Galactic Observer

John J. McCarthy Observatory

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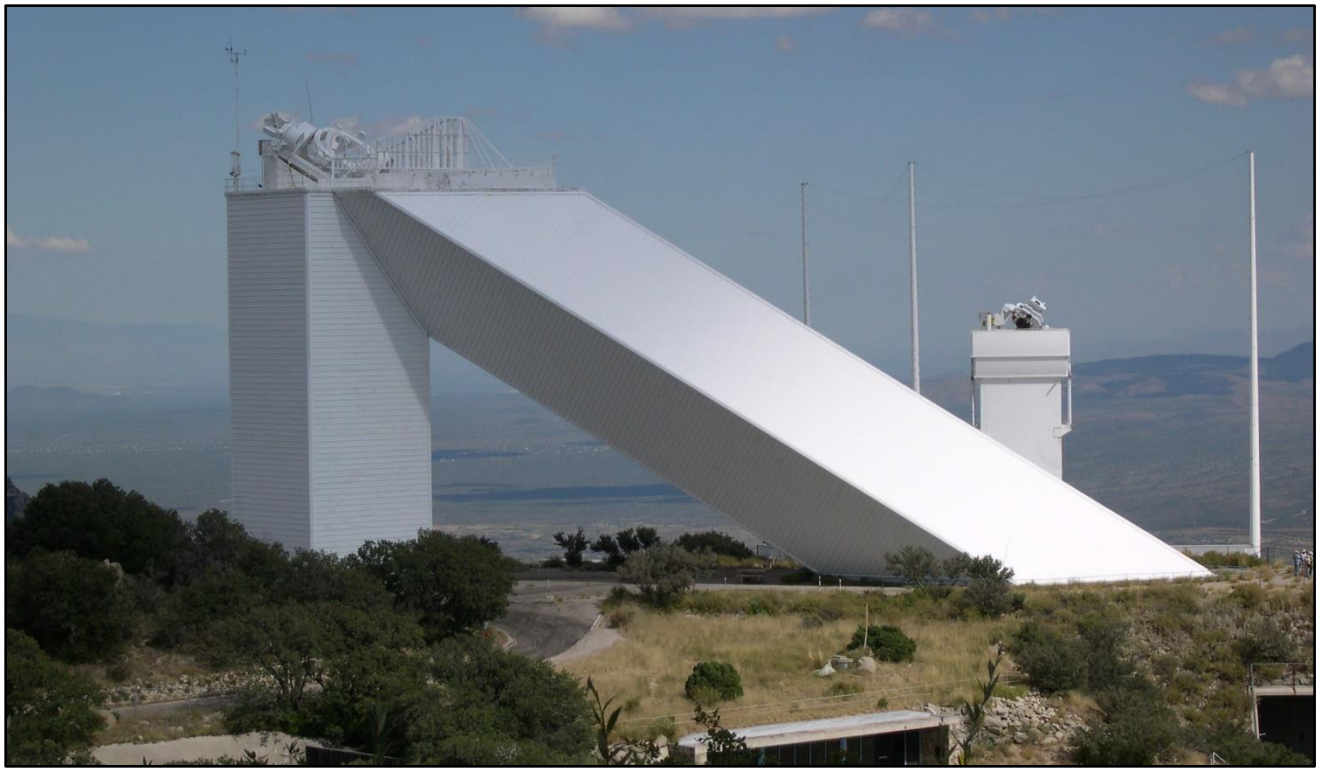
Image Credit: NASA/JPL-Caltech

"Under a Martian Sky"

The above photo, captured from video recorded by a camera on the Mars 2020 spacecraft on February 18, shows the view from under the fully inflated, 70.5-foot diameter (21.5-meter) parachute. The polyester and nylon parachute, pressure packed into a small canister (to a density of oak), was shot out of the backshell with a mortar system at 100 mph (160 kph), while the spacecraft was traveling at almost 1,000 mph (1,600 kph) - inflating in less than a second.

Hidden in the red and white pattern is a phrase and a set of coordinates. If you would like to try deciphering the code, some helpful hits are available on page 7.

March Astronomy Calendar and Space Exploration Almanac



Kitt Peak National Observatory's mountain top, with the 4-meter (158 inch) Mayall telescope at the summit (top) and the decommissioned McMath-Pierce Solar Telescope (bottom). The facility is located on a peak in the Sonoran Desert, southwest of Tucson, Arizona, and was dedicated 61 years ago on March 15, 1960. Photos: Bill Cloutier

In This Issue

"Out the Window on Your Left"

It's been more than 51 years since Neil Armstrong first stepped onto the moon's surface and 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).

Measured from shore to shore, the lava plains of Mare Nectaris (Sea of Nectar) are 220 miles (350 km) across, the smallest of any circular maria on the Moon. The once molten rock that flowed into the hollow beneath the mare billions of years ago is estimated to be almost a mile (1.5 km) thick.

Mare Nectaris denotes the location of the inner basin

Like Mare Nectaris, many of the dark patches on the Moon's nearside conceal large impact basins, carved out by collisions with an asteroid, protoplanet and/or some other remnant from the early solar system. The Moon's basins formed during a period of heavy bombardment that followed our natural satellite's formation, 4.5 billion years ago. The creation of the last major basin (Orientale) has been dated to about 3.73 billion years ago. Fractures in the crust allowed basaltic lava, heated by radiogenic decay deep within the Moon, to flow into the low-lying areas of the excavation creating the maria.

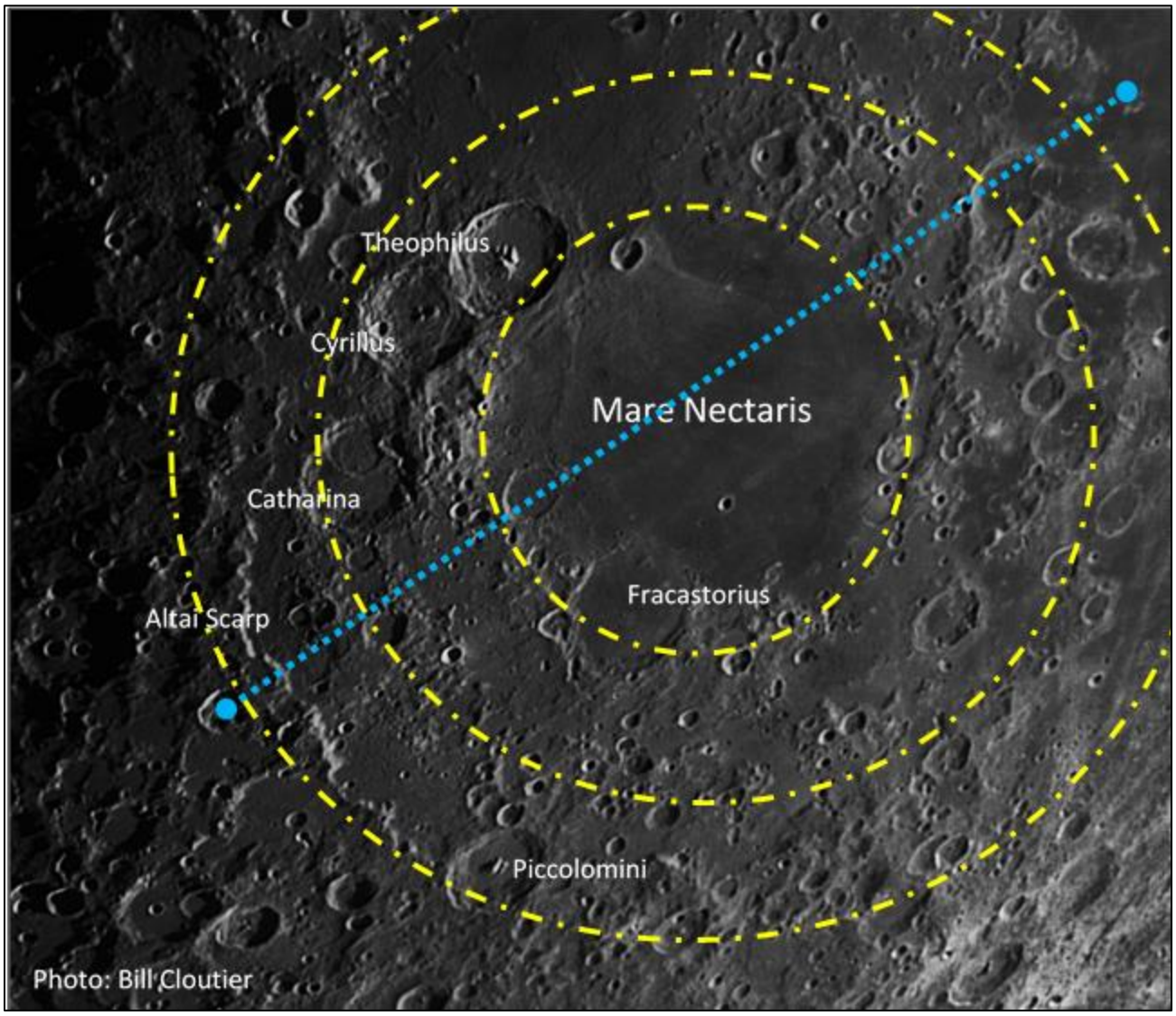
An impact basin is a class of very large craters, generally greater than 180 miles (300 km) in diameter. More than 40 basins have been identified, although with younger basins superimposed on top of older ones and degraded by subsequent smaller impacts, few basins retain their original structure and definition – Orientale on the Moon's far side being the best preserved.

Basins define much of the Moon's nearside geology with mare basalts covering 31% of the Earth-facing moonscape and basin ejecta scouring the surrounding topography and blanketing the highlands. The transformation from large crater to basin depends upon several factors, including the size and speed of the impactor, the thickness of the lunar crust, the temperature of the underlying mantle rock (malleability), and the strength of the surface rock.

The Nectaris basin was created 3.98 billion years ago, based upon samples collected by the Apollo 16 astronauts, as a result of intense shock waves produced when an impactor 19 to 31 miles (30 to 50 km) in diameter collided with the Moon. A transient cavity formed, up to 55 miles (90 km) in depth, with material from the top third of the excavation vaporized, melted or ejected. Impact melt, more than a mile thick (2 km) is believed to line the bottom of the cavity.

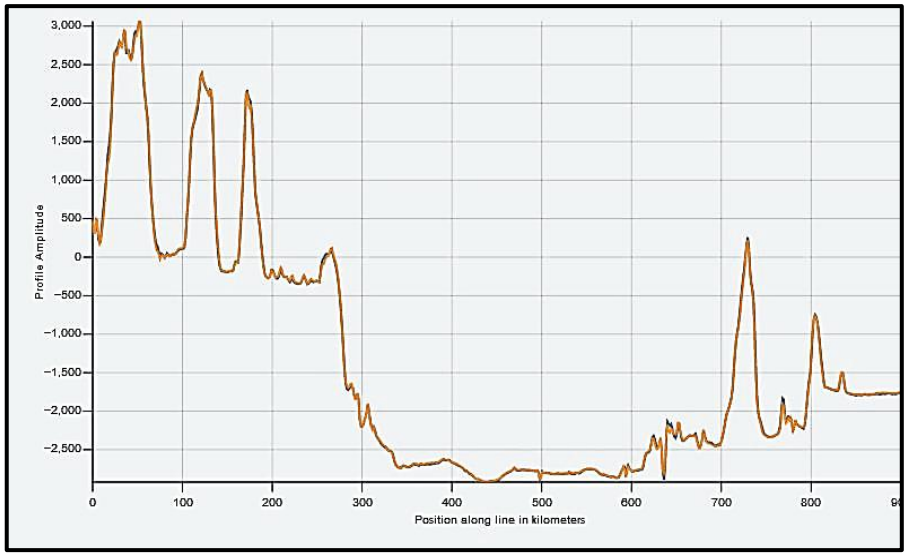
Nectaris is bounded by at least three rock rings or faults – the outer ring being defined by the Altai scarp with a diameter of 520 miles (840 km). The scarp, or high cliff, rises 2 to 2.5 miles (3.5 to 4 km) above the plain, and is the best-preserved segment of Nectaris' many rings.

