Galactic Observer

John J. McCarthy Observatory

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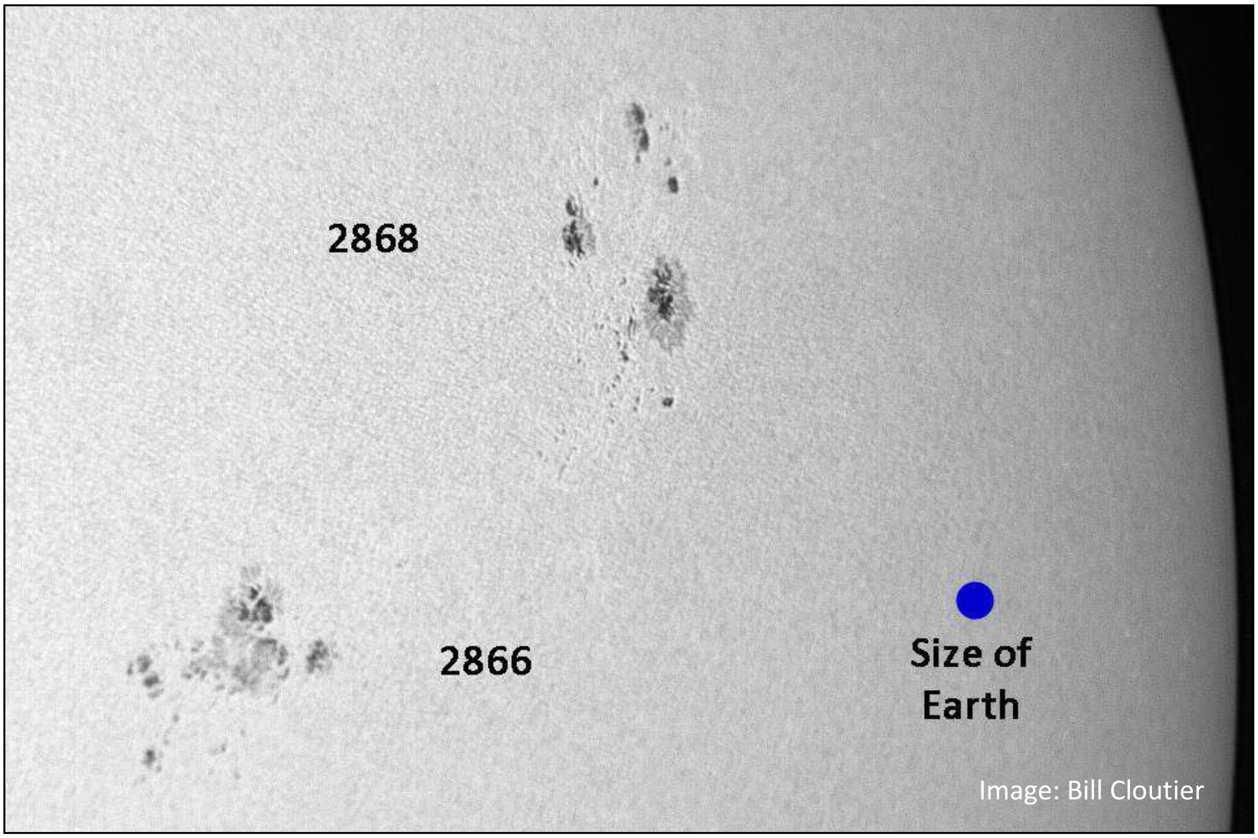
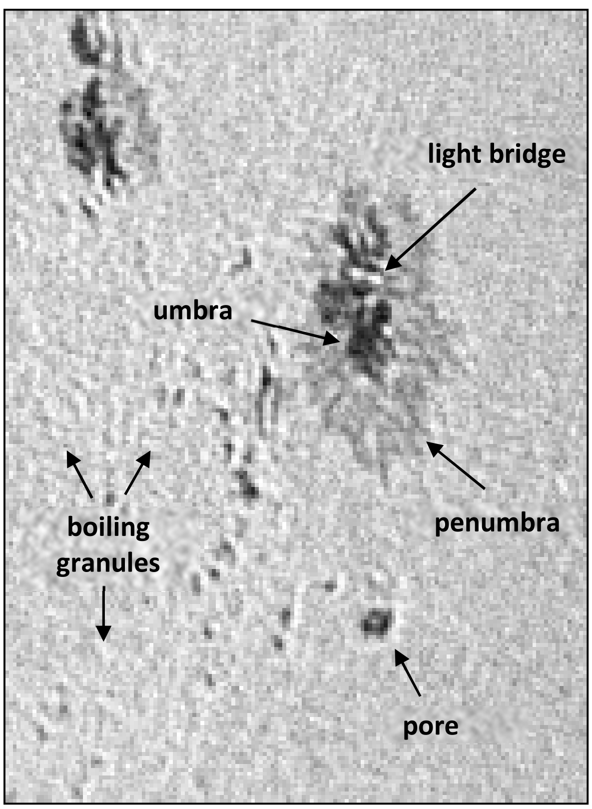
View of Mercury from the ESA/JAXA BepiColombo spacecraft as it executed its first of six flybys of the planet for a gravity assist that will eventually allow orbital capture in 2025.

November Astronomy Calendar and Space Exploration Almanac





The Sun is becoming increasingly active with days where multiple groups of sunspots can be seen. NOAA and NASA had predicted that the current solar cycle (Cycle 25) would peak in the year 2025, but based upon recent indications, it could happen up to a year early.

This image was captured with a 4.25-inch antique refractor (equipped with solar filter) on September 11th. Sunspots appear dark because they are cooler (about 3,000°F cooler) than the surrounding photosphere. A typical sunspot has a dark core (umbra), surrounded by a lighter region known as the penumbra. A narrow piece of the penumbra, spanning the umbra, is called a light bridge. A pore is a small sunspot that doesn't have a penumbra, while boiling granules are columns of gas rising from below the photosphere.

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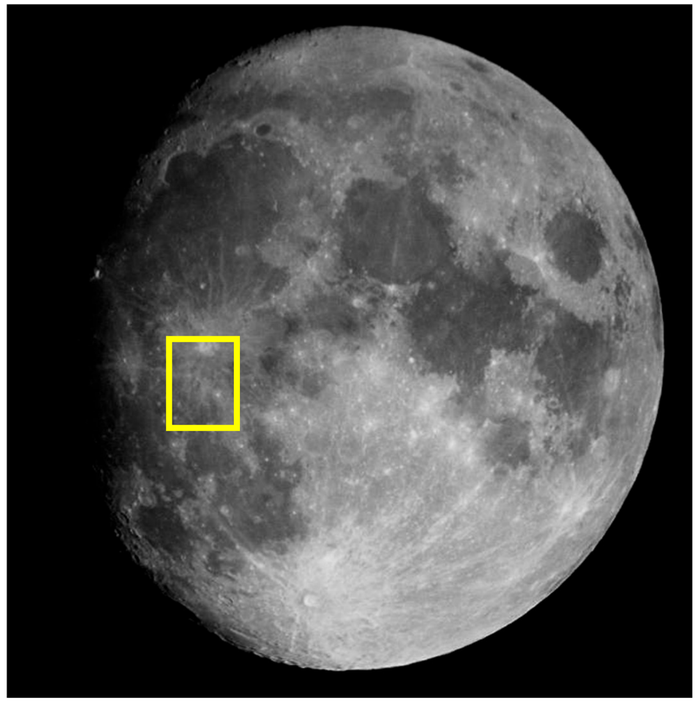
New Milford, CT

“Out the Window on Your Left”

It’s been more than 52 years since Neil Armstrong first stepped onto the moon’s surface and almost 49 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).



