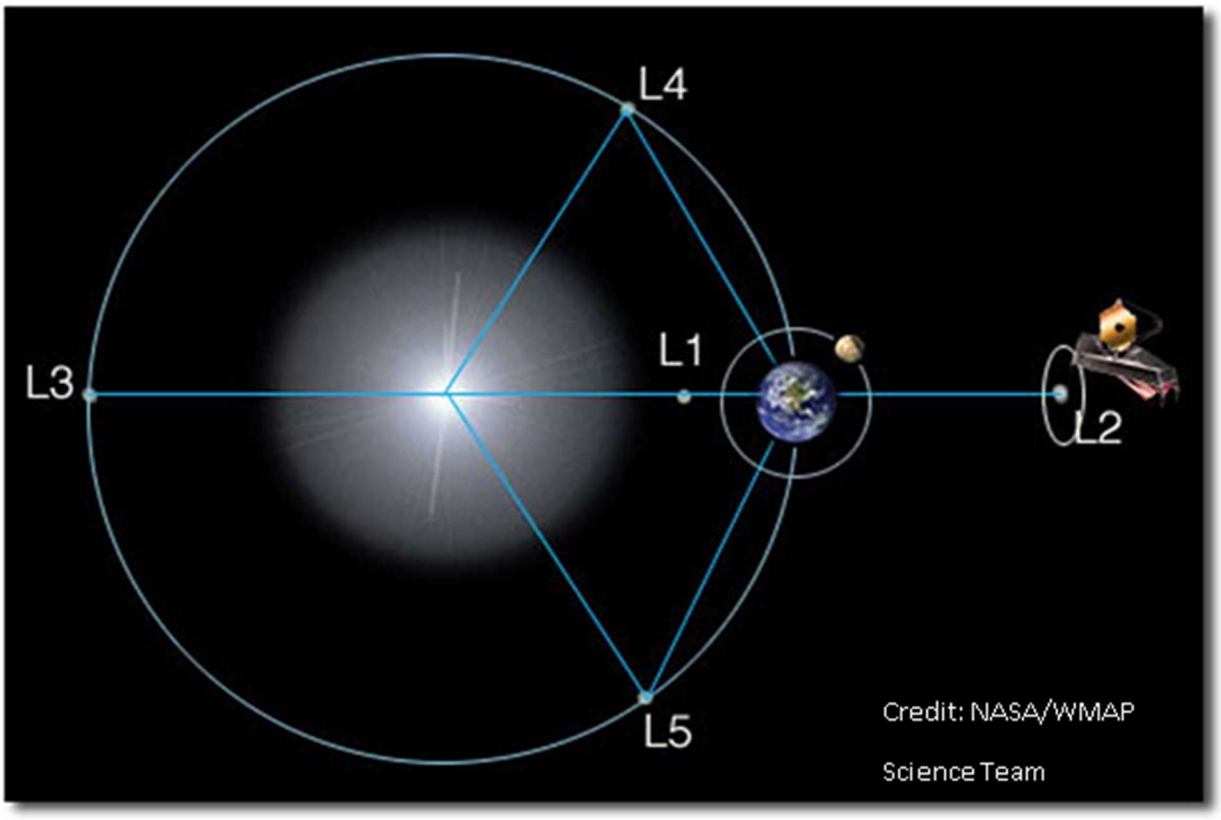
- the apparent width of the Moon (and Sun) is approximately one-half a degree (½°), less than the width of your little finger at arm's length which covers approximately one degree (1°); three fingers span approximately five degrees (5°)
- 1 astronomical unit (AU) is the distance from the Sun to the Earth or approximately 93 million miles

Solar Activity

For the latest on what's happening on the Sun and the current forecast for flares and aurora, check out www.spaceweather.com.

Lagrange Points

Five locations discovered by mathematician Joseph Lagrange where the gravitational forces of the Sun and Earth (or other large body) and the orbital motion of the spacecraft are balanced, allowing the spacecraft to hover or orbit around the point with minimal expenditure of energy. The L2 point (and future location of the James Webb telescope) is located 1.5 million kilometers beyond the Earth (as viewed from the Sun).



International Space Station and Artificial Satellites

Visit www.heavens-above.com for the times of visibility and detailed star charts for viewing the International Space Station and bright artificial satellites.

NASA's Global Climate Change Resource

Vital Signs of the Planet: https://climate.nasa.gov/

Mars 2020 Mission

The latest information on the Perseverance rover and the Ingenuity helicopter can be found at https://mars.nasa.gov/mars2020/ and https://mars.nasa.gov/technology/helicopter/

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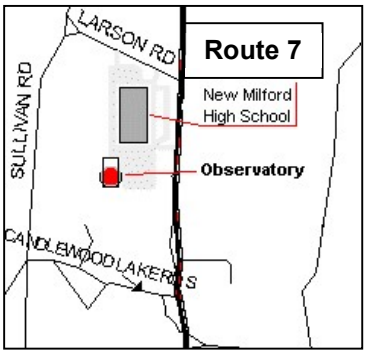

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