Nectaris Impact Basin and Ring Faults



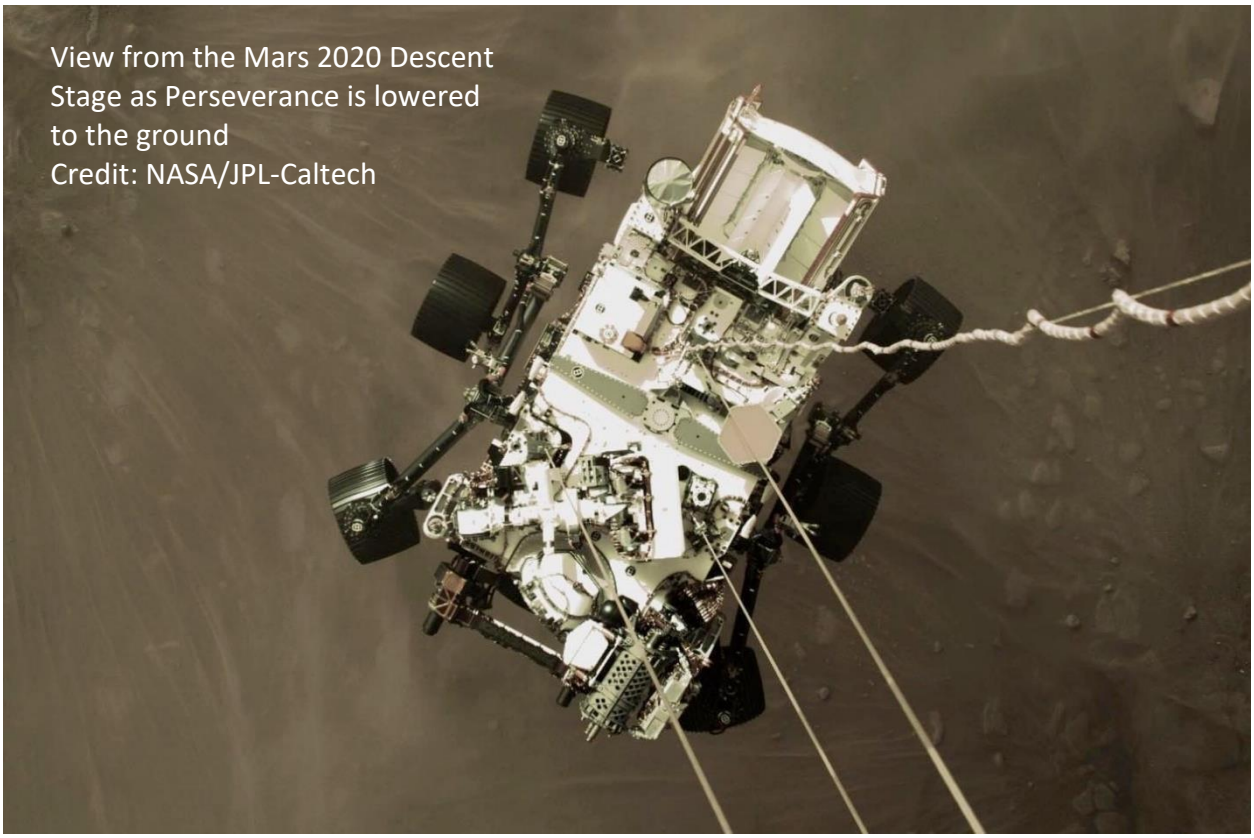
Three basin rings are charted in yellow, with the location of the topographic profile shown in blue.

Topographic profile generated by the Lunar Orbiter Laser Altimeter (LOLA) over a 560-mile (905 km) swath, from a 31 mile (50 km) polar orbit.

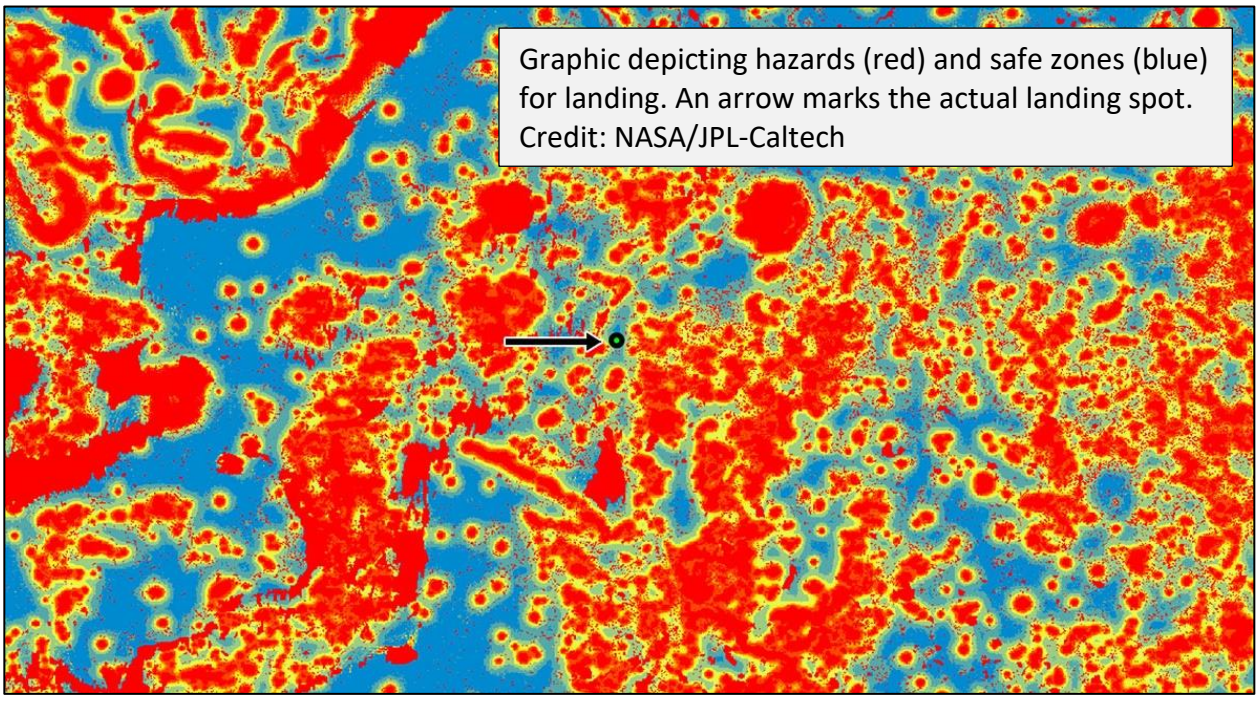


Six More Wheels on Mars

At 3:55 pm EST on February 18, the Mars 2020 team at NASA's Jet Propulsion Laboratory received a signal relayed by the Mars Reconnaissance Orbiter that the Perseverance rover was safely on the surface of Jezero crater. The landing was the culmination of a 203-day, 293-million-mile (472-million-km) journey that began at Cape Canaveral last July.



View from the Mars 2020 Descent Stage as Perseverance is lowered to the ground
Credit: NASA/JPL-Caltech

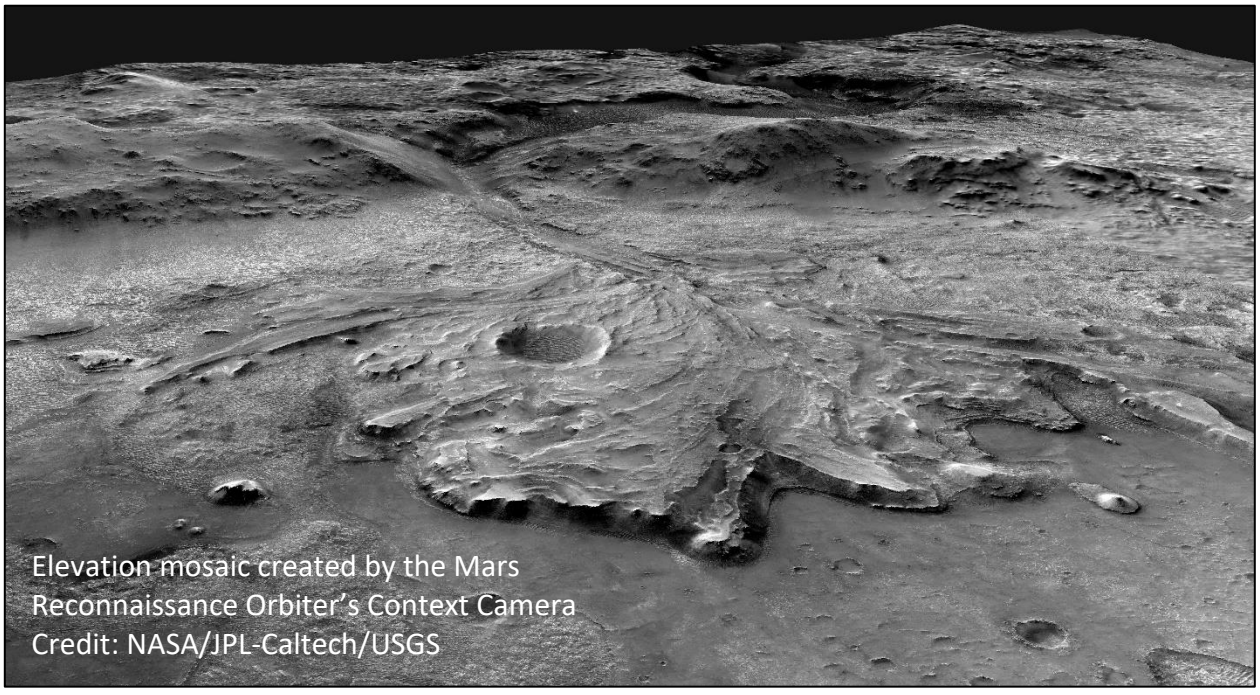


Graphic depicting hazards (red) and safe zones (blue) for landing. An arrow marks the actual landing spot.
Credit: NASA/JPL-Caltech

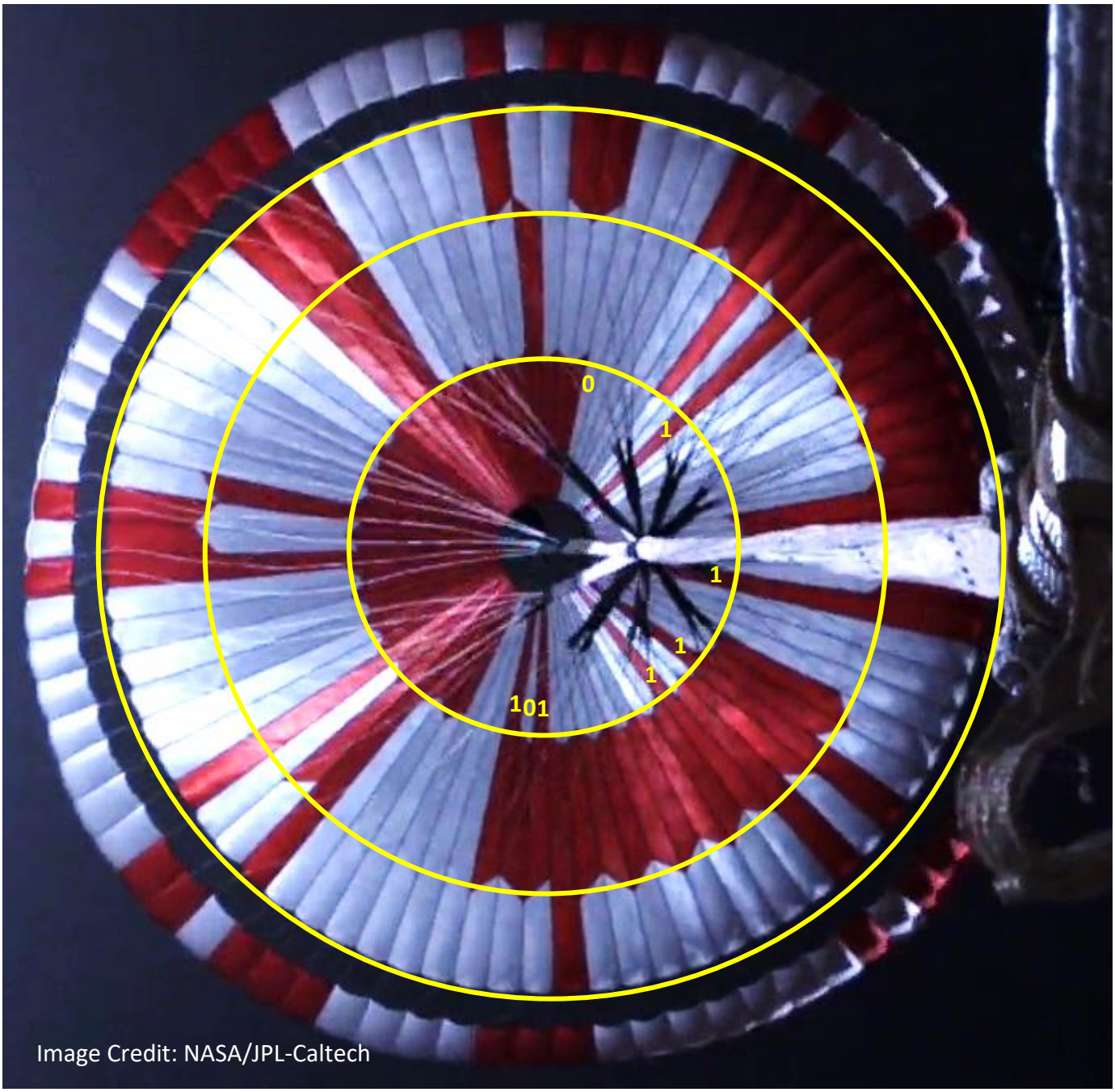
The spacecraft was equipped with two new technologies (Range Trigger and Terrain Relative Navigation) for landing the 2,263-pound (1,026-kg) rover on a hazard-free spot on the crater floor. Perseverance landed about 1.1 miles (1.7 km) from the center of the targeted area. The site is level and free from any large boulders or other obstacles with the rover reporting only a 1.2° tilt.