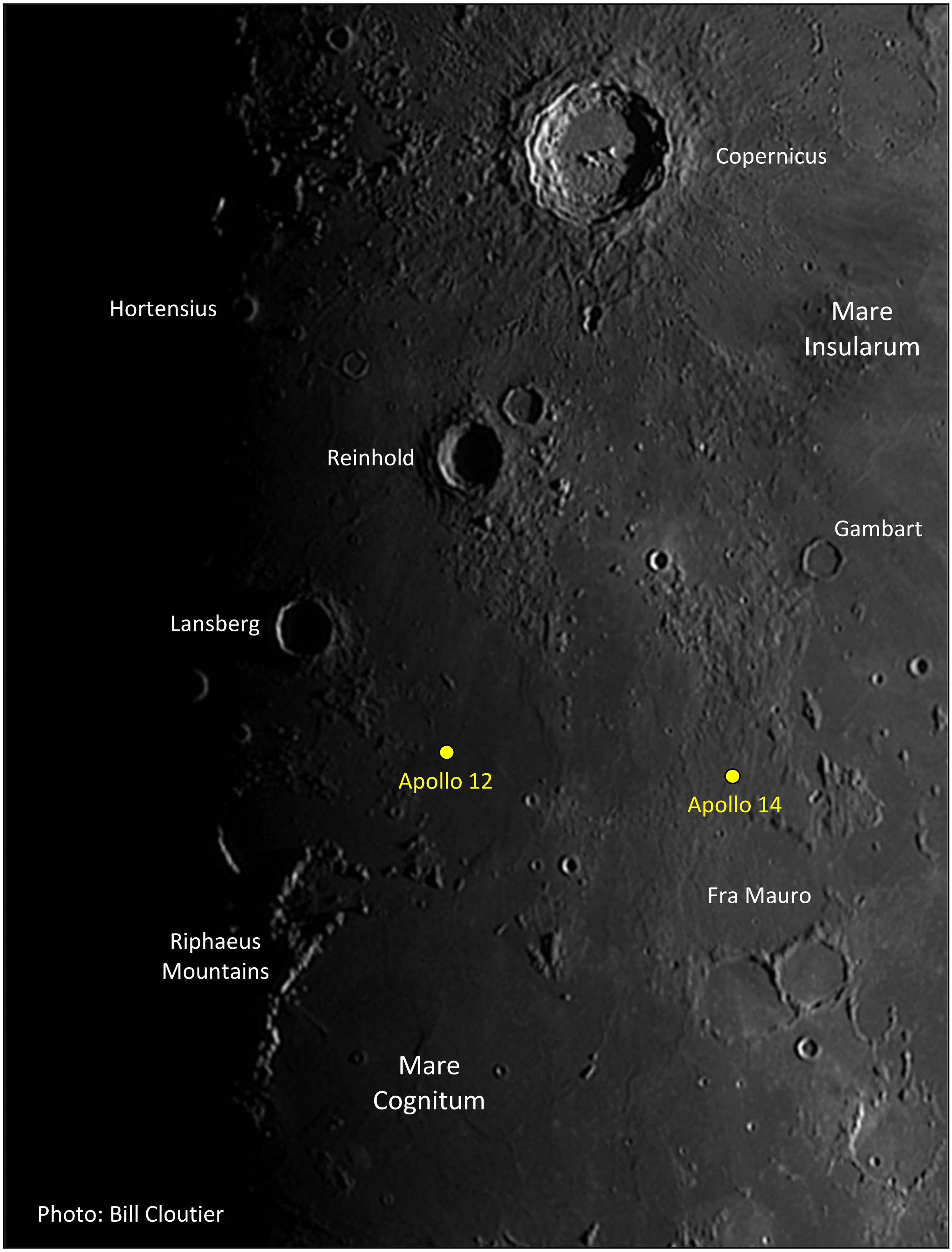
The target landing area of Apollo 12 is visible in this month’s image. The site for the second manned Moon landing was approximately 930 miles (1,500 km) west of the Apollo 11 site and similar in that it offered a relatively smooth terrain. The Apollo 12 site was selected for its proximity to Copernicus crater, 250 miles (400 km) to the north and the ejecta that was believed to have covered the site from that crater’s formation. The location was also home to Surveyor 3, an unmanned robotic spacecraft that landed on the Moon in April 1967.

The crew of the Apollo 12 Lunar Module (Pete Conrad and Al Bean) executed a pinpoint landing on November 19, 1969, setting down 535 feet from the Surveyor spacecraft (to minimize the potential of contaminating the Surveyor spacecraft by the descent engine exhaust or from dust kicked up by the engine, the landing was required to be at least 500 feet away from Surveyor). The Sun was only 6° above the horizon at touchdown, casting long shadows across the volcanic plain and adding sharp relief to the geologic features at the landing site.

Apollo 12 KREEP sample
NASA/Johnson Space Center

Conrad and Bean spent 7 hours and 45 minutes on the surface, in two separate excursions, collecting 75 pounds (34 kg) of rock and soil samples, setting up experiments, and removing pieces from Surveyor for further study back on Earth. The most unusual sample collected by the astronauts was a small rock measuring just 2 inches across (5 cm) comprised of potassium (K), rare earth elements (REE), and phosphorus (P). Referred to as KREEP, this material is believed to have formed early in the Moon’s history when its magma ocean started to crystalize. An enduring mystery is why KREEP deposits are primarily concentrated on the Moon’s nearside.

Apollo 12

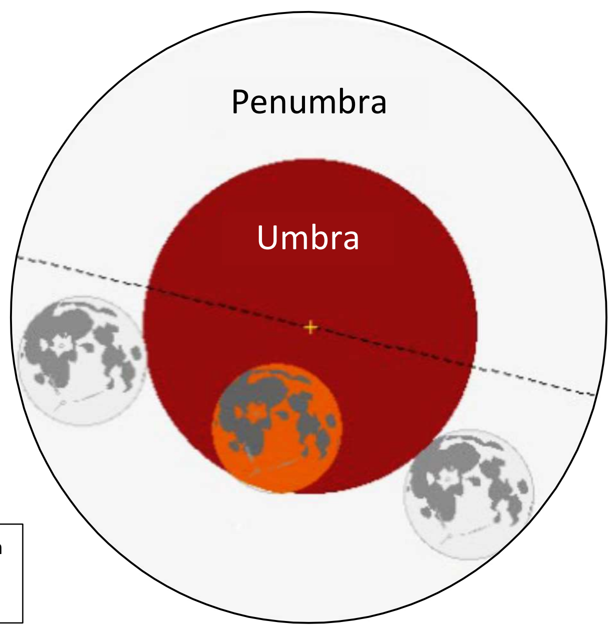

Copernicus
Hortensius
Mare
Insularum
Reinhold
Gambart
Lansberg
Apollo 12
Apollo 14
Fra Mauro
Riphaeus
Mountains
Mare
Cognitum
Photo: Bill Cloutier

Three Percent!

Partially eclipsed Moon
Photo: Bill Cloutier

On the morning of November 19th, the Moon will enter the Earth's umbral shadow (the darkest part of the shadow cast by the Earth), beginning around 2:18 AM EST. At mid-eclipse 97% of the lunar disk will be within the shadow – a not quite total lunar eclipse.

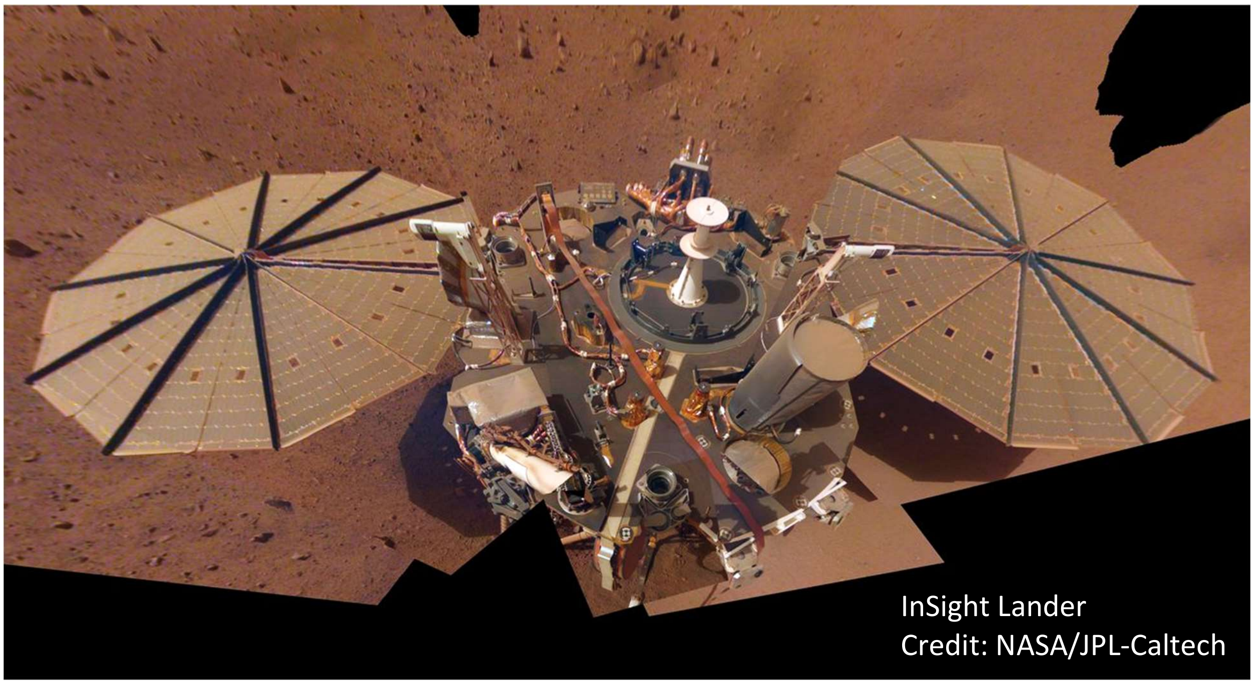
The Moon will spend almost 3-1/2 hours in the shadow, exiting the umbra at 5:47 AM EST. Mid-eclipse occurs at 4:03 AM EST with the Moon 30° above the western horizon, just below the Pleiades in the constellation Taurus. A clear western horizon will be required to see the lunar disk clear the umbra, being only 11° in altitude at that time.