The rover landing spot relative to the base of the western delta in Jezero crater
Credit: NASA/JPL-Caltech

Over the next Martian year, the rover will explore the crater floor in front of the fossilized river delta before working its way up and across the delta toward the crater rim and the ancient shoreline of the lake that filled the crater. Long term, the rover could climb the 2,000-foot-high (610-meter-high) crater rim and explore the surrounding plains.

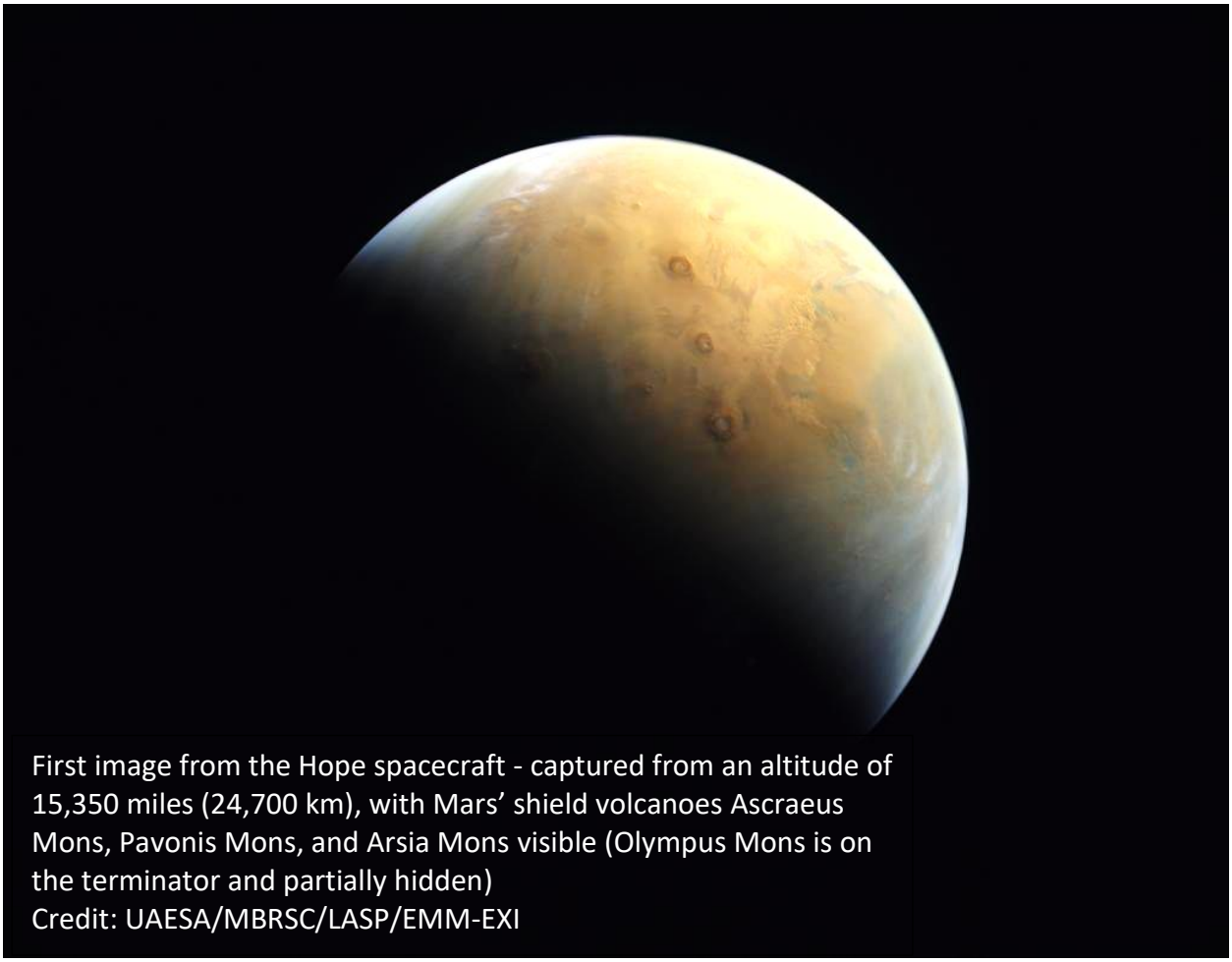

Elevation mosaic created by the Mars Reconnaissance Orbiter's Context Camera
Credit: NASA/JPL-Caltech/USGS

Decoding the Hidden Message



1. Download an image of the parachute taken by the camera on the spacecraft's backshell at https://mars.nasa.gov/mars2020/multimedia/raw-images/. You may need more than one image to see the entire chute.
2. The pattern changes as it moves out from the center, so working with each section, assign a "0" to a white panel and a "1" to a red panel (for clarity, I've just included a few notations).
3. Working clockwise you end up with 4 series of ten: 0000000100, 0000000001, 0000010010, and 0000000101 for the center section, which in binary equates to the numbers 4, 1, 18 and 5
4. The letters of the alphabet that correspond to those numbers are DARE
5. Continue on to the next section (the outer rim is a combinate of numbers and letters)

First Image from Hope



First image from the Hope spacecraft - captured from an altitude of 15,350 miles (24,700 km), with Mars' shield volcanoes Ascraeus Mons, Pavonis Mons, and Arsia Mons visible (Olympus Mons is on the terminator and partially hidden)
Credit: UAESA/MBRSC/LASP/EMM-EXI

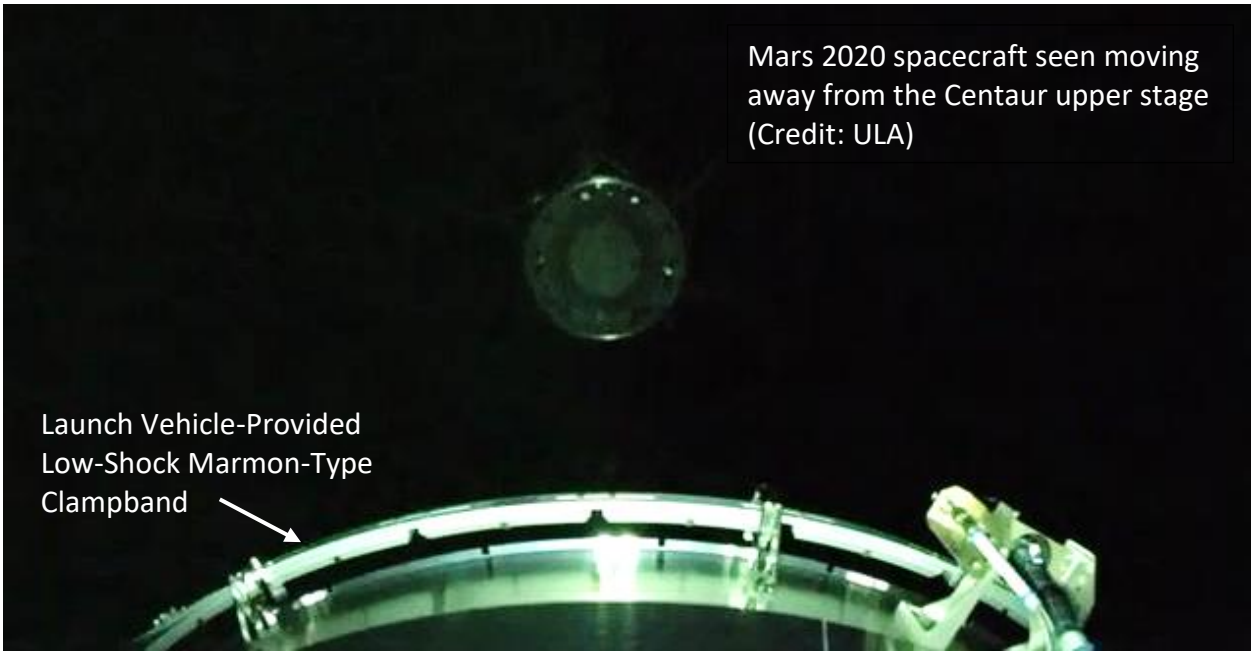
The United Arab Emirates' Hope spacecraft successfully entered orbit around Mars on February 9, becoming the first Arab country and fifth nation or agency to do so (following the former Soviet Union, United States, European Space Agency, and the Indian Space Research Organization). The spacecraft completed the seven-month journey, after having been launched on July 19 on a Japanese H-2A rocket from the Tanegashima Space Center in Japan. The Hope spacecraft was the first of three spacecraft to complete the almost 300-million-mile (480 million km) journey, with China arriving the following day and the U.S. Mars 2020 spacecraft, the following week.

The Hope spacecraft is a product of an international collaboration – constructed at the University of Colorado Boulder's Laboratory for Atmospheric and Space Physics (LASP) by a joint Mohammed bin Rashid Space Centre/LASP team, with contributions from other science and education partners. More than one-third of the Emiratis team assigned to the mission were women, as part of an effort to inspire future Arab generations to pursue space science and STEM careers.

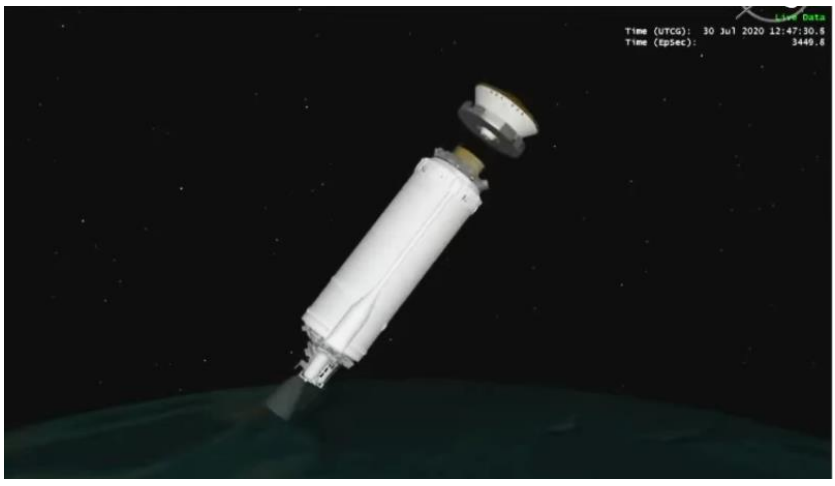
Hope's mission is to study dynamic changes in the atmosphere of Mars and the role of weather in the loss of the planet's atmosphere, over a minimum of a Martian year. It can also measure the distribution of water ice and ozone, and the temperature of the planet's surface and lower atmosphere. Over the next few months, the spacecraft will be placed in a 55-hour, equatorial operational orbit that, at closest approach, will be 12,400 miles (20,000 km) from the surface, and at it furthest, 26,700 miles (43,000 km).