Moon's passage through the umbra on the 19th
Credit: F. Espenak, NASA's GSFC

A Whole Lotta Shaking

Most Los Angeles residents likely discounted a magnitude 4.4 earthquake that shook the area around 0300 GMT on Saturday, September 18th, but when InSight's seismometer detected its largest and longest lasting marsquake since landing on Mars three years ago on the very same day, it caused quite a bit of excitement among project scientists. The marsquake, estimated at magnitude 4.2, shook the ground for nearly 90 minutes and followed two other quakes of magnitudes 4.2 and 4.1 on August 25th. The previous record holder was a magnitude 3.7 quake detected in 2019.



InSight Lander
Credit: NASA/JPL-Caltech

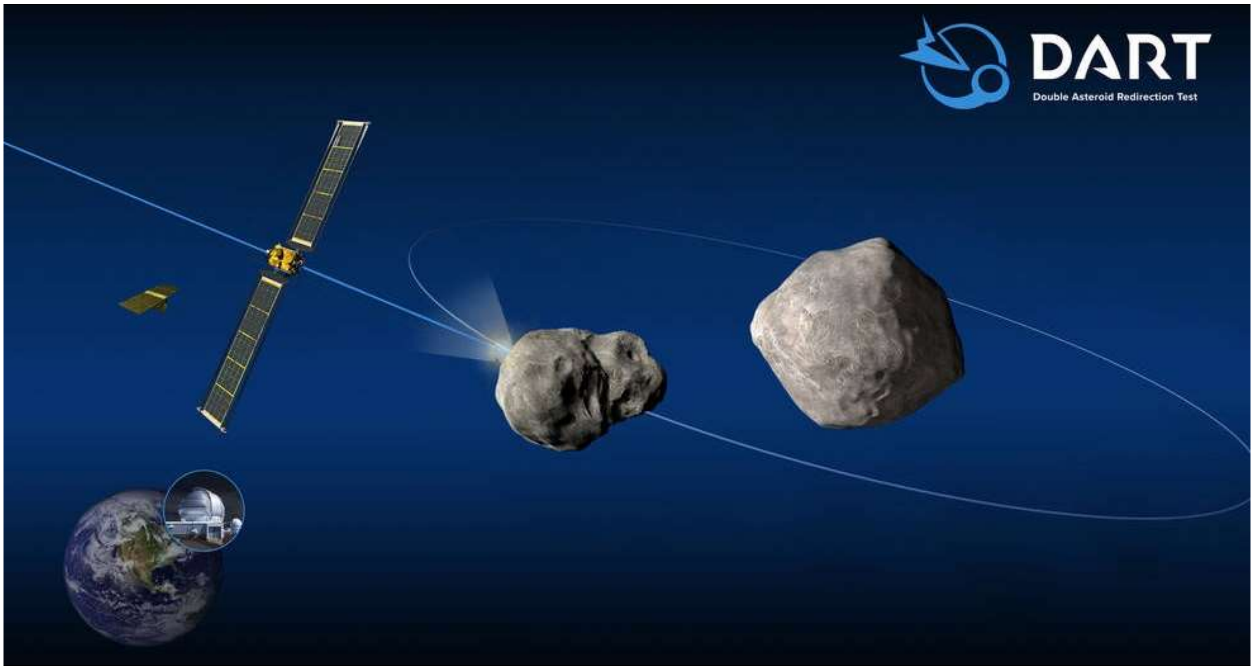
Aside from the larger tremors, the recent marsquakes were different than almost all of the other quakes detected by InSight. Past quakes were centered in the Cerberus Fossae region, roughly 1,000 miles (1,609 km) from the lander - an area where lava may have erupted onto the surface within the past few million years. Data from the September 18th tremor is still being analyzed, but the August 25th 4.2 magnitude quake is projected to have originated 5,280 miles (8,500 km) away, with Valles Marineris, the solar system's longest canyon system, a likely source (the distance to the center of the canyon is 6,027 miles or 9,700 km). The magnitude 4.1 quake was much closer, only about 575 miles (925 km) away.

The August quakes were different in another way – the magnitude 4.2 quake was dominated by slow, low-frequency vibrations, while the magnitude 4.1 quake was characterized by fast, high-frequency vibrations. Scientist use marquake data to model the interior of the planet, noting how the seismic waves change as they travel through the crust, mantle and core. Different kinds of seismic waves and from over a range of distances, reveal information about planet's internal structure. Over the past three years, scientists have used marquake date to estimate the thickness and depth of the Red Planet's internal layers, as well as the size of its molten core.

Power has been a developing issue with the InSight lander, with its dust-laden solar panels. Had the project team not devised an unorthodox method to shake some of the dust loose and improve power levels, detection of the latest quakes might not have happened. However, since July 12th, Mars has been moving closer to the Sun – which should provide some much-needed solar gain.

Making an Impact – A Planetary Defense Demonstration

NASA will launch its first kinetic impact mission in November. Targeting a small moonlet of the near-Earth asteroid (65803) Didymos, scientists anticipate being able to measure the change in the moon's orbital velocity as a result of the planned collision with the spacecraft. Called DART (for Double Asteroid Redirection Test), the demonstration is intended to evaluate one potential option for preventing an impact of Earth by a hazardous asteroid.



Schematic of the DART mission shows the impact on Didymos' moonlet Dimorphos in 2022
Credits: NASA/Johns Hopkins Applied Physics Lab

The asteroid Didymos is approximately 2,560 feet (780 meters) across. It was discovered in April of 1996 with an orbital period of about 2 years. The asteroid's orbit approaches that of Earth, at its closest point, and carries it just beyond Mars at its farthest. Didymos rotates about its axis once every 2.26 hours. The physical properties of the asteroid are fairly well known as a result of radar imaging by the Arecibo facility in 2003. Separated by about 0.62 miles (1 km), a moonlet called Dimorphos revolves around Didymos every 11.9 hours. At about 525 feet (160 meters) in size, it is tidally locked with the larger asteroid.

The launch window opens for the DART mission on November 24th. The spacecraft will launch from the Vandenburg Space Force Base on a SpaceX Falcon 9 rocket. In late September 2022, the DART spacecraft will intercept Didymos and Dimorphos at a distance of 6.8 million miles (11 million km), close enough for observations by ground-based telescopes on Earth.

The ion-engine-powered spacecraft, with its two long solar panels extending 62 feet (18.9 meters) from wingtip to wingtip, will impact Dimorphos at about 4 miles per second (6.6 kps). The collision is expected to change the orbital period of the moonlet by a fraction of one percent (several minutes). The Didymos system is an eclipsing binary (as viewed from Earth) so astronomers will be able to measure the changes in the two-body system post-impact - as compared to their current orbital elements.