Space History Trivia – Marman Clamp

What do the Marx Brothers, an early 20th century family comedy act, have to do with the success of the Mars 2020 mission? Considered among the most acclaimed comedians of their time, the American Film Institute includes five of the Marx Brothers' motion pictures in their top 100 comedies. The youngest of the brothers, Herbert Manfred "Zeppo" Marx, was also an accomplished mechanic and engineer, at one time working for the Ford Motor Company. He left the comedy troupe in 1933 and went on to establish a company in Inglewood, California that machined parts for the war effort. The signature product of the Marman Products Co. was the Marman clamp or ring. It allows two cylindrical objects to be attached end-to-end and was used by the military to secure cargo, including the two atomic bombs in their B-29s. The Marman clamp is still used today, including on United Launch Alliance's (ULA) Atlas rocket's Centaur upper stage, which was used to boost the Mars 2020 spacecraft to the Red Planet last July.



Four of the five Marx Brothers – stage names Chico, Harpo, Groucho and Zeppo (bottom)

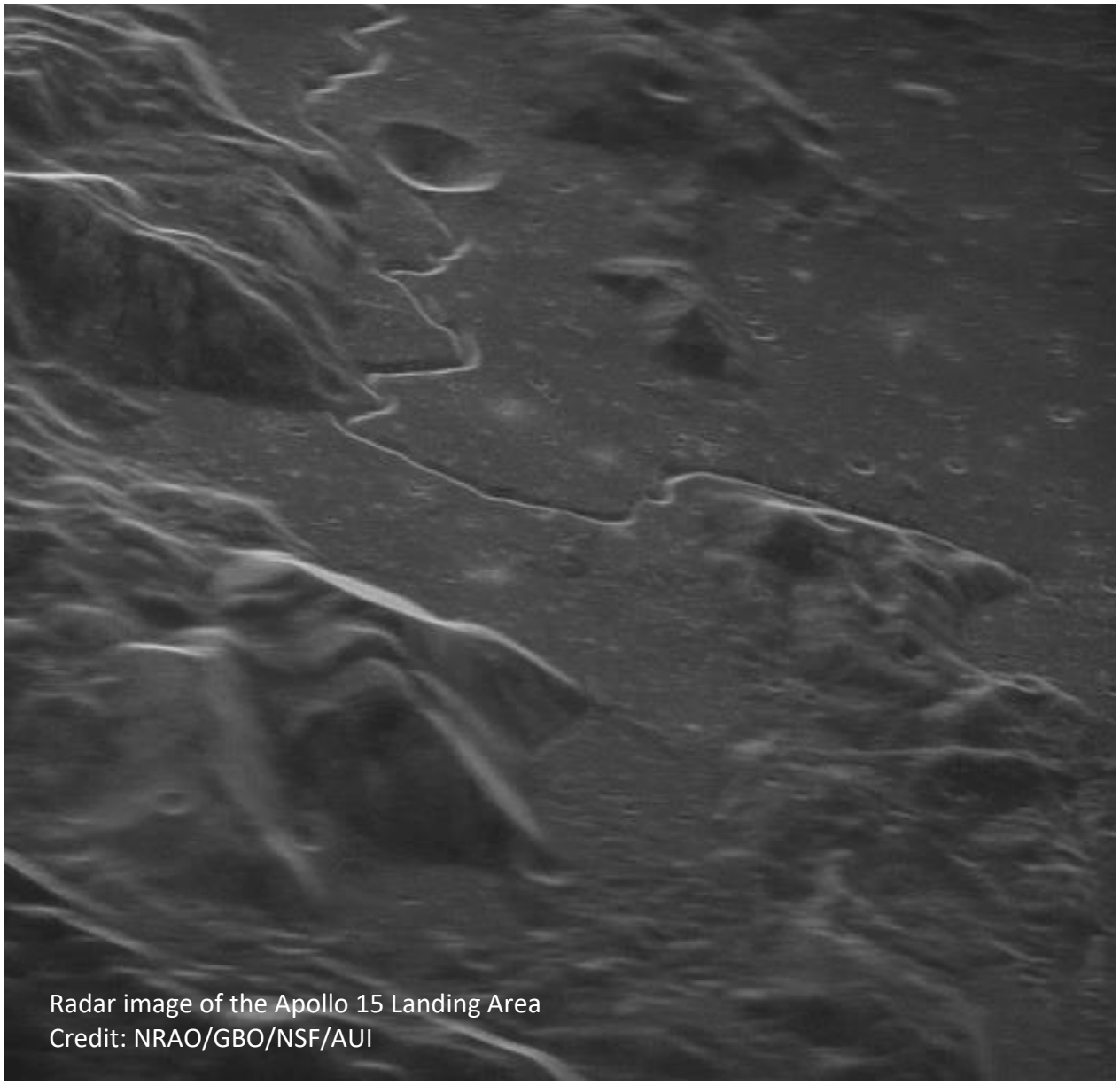


ULA Atlas V Mission Profile: Mars 2020 spacecraft separation from the Atlas-Centaur over Indonesia 57.5 minutes after launch on 30 July 2020

High-Definition Planetary Radar

A new transmitter, designed by Raytheon Intelligence & Space and installed on the Green Bank Observatory's Radio Telescope in West Virginia, has produced a detailed radar image of the Moon's surface that rivals that of visible light. In the rendering of the Apollo 15 landing site, the sinuous lava channel, Hadley Rille, threads past a small crater called Hadley C, about 3.7 miles (6 km) in diameter.

The radar signal reflected off the Moon from the signal transmitted by the 328-foot (100-meter) steerable dish at Green Bank, was received by the ten radio telescopes in the Very Long Baseline Array network (spanning the contiguous United States, Hawaii and St. Croix in the Caribbean). The collaborative effort was able to resolve details as small as 16 feet (5 meters) across. When the transmitter is upgraded, it is expected that detailed planetary imaging will be possible for objects as distant as Neptune.

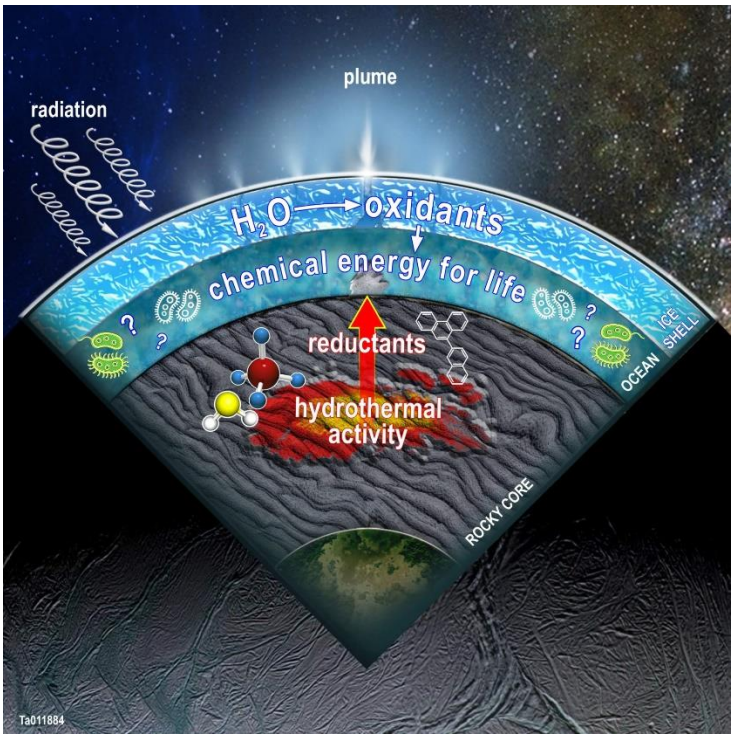


Radar image of the Apollo 15 Landing Area
Credit: NRAO/GBO/NSF/AUI

The Promise of Extant Life

While the Cassini mission ended in 2017, the data gathered from over 13 years spent in orbit around Saturn and flybys of its many moons continues to be mined for new insights and discoveries. Cassini made 22 targeted passes of Saturn's diminutive moon Enceladus (sixth-largest and about 310 miles or 500 km in diameter), many planned after the chance discovery of active, icy plumes erupting from its south pole. On October 28, 2015, the spacecraft made its deepest dive through the plumes, coming within 30 miles (48 km) of the moon's frozen surface. While Cassini wasn't designed to detect life, all indications are that Enceladus has the resources to host life, including a warm, subsurface salty ocean, a source of energy from geologic activity, and a variety of chemicals in the ocean that could support microbial life.

Life is all about a disequilibrium of energy (with a surplus available to living organisms). Free energy in the Enceladus' ocean was first discovered with the detection of molecular hydrogen in the plumes (on Earth, microbes can use the methane produced when molecular hydrogen oxidizes with carbon dioxide). With at least one potential life-sustaining source of energy identified, scientists have been looking into whether there are others.



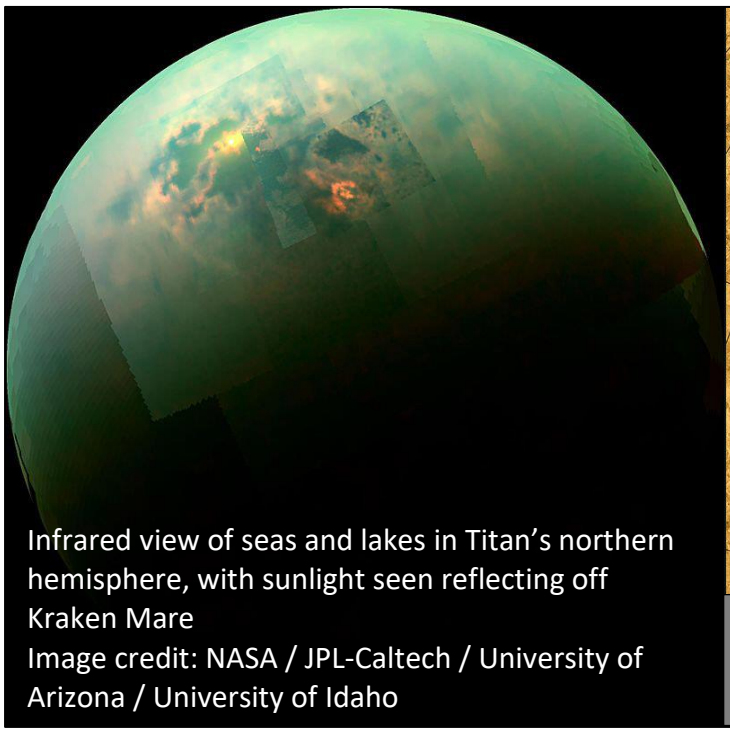
Cross-section of Enceladus, showing potential sources of oxidants from the breakdown of surface ice which, when combined with reductants from hydrothermal activity, create an energy source for life in the ocean.
Image credit: Southwest Research Institute

Newly published research has identified several additional pathways for the moon to host life. In particular, scientists looked at oxidation reactions that could provide additional sources of chemical energy. In modeling conditions on Enceladus, they found that surface ice and ocean water could be broken down into its basic components by radiolysis (molecular decomposition by ionizing radiation) from external sources, as well as from electrons and gamma rays released by the decay of an isotope of potassium, to produce oxidants. An oxidation chemistry could support metabolically-diverse microbes.

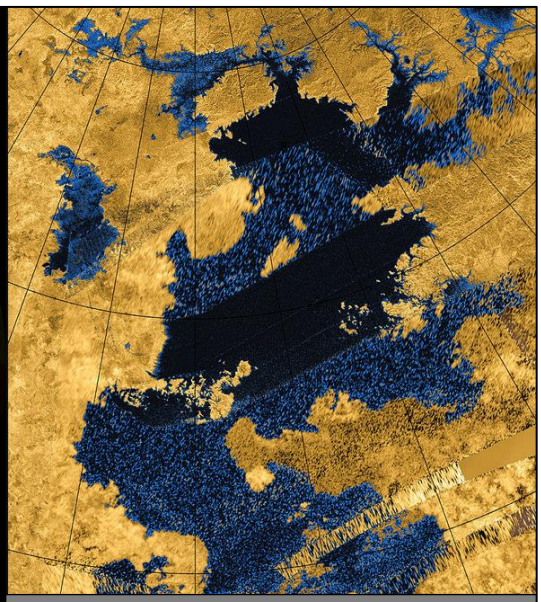
The types of creatures that may swim in this moon's ocean can only be imagined. Scientists recently discovered life at the bottom of an ocean on Earth under almost 3,000 feet of ice and 1,500 feet of freezing water in Antarctica, where, without light or energy, none was anticipated. So, should Congress/NASA decide to fund a mission such as ELF (Enceladus Life Finder), we may be able determine whether life is unique to Earth or if we can expect to encounter it on many worlds, and whether life shares a common genesis or develops independently and spontaneously.

Kraken Mare

At first glance, Saturn's largest moon Titan could be mistaken for an Earth-like world with its thick atmosphere, mountains, river channels, sand dunes, lakes and seas. The second largest moon in the solar system has a nitrogen atmosphere, with traces of methane and other hydrocarbons, and liquid cycling between the atmosphere and the surface (with rain, surface collection, and evaporation). The major difference is the moon's temperature, being so far from the Sun (over 900 million miles or 1,500 million km). At -290°F (-179°C), water ice is as hard as rock and the lakes are filled with liquid methane and ethane, instead of water. While its dense, smoggy atmosphere hides the surface in visible light, the Cassini spacecraft scanned the moon with its radar during 127 close flybys, building a comprehensive map of its surface features. In January 2005, a probe released by the Cassini spacecraft (the European Space Agency's Huygens probe) descended through Titan's atmosphere. In addition to providing our first view of the alien landscape, the probe also detected a possible subsurface ocean, 35 to 50 miles (55 to 80 km) below the frozen surface.



Infrared view of seas and lakes in Titan's northern hemisphere, with sunlight seen reflecting off Kraken Mare
Image credit: NASA / JPL-Caltech / University of Arizona / University of Idaho



False-color, radar mosaic of Kraken
Image: JPL-Caltech/ NASA/ASI/ USGS

Scientists have recently revisited the data from the last flybys of Titan by the Cassini spacecraft, and radar scans of Mare Kraken in particular. While Cassini's radar altimeter couldn't reach the seafloor, scientists now believe that it is more than 10 times deeper than originally thought, with a depth of 1,000 feet (300 meters) or more, and contains about 80% of the moon's surface liquids.

Mare Kraken is located in the northern hemisphere (between 70° and 80°N) and covers an area equivalent to the Great Lakes on Earth. The sea contains a mixture of methane and ethane, which challenged expectations. Models had predicted an ethane-rich body based on its size, geographical location, and the systematic depletion of methane in Titan's atmosphere (with the weak sunlight providing the energy to convert methane to ethane). Questions remain on how Titan's lakes were created and filled, due to the absence of runoff channels. The moon is scheduled to be visited by the Dragonfly mission in 2034, but to explore a sea would require a submarine – an idea that has attracted funding for concept development, but not as an official mission.

Heavy Metal

In August 2021, NASA will be launching a mission to the asteroid 16 Psyche. With a gravity assist from Mars in 2023, the solar-electric propelled spacecraft (also called Psyche) is expected to enter orbit around the asteroid in 2026. Over the 21-month primary mission, the spacecraft's instruments will map and characterize the asteroid from four increasingly-closer staging orbits (the final orbit will be about 44 miles or 70 km from the surface). Psyche will be equipped with a multispectral imager, a gamma-ray and neutron spectrometer, a magnetometer, and a radio instrument (for gravity measurements).

Psyche, the asteroid, is named for the consort of the Greek god Eros and was discovered by Italian astronomer Annibale de Gasparis on March 17, 1852. As a Main Belt asteroid, it is located between Mars and Jupiter, and takes about five years to orbit the Sun. Earth-bound observations suggest that the minor planet has a potato shape, 173 miles by 144 miles by 117 miles (279 km by 232 km by 189 km), and rotates once on its axis every 4 hours. It is commonly classified as a M-type or metallic asteroid, originally believed to be comprised of primarily metallic iron and nickel – possibly, the exposed core of an early protoplanet that lost its outer, rocky layers through some calamitous event billions of year ago. However, recent observations suggest that its composition, based upon its bulk density, radar albedo and spectral signature, is more varied – likely a mixture of silicate rock and metal, with a metal content only between 30 and 60 percent by volume.

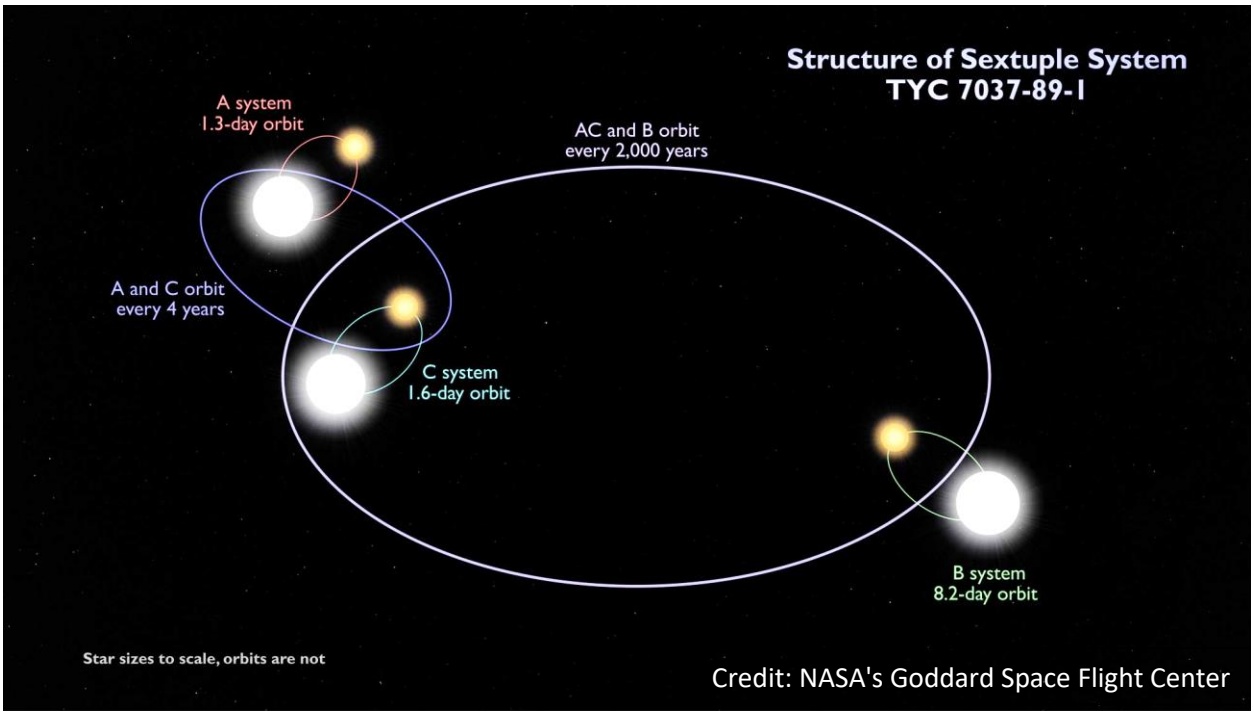
An artist's concept of the Psyche spacecraft in orbit around the metal-world Psyche
Credit: Maxar/ASU/P. Rubin/NASA/JPL-Caltech

Enigma Times Six

Isaac Asimov wrote the classic science fiction story "Nightfall" in 1941, about the people on a planet in a six-star system and under constant daylight, facing a once-in-a-millennium eclipse and darkness. Writers like Asimov considered themselves "futurists," creating imaginary storylines, but staying within the natural laws of the universe.

Fifty-five years later, a gas giant was discovered orbiting a sun-like star in a triple star system (16 Cygnus). Today, more than 100 planets have been detected in multiple star systems, in various configurations (in most instances, circumstellar where the planet orbits one star, but in few instances circumbinary, where a planet orbits multiple stars).

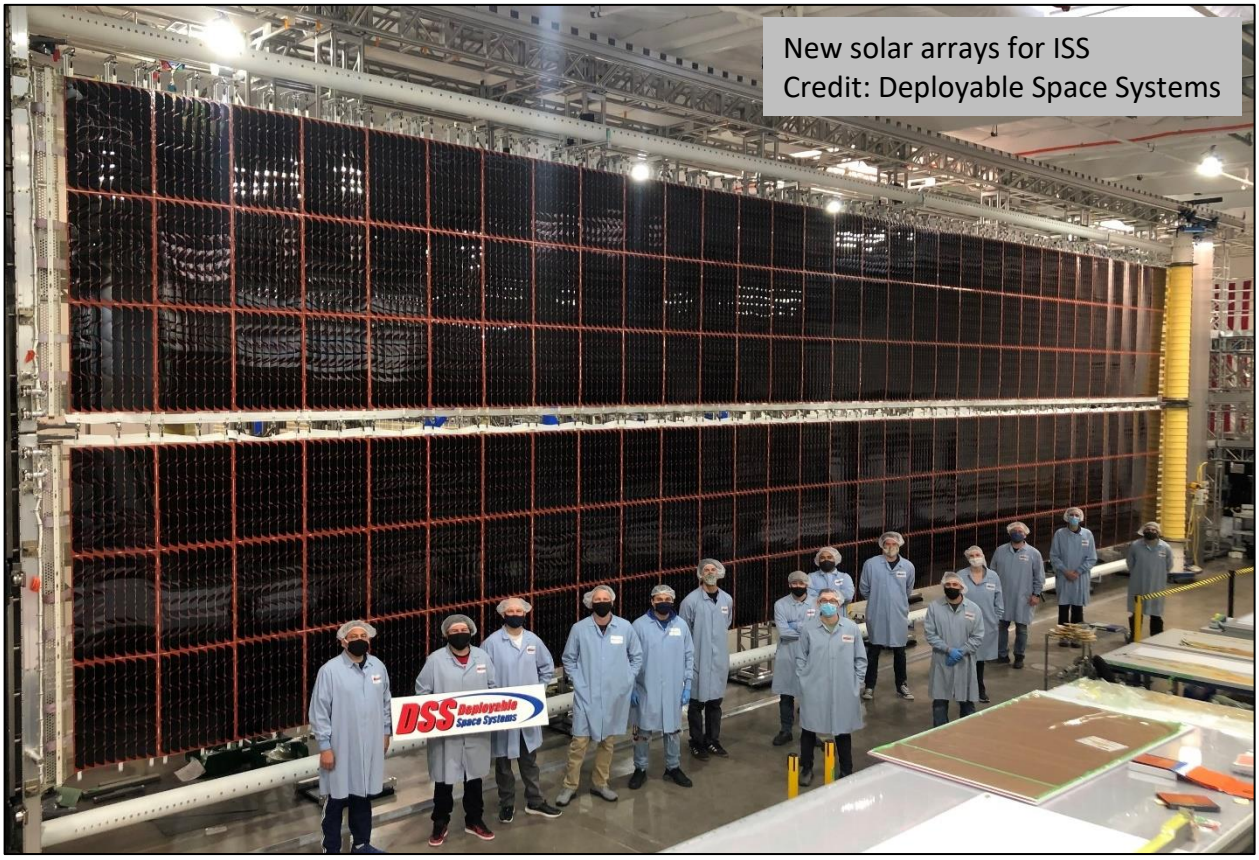
While several six-star systems are known (at least three, including Castor), NASA's Transiting Exoplanet Survey Satellite (TESS) has recently discovered one with very unusual properties – the first known sextuply-eclipsing sextuple star system, called TYC 7037-89-1 or TIC 168789840. Located about 1,900 light-years away in the constellation Eridanus (the River), the system consists of three binary stars, with orbital planes almost edge-on to our line of sight. As such, we are able to see each star in a pair (designated by the letters A, B and C) pass in front or eclipse one other.