American and Italian engineers attach the CubeSat to the DART spacecraft
Credits: NASA/Johns Hopkins APL/Ed Whitman

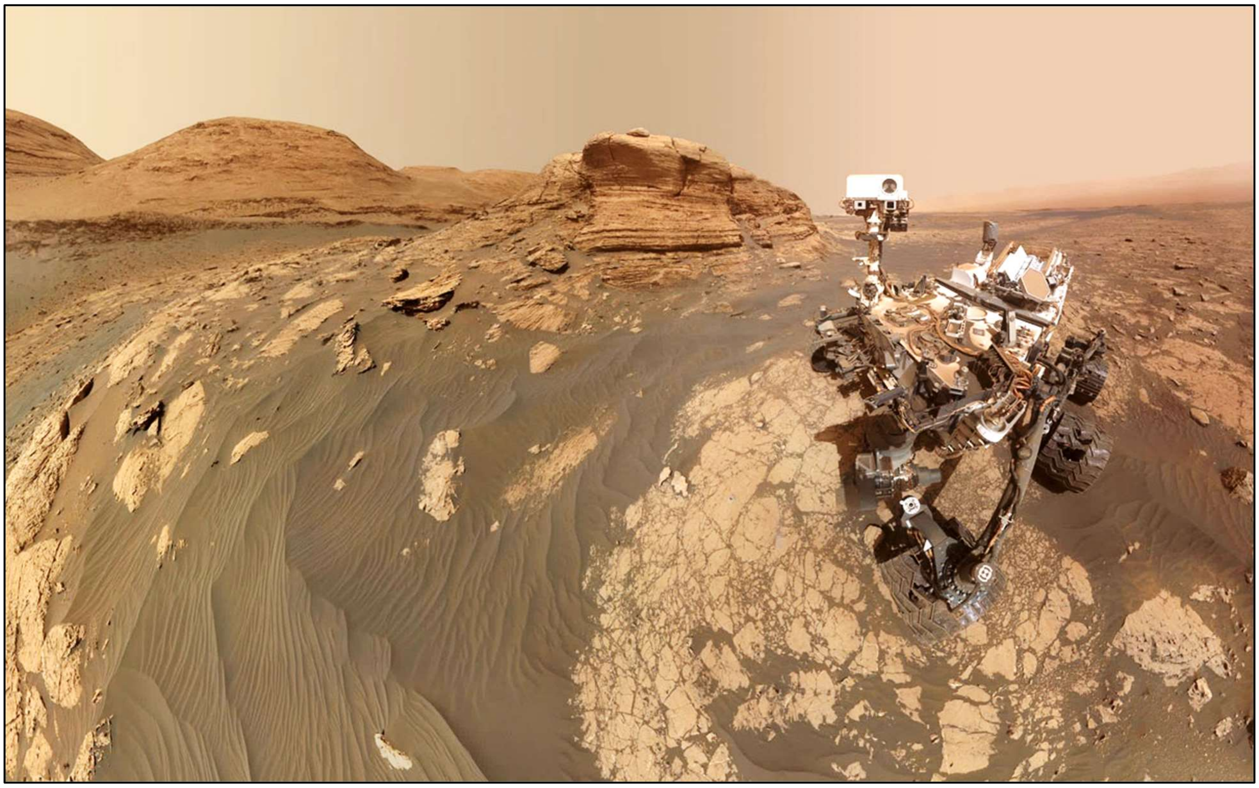
The approach to the binary asteroid will be recorded by the spacecraft's main imager – the Didymos Reconnaissance and Asteroid Camera for Optical navigation or DRACO. The actual impact and aftermath will be recorded by a small, solar-powered 31-pound (14 kg) CubeSat. The miniature spacecraft is equipped with two optical cameras. Deployed 10 days prior to impact, the contribution from the Italian Space Agency will have a front row seat for the impending collision. Its onboard propulsion system will be used to alter its trajectory so that it arrives about three minutes after the impact. That will allow it to record the ejecta plume and any resulting crater.

DART is powered by Roll-Out Solar Arrays, a new technology that was first tested on the ISS in 2017. The flexible and rollable modular panels, which will unfurl to a length of 28 feet, are lighter, stiffer and more compact than traditional arrays.

ISS Demonstration
Credit: NASA

Moving On Up

Over nine Earth-years on Mars and more than seven since reaching the base of Mount Sharp, NASA's Mars Science Laboratory, named Curiosity, has been working its way up the 3.4-mile (5.5 km) mountain in the center of Gale crater. Its well-worn rover wheels have covered over 16 miles (26 km) navigating the challenging terrain.

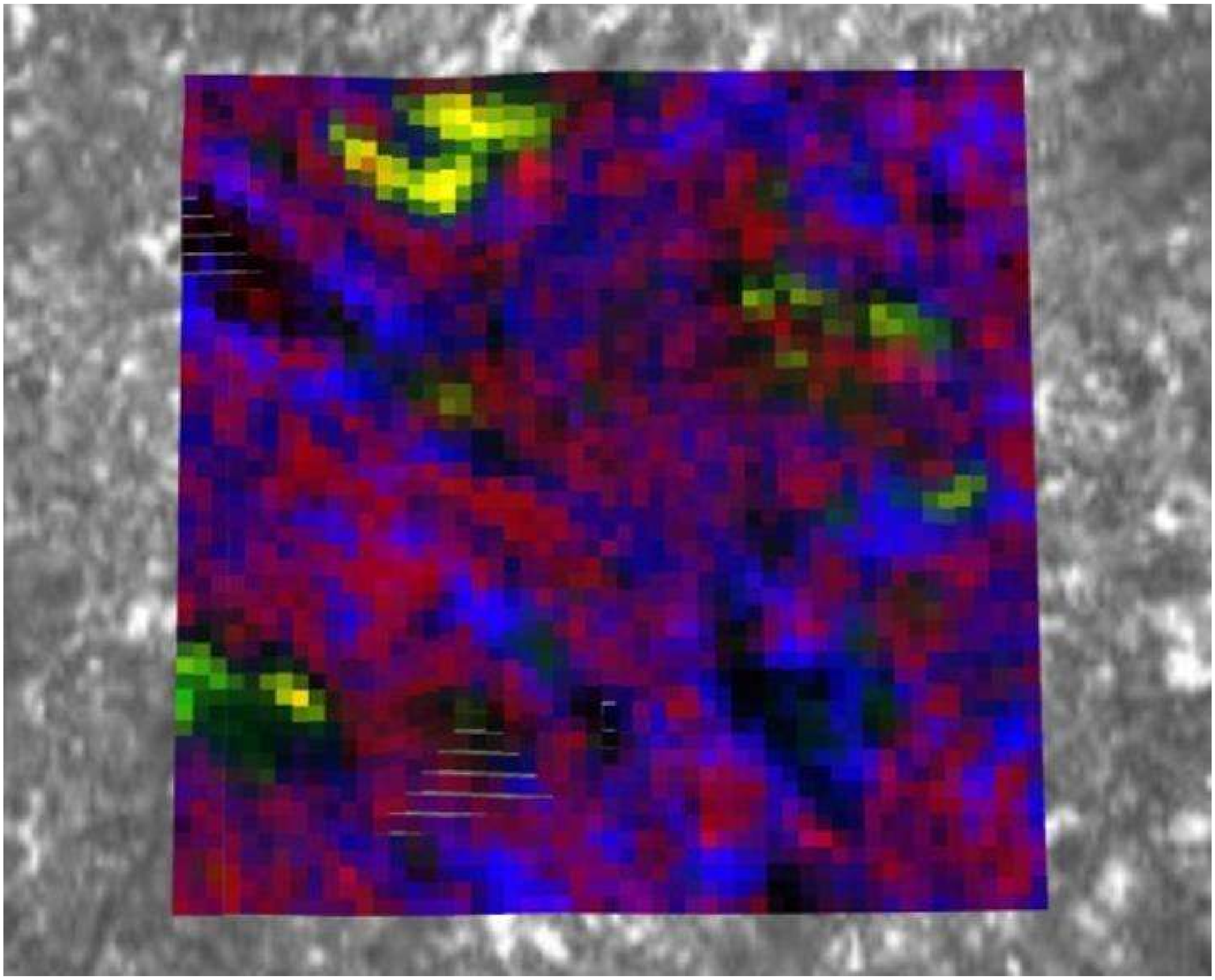


Curiosity poses in front of Mont Mercou, a rock outcrop that stands 20 feet (6 meters) tall, for a selfie created from a camera on its mast, as well as one on the robotic arm.
Credits: NASA/JPL-Caltech/MSSS