Another interesting feature of the system is that the primary stars in each binary pair are of similar size and mass (1.22 and 1.30 times the Sun's mass, between 1.46 and 1.69 solar radii and slightly hotter than our Sun), while their companions, smaller and cooler, are also of similar size and mass (about half the Sun's size and mass and about as third as hot). The similarities suggest that the primaries might have formed first as a triplet, with their companions forming later, perhaps, as more gas became available, for example, as the triplet encountered a nearby nebula. The stars in each pair are also very close to one another (a small fraction of the distance Mercury orbits our Sun) - much too close to have formed in their current position, at least according to current theory - raising another question on where they might have originated. Residents on a planet in the system (if they exist) would have a view only Asimov could have imaged.

Power Boost

The International Space Station is powered by eight solar arrays, the first set having been installed over 20 years ago (and the last in March 2009). Under a new $100 million contract, Boeing will provide six new, more powerful arrays that will partially replace/supplement the existing ones, which have showed signs of degradation. The new 63-foot-by-20-foot (19-meter-by-6-meter) arrays will yield a 20 to 30 percent increase in power and support the station's expanding research activities, as well as flourishing commercial enterprises.



New solar arrays for ISS
Credit: Deployable Space Systems

The new arrays will be delivered to the station in pairs on three, future SpaceX cargo-carrying Dragon spacecraft. Starting as soon as May, the new panels will partially overlay six of the existing arrays.

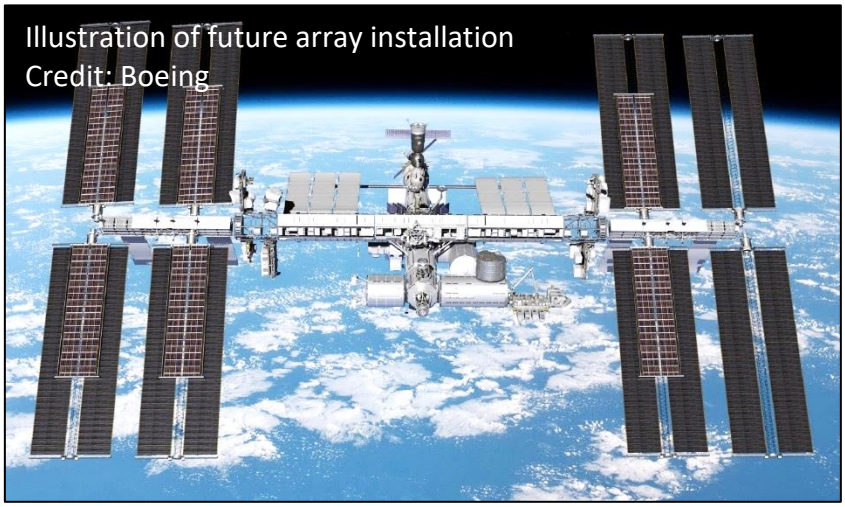


Illustration of future array installation
Credit: Boeing

The power boost follows a four-year-long project to replace the original nickel-hydrogen batteries with more-efficient lithium-ion batteries. The batteries, charged by the solar arrays, provide station power when the arrays are in Earth's shadow, which occurs 16 times each day – each time for approximately 45 minutes.

Saturn's Tilt

Saturn's axis of rotation is almost 27° to the plane of the solar system. The tilt, like Earth's, induces seasonal changes in the gas-giant's atmosphere, as one hemisphere and then the other is tilted towards the Sun. Unlike Earth, individual seasons last longer than 7 years on Saturn.

NASA's Hubble Space Telescope image
Credits: NASA, ESA, A. Simon (Goddard Space Flight Center), M.H. Wong (University of California, Berkeley), and the OPAL Team

The work of scientists from the French National Center for Scientific Research and Sorbonne University has shown that Saturn's current tilt can be explained by the migration of its moons, in particular, its largest moon, Titan. Their work also predicts that the tilt will continue to increase and could more than double over the next billion years.

Saturn's moons have been moving away from the planet – but at a much faster rate than expected. Researchers believe that this migration is affecting the inclination the planet. According to their model, Saturn's rotational axis had been relatively stable for its first three billion years and only slightly tilted. About a billion years ago, the gradual, but nonstop migration of the moons progressed to a point that triggered a "response" from the planet's spin axis – which continues today.

Researchers also predict a similar response to the observed migration of Jupiter's four large Galilean moons and resonance (periodic gravitational influence) with the orbit of Uranus. Models suggest that Jupiter's axis, currently inclined at only 3°, could increase to more than 30° over the next five billion years.

Meteorite Spotlight – Dar al Gani 476

In the summer of 2018, the Observatory greatly expanded its meteorite teaching collection with the addition of a diverse and comprehensive set of meteoritic specimens from a reputable collector looking to convey his collection to someone who would maintain its integrity and capitalize on its intrinsic educational value. The collection includes whole stones, slices and fragments, numbering more than 200, from historic and scientifically-significant falls and meteorite finds dating back to 1492. From time to time, we will highlight one or more of the specimens from the collection in this newsletter.

In 1998, a small, brownish stone was found in Dar al Gani, Libyan Sahara. Weighing in at almost 4.5 pounds (2,015 grams), the stone was classified as Martian in origin.

McCarthy Observatory's Dar al Gani sample
Image: Gerard Bianchi

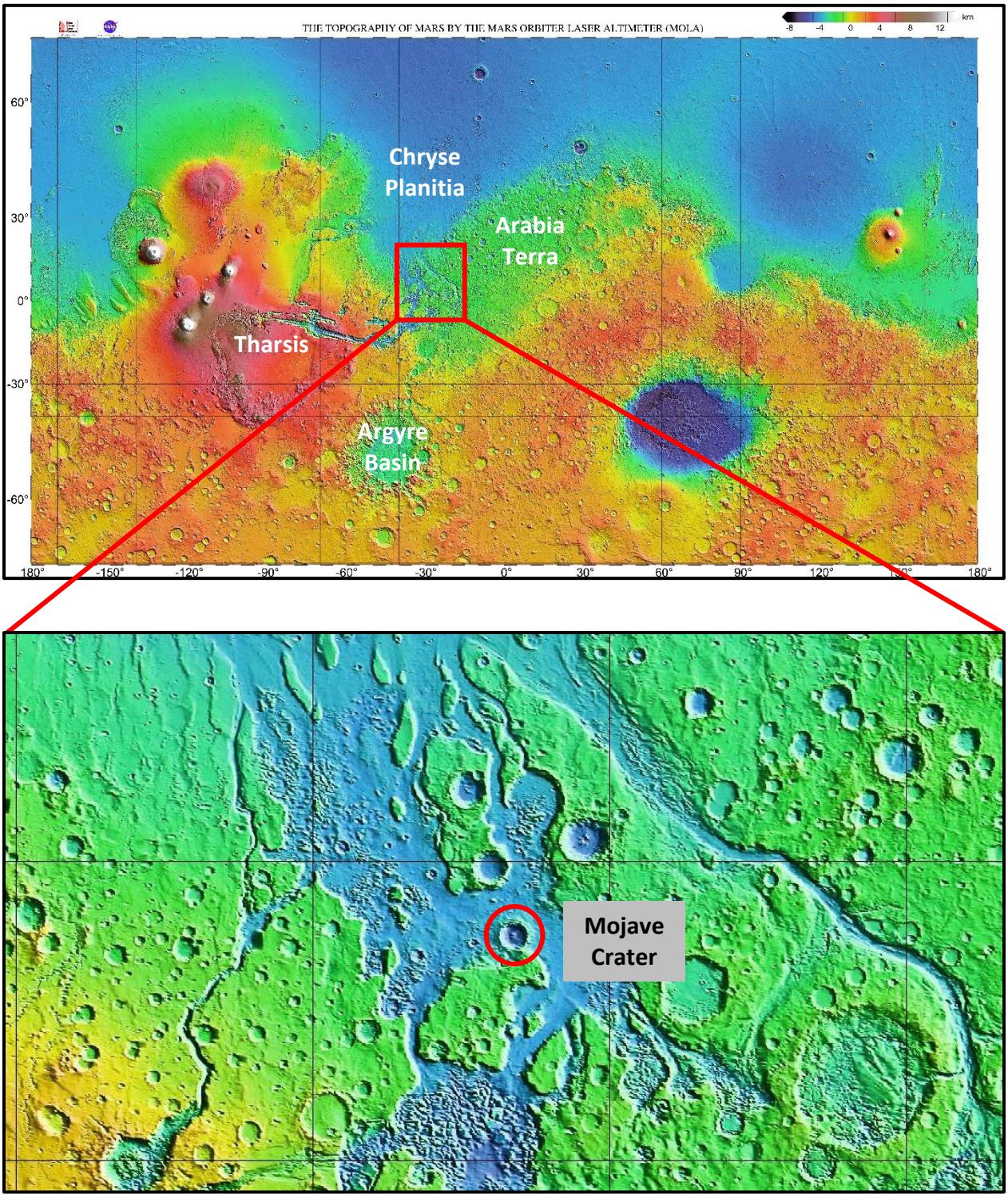
The Martian basalt (shergottite) was one of many recovered in, what appears to be, a strewn field from a shower of similar meteorites. The stone(s) does not display a fusion crust, likely eroded by weathering in the desert.

The age of the Dar al Gani stone is estimated at 474 million years, with an exposure age to cosmic rays (during the transit from Mars to Earth) of ~ 1 million years. Shergottites are the most abundant of the Martian meteorite subgroups and named after an 11-pound (5,000 gram) Martian meteorite that fell in Shergotty, Gaya, Bihar, India in 1865. Martian meteorites differ from those associated with asteroids in that they are magmatic rocks (from volcanically active worlds) with young crystallization ages. Their association with Mars was made when gases entrapped in the rocks were found to be similar in composition to the Martian atmosphere as measured by the Viking landers.

Martian meteorites are remnants of a violent collision, when an object such as an asteroid impacts the Red Planet, creating a large crater and ejecting tons of material from below the surface into the atmosphere. Most of the ejecta falls back to the surface, but with Mars' lower gravity, if the energy of the impact is great enough, some of the material can attain escape velocity and permanently leave the planet. With the proper trajectory, these space travelers can eventually intersect Earth's orbit and enter its atmosphere. Survivors of the atmospheric transit and ram pressure fall to the ground, waiting to be discovered.

A group of researchers proposed in 2014 that the common age of many shergottites suggests a singular ejection event, and offered the Mojave crater as the possible source. Mojave crater is approximately 37 miles (60 km) in diameter and believed to be less than 5 million years old. The crater lies on some very ancient terrain, so if it is the source, it would imply that shergottites are actually much older than their currently measured age and that the shock of the impact reset their radiometric clocks, making them appear younger than their original crystallizing age.

The McCarthy Observatory's sample of Dar al Gani 476 is a 0.866-gram slice.



Topographic shaded relief map of Mars with the location of the Mojave crater – suspected source of Shergottite meteorites

Image Credit: MOLA Science Team

Flight of the Spider

The Apollo 9 mission was the first manned test flight of all the hardware needed for a lunar landing, including the lunar module. The Saturn V, launched from the Kennedy Space Center on March 3, 1969, carried the record setting payload into low-Earth orbit. The mission was commanded by James McDivitt, with David Scott as the Command Service Module (CSM) Pilot and Russell Schweickart as the Lunar Module (LM) Pilot.

David Scott stands in the open hatch of the Command Module (CM). The photograph was taken by Schweickart on March 6, from the porch of the LM during his brief excursion outside the vehicle. At that time, the CM nicknamed "Gumdrop" was docked to the LM nicknamed "Spider."