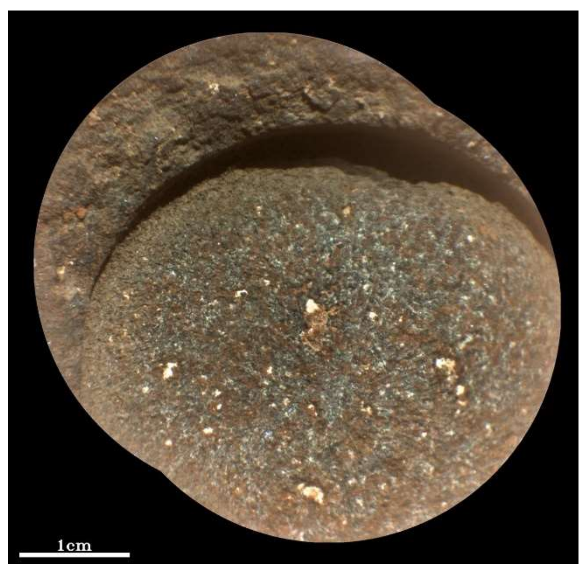
The mountain is a geologic time capsule, recording changing conditions on the planet in its rock layers and chemistry, as it went from a wet and warm world to one dry and cold. Curiosity has found conclusive evidence that the crater once held a lake (the crater was created by an asteroid strike some 3.6 billion years ago). Around the rover's landing area, the mineral-rich clay layers showed signs of being altered, likely by briny (very salty) water (clays typically form in the presence of liquid water and are also an excellent substance for preserving microbial fossils).

Curiosity also encountered clays on Mount Sharp's lower slopes. As it climbed higher, the rover has observed changes in the rock strata - gathering samples and collecting corings of rock, mudstone and other intriguing geology (the rover recently used its wheels to crush some nodules so that Earth-bound geologists could see inside). The mobile lab has also discovered organic chemicals (the carbon-containing building blocks of life) and detected several methane bursts – the source of which still remains a mystery. Despite the number of miles on the odometer, the mission team expects that Curiosity will operate for several more years. The rover is currently climbing out of the region enriched with clay minerals and into one dominated by sulfates – signaling a past environmental transition from wet to dryer conditions.

Martian History in a Grain of Salt



Salt crystals (yellow pixels) in abrasion target
Credit: NASA/JPL/Caltech/DTU/UW/QUT



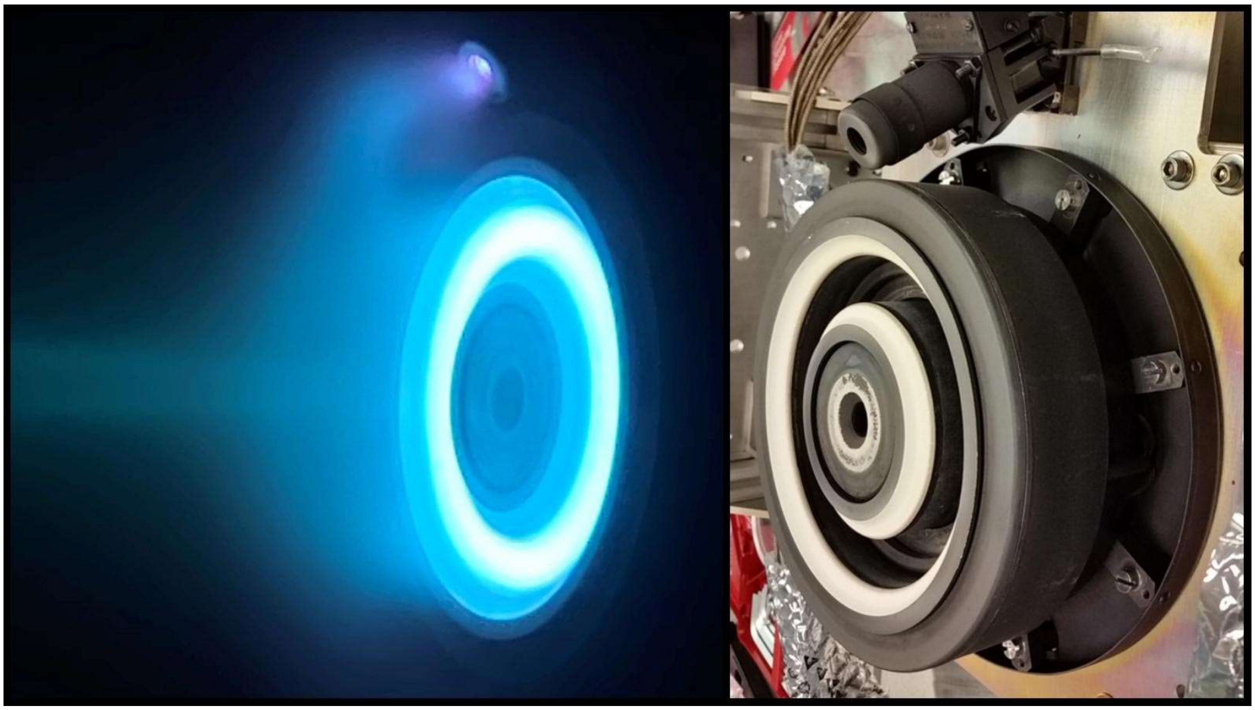
Two-inch (5 cm) diameter abrasion
Credit: NASA/JPL-Caltech/LANL/CNES/ IRAP

NASA's Perseverance rover successfully acquired two samples in early September from a rocky ridge in Jezero crater. In preparing the target for sampling (coring), the rover uses an abrading bit to remove the dust covered and weathered surface.

Before coring, the rover placed PIXL, an instrument located at the end of Perseverance’s 7-foot long (2-meter) arm on the target. PIXL, short for Planetary Instrument for X-ray Lithochemistry, has a very narrow X-ray beam that can be used to search for chemical fingerprints left by ancient microbes. In this instance PIXL detected salt crystals that could contain bubbles of ancient water - revealing more about the climate in which they formed.

Electric Propulsion

The Ad Astra Rocket Company set a record earlier this year when its VASMIR® electric rocket engine operated at a power level of 82.5 kW for 28 hours during a test at the company's Texas research facility near Houston. It is a long way from the 200 MW cited as the power needed for a 39-day flight to Mars, but a significant step toward the 100- kW/100-hours milestone set by NASA. According to the company, the VASMIR® engine can provide the high power of a chemical rocket engine, but with 10 times the fuel efficiency.



The blue glow from an operating electric Hall-effect thruster (left) is a characteristic of the xenon plasma discharged by the engine. The thruster (right) will be used to power NASA's Psyche spacecraft to the asteroid belt.
Credit: NASA/JPL-Caltech

The thrust in an electric-propulsion engine is provided, in general, by either electrothermal, electrostatic or electromagnetic means. Ion and Hall-effect thrusters (a type of ion thruster where the propellant is accelerated by an electric field) have been used in limited application since the 1960s, initially as a means of satellite station-keeping.