Credit: NASA

The crew would complete 152 orbits of the Earth, challenging the human physiology in ten days of weightlessness. During the first day on orbit, the CSM separated from the Saturn V's third stage. Turning around to face the rocket booster, the CSM docked with the LM nested inside. Using the CSM's thrusters, the joined pair moved a safe distance away. The third stage engine was then restarted to simulate a maneuver required for a deep space mission. It was eventually placed in a heliocentric orbit.

A view of the free flying LM with its landing legs extended captured on March 7th by David Scott who remained in the CM while McDivitt and Schweickart checked out the LM. The circular opening in the top of the ascent stage allowed astronauts to transfer between vehicles when docked.

Credit: NASA

The crew of Apollo 9 used the CSM's propulsion system to change orbit and test the structural integrity of the joined CSM and LM under load. On Flight Day 3, McDivitt and Schweickart entered the LM through a tunnel connecting the two vehicles to test fire the LM's descent engine before returning to the CM. Schweickart's spacewalk scheduled for Flight Day 4 was cut short because of nausea. He did spend a short time outside the LM to check out the life support system backpack which the moonwalkers would use.

McDivitt and Schweickart would enter the LM again on Flight Day 5. This time the two vehicles separated, with the LM moving 113 miles away and 12 miles above the CM. The descent stage of the LM was then jettisoned and the ascent stage engine fired for the first time. The ascent engine was used to lower the LM's altitude and rendezvous with the CM. With docking and the transfer of McDivitt and Schweickart back into the CM, the LM was jettisoned, its mission complete.

The crew of Apollo 9 accomplished all of the primary mission objectives, including rendezvous and docking of the two spacecraft, LM operations as a separate and independent spacecraft, transfer of the crew between the two spacecraft, a simulated rescue operation assuming a lunar landing abort, multiple restarts of the CM's propulsion system (seven burns), and a full checkout of the CSM and LM systems. On Flight Day 10, the CM separated from the Service Module and reentered the Earth's atmosphere, splashing down in the Atlantic Ocean within three miles of the recovery ship, the USS Guadalcanal.

The near-Earth success of Apollo 9 would be repeated in lunar orbit by Apollo 10 in May of 1969, the precursor to the first Moon landing by the crew of Apollo 11 in July. Apollo 9 would also play a role in determining which astronaut would take that first step on Moon. McDivitt was originally selected to command Apollo 8, with the same mission objectives (full check out of the CSM and LM). However, the LM was behind schedule and wouldn't be ready, so NASA decided to send the Apollo 8 CM to the Moon without the LM.

McDivitt declined the command of Apollo 8's new mission (believing it was a publicity stunt), electing to trade places with the Apollo 9 crew, commanded by Frank Borman, in anticipation that the LM would be available for that flight. McDivitt's decision resulted in the swap of the backup crews for the two missions with Pete Conrad moving to command Apollo 12 rather than 11. Had McDivitt agreed to remain with Apollo 8, it's likely that Conrad would have taken the first step.

"The Times regrets the error"

On March 16, 1926, in Auburn, Massachusetts, Robert Goddard launched the first liquid fueled rocket on a flight that lasted only 2½ seconds. A graduate of Worcester Polytechnic Institute, despite discharging a powder rocket from the basement of the physics building, the significance of Goddard's feat is compared by space flight historians to the first aircraft flight at Kitty Hawk. Among his achievements, Goddard was first to prove that rockets would work in a vacuum and to mathematically explore the practicality of using rocket propulsion to reach high altitudes and even the Moon (1912). While he was eventually banished from the fields of Auburn by the fire marshal (and ridiculed in a 1920 New York Times editorial), the launch site is commemorated by markers on what is now the Pakachoag Golf Course. The next time you are driving on the Massachusetts Turnpike towards Boston and points north, look to your left as you pass Exit 10. Just beyond the large shopping mall is where history was made.

Dr. Goddard with his liquid oxygen-gasoline rocket "Nell" in its launching frame

NASA photo

Zodiacal Light

The solar system is filled with tiny dust particles from the passing of comets and collisions of asteroids. The dust orbits in the same plane as the Earth and the other planets. Shortly before sunrise and just after sunset, sunlight can be seen reflecting off this disk of debris. Called the zodiacal light, it is best observed when the ecliptic (the apparent path of the Sun and planets) is nearly perpendicular to the horizon (on spring evenings and autumn mornings). The best time to glimpse the zodiacal light is when the Moon is absent from the evening sky (for example, during the second week of March and around the New Moon on the 11th).

Sunrise and Sunset (New Milford, CT)

March, the month named for the planet Mars, denotes the end of the long winter nights. The Sun crosses the celestial equator at 4:37 am (EDT) on the 20th marking the Vernal Equinox and the beginning of the spring season in the northern hemisphere.

Sun	Sunrise	Sunset
March 1st (EST)	06:27	17:44
March 15th (EDT)	07:04	19:00
March 31st (EDT)	06:37	19:18

Astronomical and Historical Events

1st Aten Asteroid 2011 DW near-Earth flyby (0.036 AU)
1st Amor Asteroid *887 Alinda* closest approach to Earth (0.746 AU)
1st Amor Asteroid *481984 Cernunnos* closest approach to Earth (2.244 AU)
1st History: U.S. astronaut Scott Kelly and Russian cosmonaut Mikhail Kornienko return to Earth after a one-year stay on the International Space Station (2016)

Astronomical and Historical Events (continued)

1st History: Soviet spacecraft Venera 13 lands on Venus and records first color panoramic views of the surface (1982)
1st History: discovery of Saturn's moon *Helene* by Pierre Laques and Jean Lecacheux from the Pic du Midi Observatory in the French Pyrenees; named after Helen of Troy (1980)
1st History: Soviet spacecraft Venera 3 lands (crashes) on Venus, becoming first spacecraft to impact the surface of another planet (1966)
2nd Moon at perigee (closest distance from Earth)
2nd Apollo Asteroid 2016 DV1 near-Earth flyby (0.010 AU)
2nd Apollo Asteroid 1999 RM45 near-Earth flyby (0.020 AU)
2nd Aten Asteroid 2011 EH17 near-Earth flyby (0.024 AU)
2nd Binary Aten Asteroid 152931 (2000 EA107) closest approach to Earth (1.115 AU)
2nd History: launch of an unmanned SpaceX Crew Dragon spacecraft. First American spacecraft to autonomously dock with the International Space Station (2019)
2nd History: launch of the Rosetta spacecraft (2004); rendezvoused with *Comet 67 P/Churyumov-Gerasimenko* in May 2014, sending a lander to its surface in November 2014
2nd History: launch of Pioneer 10, a Jupiter flyby mission (1972)
3rd Aten Asteroid 2020 SP near-Earth flyby (0.047 AU)
3rd Amor Asteroid *3551 Verenia* closest approach to Earth (1.964 AU)
3rd Plutino *90482 Orcus* at Opposition (47.129 AU)
3rd History: Chinese National Space Agency announces the Chang'e lunar exploration program (2003)
3rd History: launch of Apollo 9 with astronauts James McDivitt, David Scott and Russell Schweickart in the first manned flight test of the lunar module (1969)
3rd History: launch of the Pioneer 4 spacecraft towards the Moon; first U.S. spacecraft to escape the Earth's gravity (1959)
4th Last Quarter Moon
4th Amor Asteroid *3988 Huma* closest approach to Earth (1.957 AU)
4th History: discovery of Jupiter's rings by the Voyager 1 spacecraft (1979)
5th History: discovery of Jupiter moon *Thebe* by Steve Synnott (1979)
5th History: Soviet spacecraft Venera 14 lands on Venus and uses a screw drill to obtain a surface sample that was determined to be similar to oceanic basalts on Earth (1982)
5th History: flyby of Jupiter by the Voyager 1 spacecraft (1979)
6th Mercury at its Greatest Western Elongation (separation from the Sun in the morning sky) (27°)
6th Aten Asteroid *99942 Apophis* closest approach to Earth (0.113 AU)
6th Kuiper Belt Object 2017 FO161 at Opposition (77.151 AU)
6th History: Valentina Tereshkova's birthday (1937), Soviet cosmonaut became the first woman to fly to space in 1963
6th History: Dawn spacecraft enters orbit around the dwarf planet *Ceres* (2015)
6th History: launch of the Kepler telescope from Cape Canaveral Air Force Station aboard a Delta II rocket (2009); designed to survey nearby stars for Earth-size and smaller planets; as of February 2019, Kepler discovered 2,414 confirmed planets with just as many yet to be confirmed3,255
6th History: flyby of Comet Halley by Vega 1, a Soviet spacecraft (1986)
7th Kuiper Belt Object 523671 (2013 FZ27) at Opposition (46.772 AU)

Astronomical and Historical Events (continued)

7th History: John Herschel born, first astronomer to survey the southern hemisphere (1792)
8th Atira Asteroid 164294 (2004 XZ130) closest approach to Earth (0.607 AU)
8th Kuiper Belt Object *88611 Teharonhiawako* at Opposition (46.190)
8th Kuiper Belt Object 532037 (2013 FY27) at Opposition (78.797 AU)
8th History: maiden voyage of Europe's first unmanned cargo ship to the International Space Station; the Jules Verne was launched from Kourou, French Guiana aboard an Ariane 5 rocket; in addition to delivering supplies to the ISS, the cargo ship contained a manuscript by the 19th century French author and science fiction pioneer with computations of distances from Earth to several astronomical destinations, as well as to the center of the planet (2008)
8th History: flyby of *Comet Halley* by Susei, a Japanese spacecraft (1986)
8th History: discovery of rings around Uranus by NASA's airborne observatory (1977)
9th Aten Asteroid *3554 Amun* closest approach to Earth (1.543 AU)
9th History: launch of Ivan Ivanovich on Sputnik 9, a mannequin used to test the Russian Vostok spacecraft in preparation for its crewed missions (1961)
9th History: Space Shuttle Discovery (STS-133) makes its final landing (2011)
9th History: flyby of *Comet Halley* by Vega 2, a Soviet spacecraft (1986)
9th History: launch of the Soviet spacecraft Sputnik 9, with dog Chernushka (1961)
9th History: Yuri Gagarin born; first person to orbit the Earth in 1961 (1934)
10th Apollo Asteroid 535844 (2015 BY310) near-Earth flyby (0.036 AU)
10th History: Mars Reconnaissance Orbiter arrives at Mars (2006)
10th History: flyby of *Comet Halley* by Sakigake, a Japanese spacecraft (1986)
10th History: Uranus' rings discovered by astronomers James Elliot, Edward Dunham, and Jessica Mink using the Kuiper Airborne Observatory while observing a stellar occultation (1977)
11th New Moon
11th Asteroid *55 Pandora* closest approach to Earth (2.118 AU)
11th History: launch of Pioneer 5 into solar orbit between the Earth and Venus; confirmed the existence of interplanetary magnetic fields (1965)
11th History: Urbain Leverrier born, mathematician and astronomer, predicted existence of Neptune (1811)
13th **Second Saturday Stars - Open House at McCarthy Observatory**
13th Asteroid *87 Sylvia* (2 Moons) closest approach to Earth (2.826 AU)
13th History: flyby of *Comet Halley* by Giotto, a European Space Agency spacecraft (1986)
13th History: discovery of Saturn's moon *Calypso* by Dan Pascu, P.K. Seidelmann, William Baum and D. Currie (1980)
13th History: Percival Lowell born, established observatory in Flagstaff, AZ to observe Schiaparelli's Martian "canali" and look for other signs of life (1855)
13th History: William Herschel discovers the planet Uranus; originally named Georgium Sidus by Herschel in honor of his patron, King George III of England (1781)
13th History: Galileo Galilei publishes "Sidereus Nuncius" (Starry Messenger), the first scientific treatise based on observations made through a telescope; it described Galileo's early observations of the Moon, the stars, and the moons of Jupiter (1610)
14th Daylight Saving - Set Clock Ahead 1 Hour (United States)
14th Amor Asteroid 3271 Ul closest approach to Earth (1.720 AU)
14th Asteroid *93 Minerva* (2 Moons) closest approach to Earth (1.854 AU)