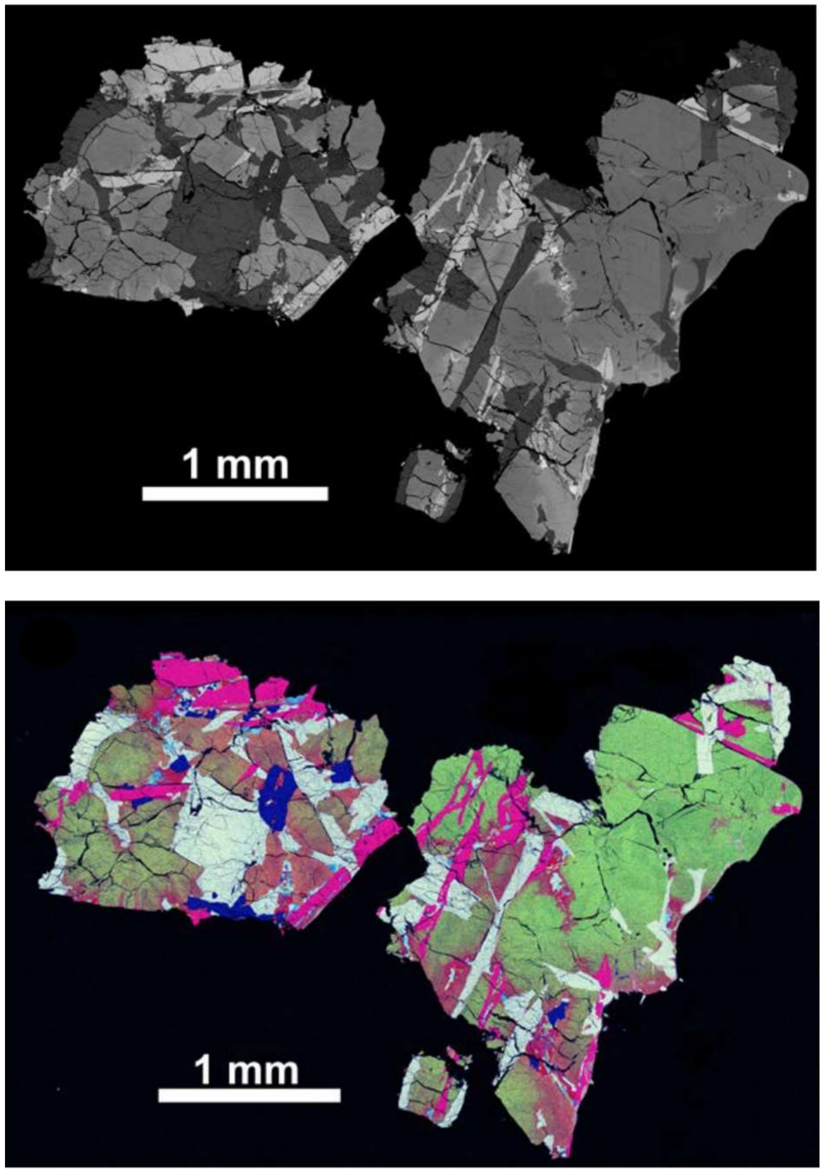
NASA's Deep Space 1, in 1998, was the first spacecraft that used an ion engine as its primary method of propulsion, successfully rendezvousing (fly-bys) with both Asteroid 9969 Braille and then Comet 19P/Borrelly. The technology would later be used by the Dawn spacecraft to visit the asteroid Vesta, before traveling to the dwarf planet Ceres.

The Psyche spacecraft, scheduled to launch in August 2022, will be the first time that Hall-effect thrusters have been used beyond lunar orbit. The spacecraft's thrusters will be powered by its solar arrays that will convert sunlight into electricity. The thrusters will use xenon gas to create the thrust that will propel the spacecraft and reach the main asteroid belt between Mars and Jupiter where Asteroid 16 Psyche is located – a journey of three and one-half years.

A Lunar Mystery

In December 2020, a capsule containing material collected from the Moon's surface by the Chang'e-5 spacecraft landed in Inner Mongolia. Nearly 4 pounds (1.73 kg) of rock and regolith were returned from the northwest region of Oceanus Procellarum (Ocean of Storms), not far from the volcanic outcropping Mons Rümker.

To date, only 1% of the sample has been examined by Chinese laboratories; however, papers published in the journals Nature and Science within the past month reveal some of the findings of the ongoing analysis that raise puzzling questions about the Moon's past.



Back-scattered electron image and false color energy dispersive spectroscopy element map of a fragment from the Chang'e 5 sample. Qualitative concentration and distribution of different elements in the sample are represented by different colors: blue=silica, green= magnesium, red=iron, white=aluminum, yellow=calcium, pink=titanium, cyan=potassium.
Credit: Beijing SHRIMP Center

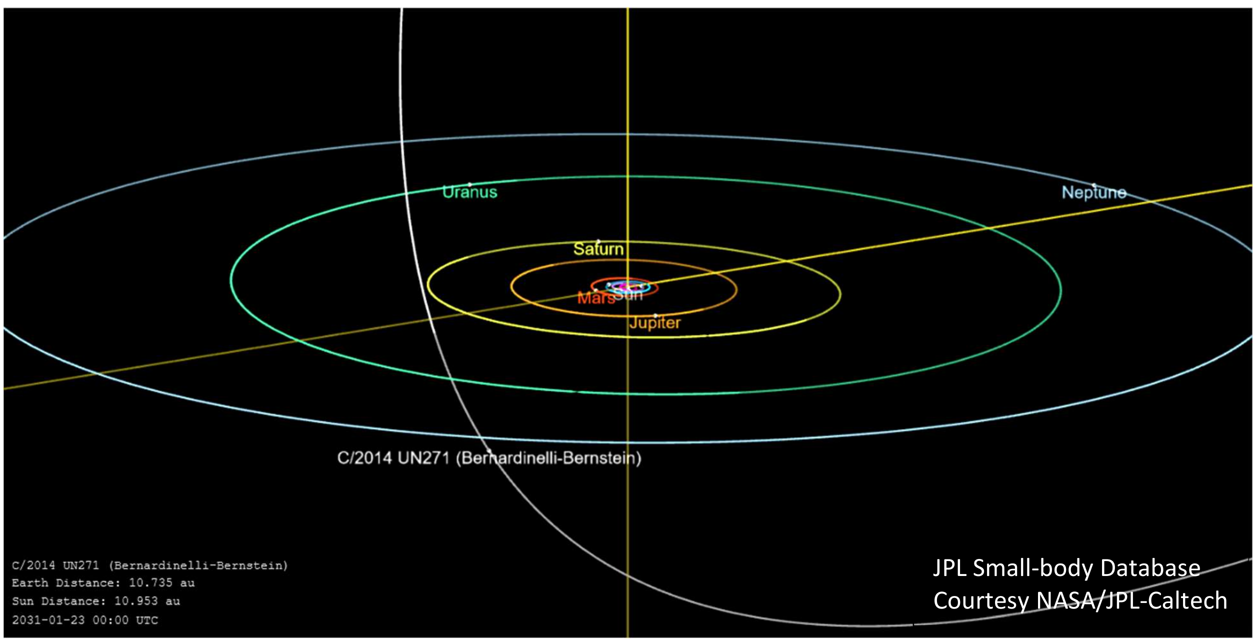
Scientists had thought that lunar volcanism tapered off 3 billion years ago as the Moon cooled (basalt samples returned by Apollo 11 ranged in age from 3.6 to 3.9 billion years). However, radioisotopic analysis of the Chang'e-5 basalt samples indicates a crystallization age closer to 2 billion years. Most unexpected - the samples are iron-rich, magnesium and water deficient, and appear to have been produced by an as-of-yet undetermined heat source (the temperature of basaltic magmas can exceed 1,800°F or 1,000°C) inside a Moon thought to be geothermally cold.

The basaltic lavas in Oceanus Procellarum are rich in heat-producing elements such as potassium, uranium and thorium (the heat is generated from radioactive decay). The samples analyzed; however, suggest that the young basalt came from a source near the mantle containing lower levels of these heat-producing elements – indicating that the Moon may have cooled at a slower rate.