Astronomical and Historical Events (continued)

14th Amor Asteroid *719 Albert* closest approach to Earth (3.028 AU)
14th Pi Day
14th History: launch of ESA's ExoMars Trace Gas Orbiter and Schiaparelli lander aboard a Russian Proton rocket from the Baikonur Cosmodrome in Kazakhstan (2016)
14th History: Stardust passes within 112 miles (181 km) of the nucleus of *Comet Tempel 1* (2011)
14th History: John J. McCarthy Observatory issued Observatory Code Number 932 by the Minor Planet Center of the International Astronomical Union (2001)
14th History: first European launch of a liquid-fueled rocket by Johannes Winkler (1931)
14th History: Albert Einstein born, developed theories of mass to energy conversion and the curvature of space and time in large gravitational fields (1879)
14th History: Giovanni Schiaparelli born, director of the Milan Observatory and first to describe faint features on Mars as "canali" (1835)
15th Atira Asteroid 434326 (2004 JG6) closest approach to Earth (1.209 AU)
15th Centaur Object *346889 Rhiphonos* at Opposition (12.945 AU)
15th 52nd Lunar and Planetary Science Conference (virtual) (15th – 19th)
15th History: dedication of the Kitt Peak National Observatory (1960)
15th History: Alan Bean born; astronaut, moonwalker and artist (1932)
16th Atira Asteroid 413563 (2005 TG45) closest approach to Earth (0.609 AU)
16th Amor Asteroid *6050 Miwablock* closest approach to Earth (2.221 AU)
16th History: third and final flyby of Mercury by the Mariner 10 spacecraft (the last of the Mariner probes); Mariner 10 was also the first spacecraft to use solar radiation pressure on its solar panels and the antenna for attitude control during flight (1975)
16th History: launch of Gemini 8 with astronauts Neil Armstrong and David Scott; first docking with another space vehicle, an unmanned Agena stage (1966)
16th History: launch of the first Titan II Intercontinental Ballistic Missile, also used as the launch vehicle for the manned Gemini spacecraft in the early 1960's (1962)
16th History: Robert Goddard launches first liquid-fuel rocket in Auburn, MA (1926)
16th History: Caroline Herschel born (1750)
17th History: discovery of Asteroid 16 *Psyche* by Annibale de Gasparis (1852)
17th History: launch of the Gravity Recovery And Climate Experiment (GRACE) spacecraft (2002)
17th History: launch of Vanguard 1, 4th artificial satellite and oldest still orbiting Earth (1958)
17th History: discovery of Saturn's moon *Phoebe* by William Pickering (1899)
18th Moon at apogee (furthest distance from Earth)
18th Apollo Asteroid 2006 QV89 closest approach to Earth (1.511 AU)
18th History: MESSENGER enters orbit around Mercury (2011)
18th History: New Horizons spacecraft (on its way to Pluto) crosses the orbit of Uranus (2011)
18th History: explosion during launch of a Vostok rocket carrying a military spy satellite kills 48 members of the Soviet Missile Troop; likely cause of explosion was an oxygen peroxide leak caused by the poor quality of the rocket's fuel filters (1980)
18th History: Alexei Leonov performs first spacewalk from Soviet Voskhod spacecraft (1965)
19th First Quarter Moon
19th Amor Asteroid *3122 Florence* (2 Moons) closest approach to Earth (1.539 AU)
19th Apollo Asteroid *2101 Adonis* closest approach to Earth (1.728 AU)
19th Centaur Object *37117 Narcissus* at Opposition (4.861 AU)

Astronomical and Historical Events (continued)

19th Binary Kuiper Belt Object *385446 Manwe* at Opposition (44.186 AU)
19th Kuiper Object 145480 (2005 TB190) at Opposition (47.270 AU)
19th History: Tenham meteorite fall; fragments of a large meteor rain down on a remote area of western Queensland, Australia (1879)
19th History: Moon flyby by the Hiten spacecraft; Japan's first lunar flyby, orbiter and surface impactor (1990)
20th Vernal Equinox (beginning of the Spring season in the northern hemisphere) at 4:37 am EDT (09:37 UT)
20th Amor Asteroid *2059 Baboquivari* closest approach to Earth (2.628 AU)
20th Kuiper Belt Object 2014 YA50 at Opposition (40.933 AU)
21st Apollo Asteroid 231937 (2001 FO32) near-Earth flyby (0.013 AU)
21st History: launch of Ranger 9, Moon impact mission; transmitted the highest resolution imagery obtained to that date before impacting the floor of Alphonsus crater on the 24th (1965)
21st History: discovery of Saturn's moons *Tethys* and *Dione* by Giovanni Cassini (1684)
22nd History: launch of space shuttle Atlantis (STS-76), third mission to Russian space station Mir and transfer of the first American woman, Shannon Lucid, to the station (1996)
23rd History: launch of Gemini 3 with astronauts Virgil Grissom and John Young, first manned Gemini flight (1965)
23rd History: Wernher von Braun born, German rocket scientist and leader of the U.S. moon program (1912)
24th Comet 10P/Tempel at Perihelion (1.412 AU)
24th History: discovery of Comet Shoemaker-Levy 9 (1993)
25th Amor Asteroid *3199 Nefertiti* closest approach to Earth (1.095 AU)
25th Amor Asteroid *5370 Taranis* closest approach to Earth (4.031 AU)
25th History: launch of the IMAGE spacecraft, first mission dedicated to mapping the Earth's magnetosphere (2000)
25th History: close approach of Comet Hyakutake (0.10 AU) to Earth (1996)
25th History: launch of Soviet spacecraft Sputnik 10 with dog Zvezdochka (1961)
25th History: Christiaan Huygens discovers *Titan*, Saturn's largest moon (1655)
26th Atira Asteroid 2015 DR215 closest approach to Earth (0.387 AU)
26th Amor Asteroid *7336 Saunders* closest approach to Earth (2.183 AU)
26th History: American astronomer J.W. Draper takes first photograph of the Moon (1840)
27th Full Moon (Full Worm Moon)
27th Apollo Asteroid 2020 GE near-Earth flyby (0.032 AU)
27th History: U.S. astronaut Scott Kelly and Russian cosmonaut Mikhail Kornienko arrive at the International Space Station for a year-long mission (2015)
27th History: launch of the Soviet atmospheric probe and lander Venera 8 to Venus (1972)
27th History: launch of Mariner 7, Mars flyby mission (1969)
27th History: President Eisenhower approves the military lunar program to be managed by the Advanced Research Projects Agency (1958)
28th History: flyby of Comet Halley by the ICE spacecraft (1986)
28th History: Heinrich Olbers discovers the asteroid 2 *Pallas* (1802)
29th Atira Asteroid 481817 (2008 UL90) closest approach to Earth (0.539 AU)
29th Amor Asteroid *1916 Boreas* closest approach to Earth (1.760 AU)
29th Apollo Asteroid *11066 Sigurd* closest approach to Earth (1.777 AU)

Astronomical and Historical Events (continued)

29th Binary Kuiper Belt Object *58534 Logos* at Opposition (42.542 AU)
29th History: First flyby of Mercury by the Mariner 10 spacecraft (1974)
29th History: Heinrich Olbers discovers the asteroid 4 *Vesta* (1807)
30th Moon at perigee (closest distance from Earth)
30th Asteroid *4987 Flamsteed* closest approach to Earth (1.167 AU)
30th Apollo Asteroid 2011 MD closest approach to Earth (1.314 AU)
30th Amor Asteroid *1980 Tezcatlipoca* closest approach to Earth (1.476 AU)
31st History: discovery of Dwarf Planet *Makemake* by Mike Brown, et al's (2005)
31st History: launch of Soviet spacecraft Luna 10, first man-made object to go into orbit around another planetary body; detected evidence of mass concentrations on the Moon called "mascons" (1966)

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

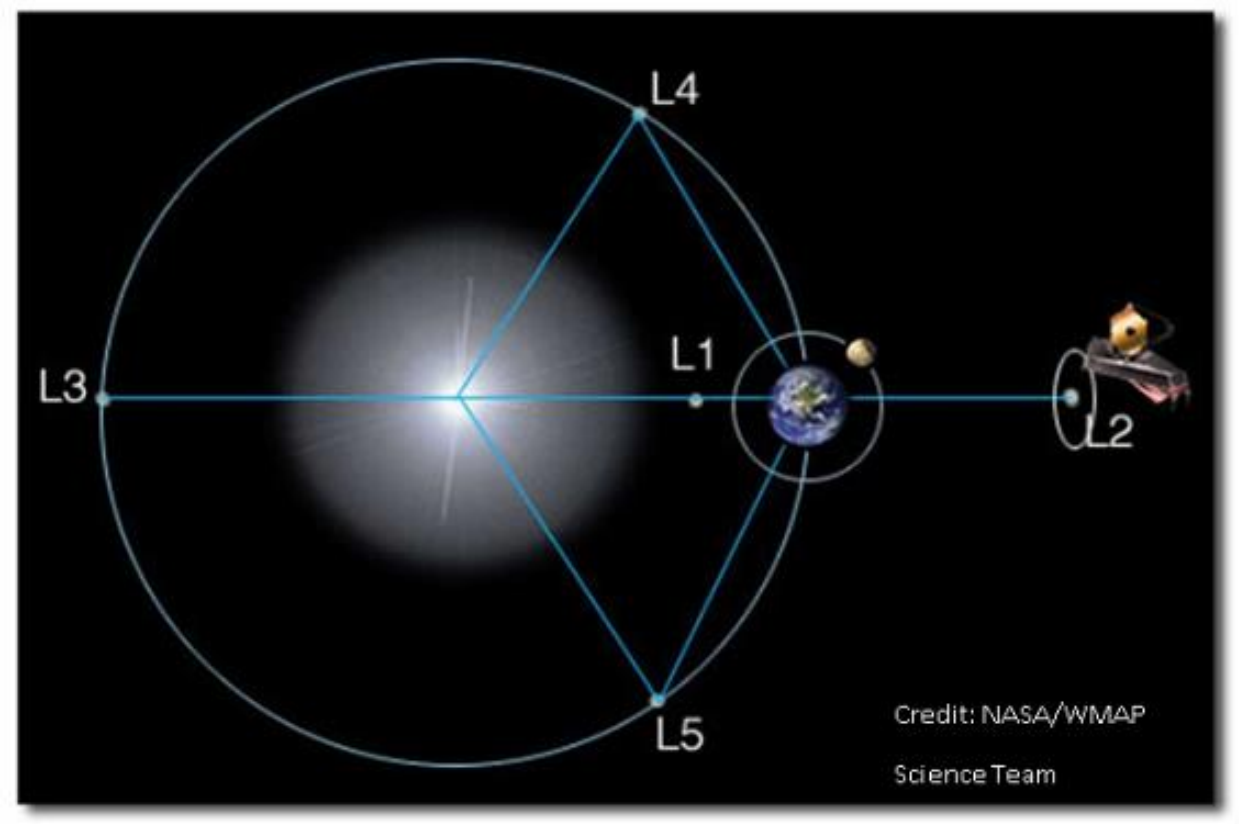
- the apparent width of the Moon (and Sun) is approximately one-half a degree (½°), less than the width of your little finger at arm's length which covers approximately one degree (1°); three fingers span approximately five degrees (5°)
- 1 astronomical unit (AU) is the distance from the Sun to the Earth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

Mars 2020 Mission

The latest information on the Perseverance rover and its exploration of Jezero crater can be found at https://mars.nasa.gov/mars2020/

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 Starlink Satellites

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

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

NASA's Global Climate Change Resource

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

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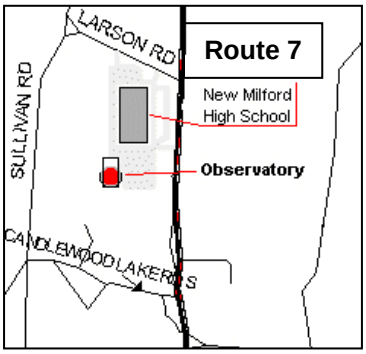

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