Messenger from the Past

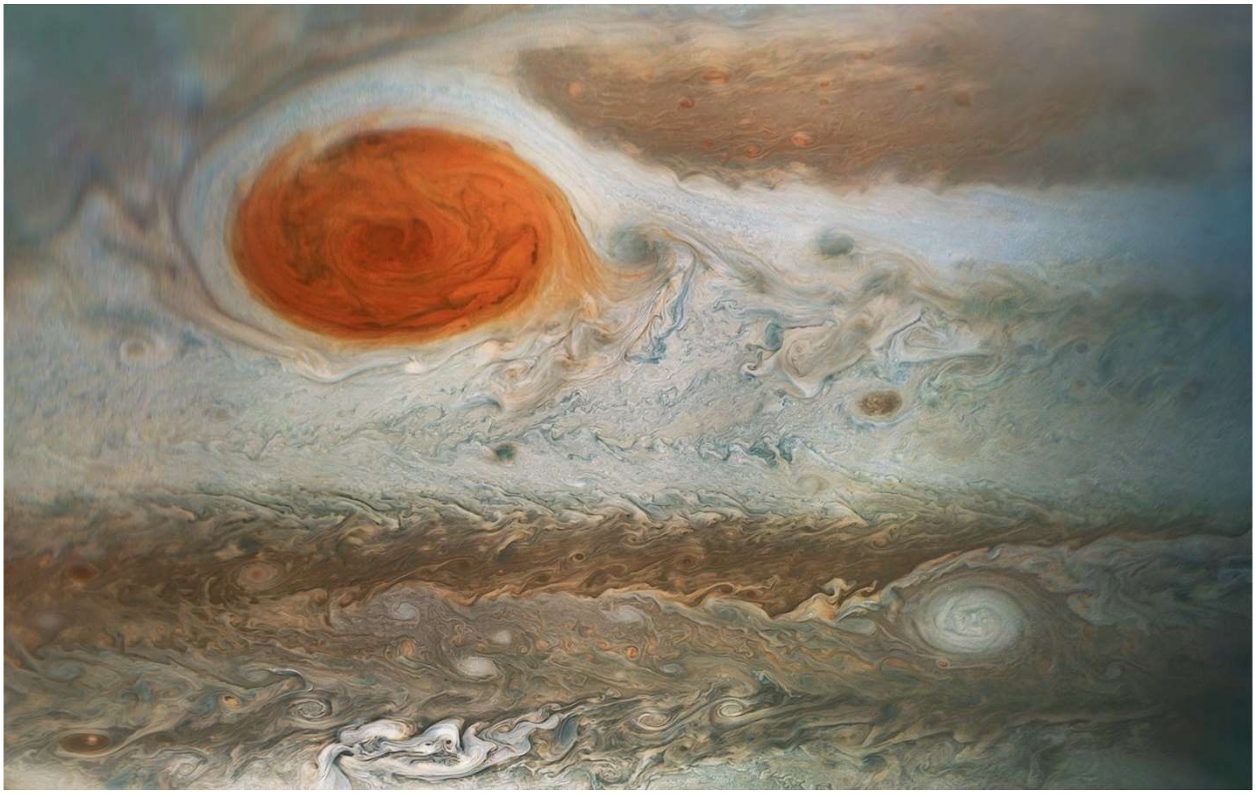
The Dark Energy Survey was a five-year international and collaborative effect to quantify the distribution of dark matter and the effect of dark energy on the acceleration of the expansion of the Universe. The survey involved mapping of 300 million galaxies in the southern sky in the infrared and near-infrared using an extremely sensitive 570-Megaixel digital camera mounted on a 4-meter telescope at the Cerro Tololo Inter-American Observatory in Chile. In a subsequent search of the 80,000 exposures, more than 800 previously unknown objects located beyond the orbit of Neptune were also discovered in the images - including one truly massive comet.

The comet, designated C/2014 UN271 (Bernardinelli-Bernstein), is inbound from the Oort Cloud region (a spherical reservoir of ancient, icy bodies believed to surround our solar system and extend one-quarter to halfway to the nearest neighboring star) for the first time in more than 3.5 million years. Estimated to be 96 miles (155 km) in size, astronomers believe that Bernardinelli-Bernstein started its approach from a distance of 40,400 astronomical units (±260) from the Sun (1 astronomical unit or au is the mean distance between the Earth and Sun). the comet was discovered in 2014 - 29 au from the Sun (the planet Neptune orbits at a distance of about 30 au).



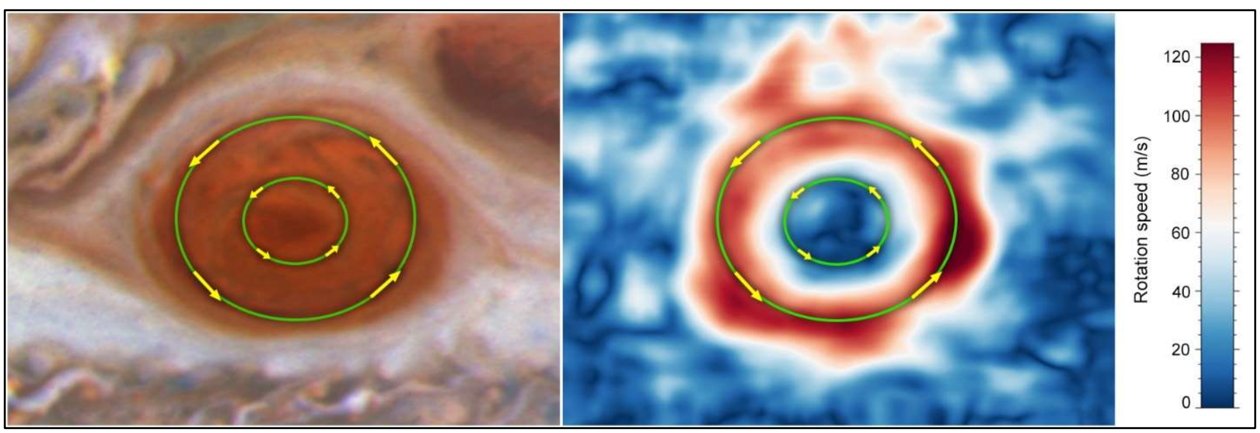
This isn't the first time that Bernardinelli-Bernstein has visited the inner solar system since being ejected from the Oort Cloud; however, there is no evidence for the comet coming any closer than 18 au to the Sun in the past – making it one of the most pristine bodies ever observed (i.e., unaltered by the Sun's heating). The comet will make its closest approach to the Sun in early 2031, at a distance of 10.97 au (just beyond Saturn's orbit). It has already shown signs of activity (images taken by the Transiting Exoplanet Survey Satellite in 2018, when the comet was at 23.8 au, showed signs of a coma). The coma, or cloud of gas and dust surrounding the comet's core, has been confirmed by astronomers at the Las Cumbres Observatory, who also recently reported an apparent outburst from the comet in June. Astronomers are already marshaling their resources (including the possibility of using the James Webb telescope, scheduled to be launched in December) for an intense observing campaign that they hope will tell us about the conditions in the early solar system, some 4.5 billion years ago, and the chemistry of the outer realm during a time period when planets were forming.

Spinning Up



A color-enhanced composite image of the Great Red Spot captured by the Juno spacecraft
Image credits: NASA/JPL-Caltech/SwRI/MSSS/ Gerald Eichstädt /Seán Doran © CC NC SA

Researcher's analyzing Hubble Space Telescope observations of Jupiter have found that the average wind speed in the outer regions of Jupiter's Great Red Spot is speeding up – an increase of 8% from 2009 to 2020 - now exceeding 400 mph (650 kph). The winds in the inner most region; however, are moving more slowly. The winds in both regions move counterclockwise.

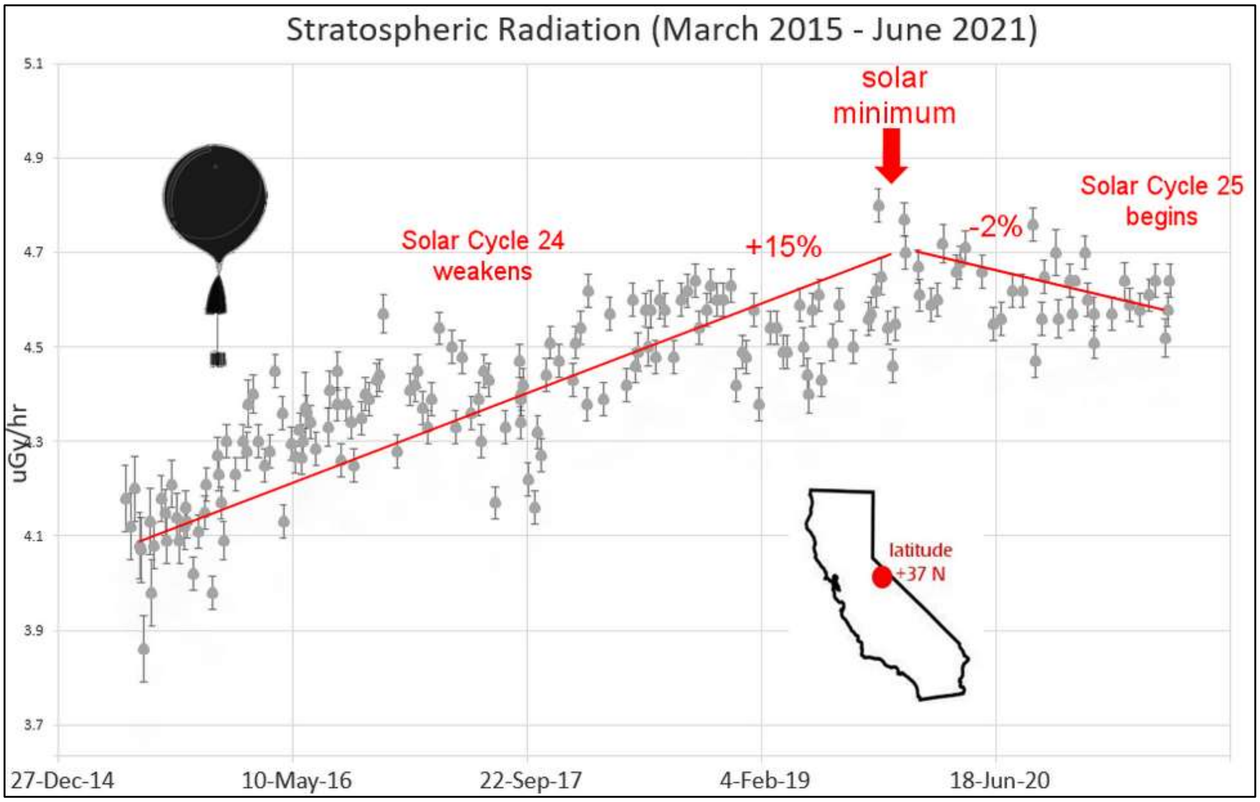


Credits: NASA, ESA, Michael H. Wong (UC Berkeley)

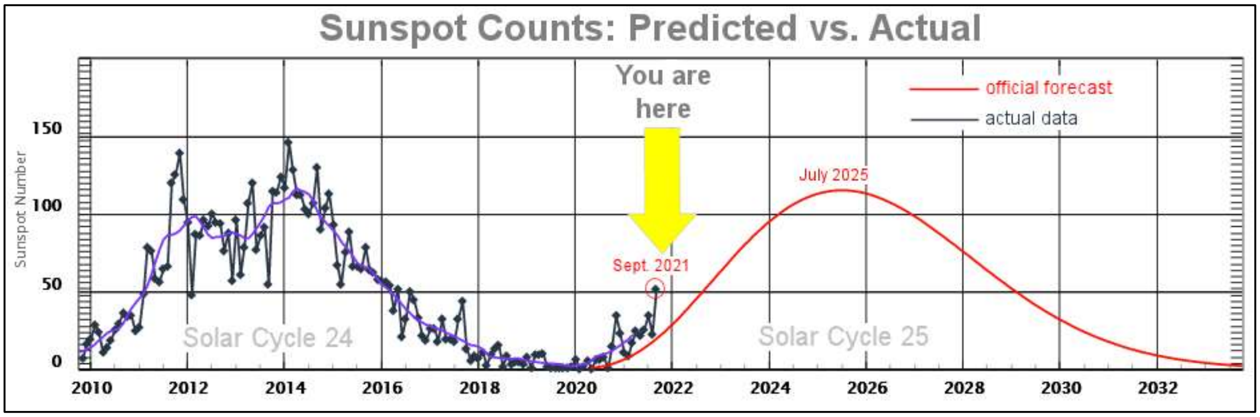
While Jupiter's Great Red Spot is still larger than the Earth, with a current diameter of 10,000 miles (16,000 km), the overall size of the anticyclonic storm has been shrinking and becoming more circular in shape (than oval) based on observations that date back to the 1870s.

Solar Cycle 25

The eleven-year solar cycle, triggered when the Sun's magnetic fields completely flips, is beginning again, and progressing ahead of predictions. Cycle activity is indicated by changes in the activity on the Sun's surface (photosphere), such as sunspots, and the growing strength of the Sun's magnetic field, which deflects incoming cosmic rays from galactic sources.

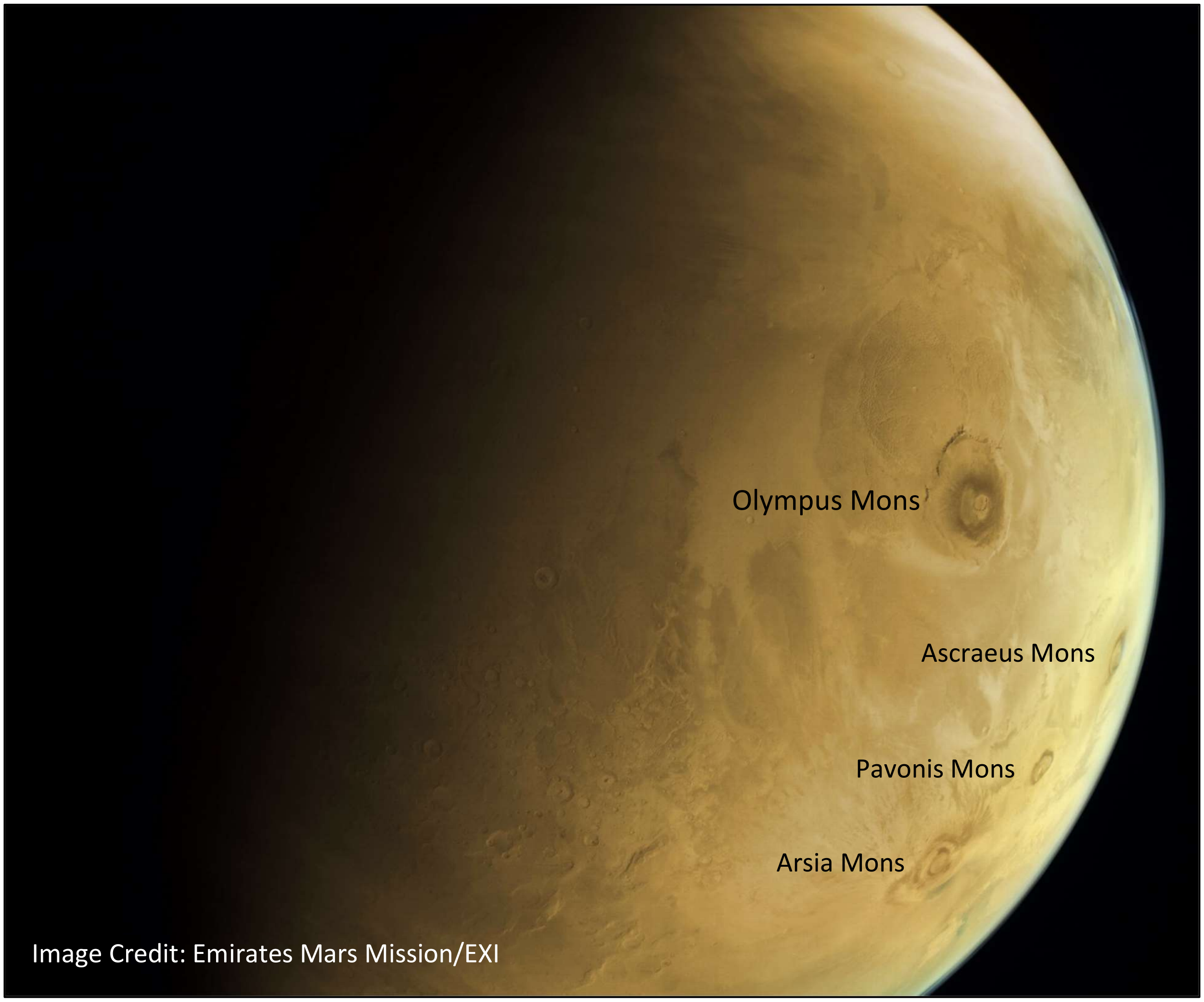


Decline in cosmic radiation over California correlates with the reawakening of solar activity
Credit: Spaceweather.com and the students of Earth to Sky Calculus



Sunspot counts over time. Initial predictions were for a relatively weak Solar Cycle 25, peaking in mid-2025. To date, higher than expected sunspot numbers suggested a stronger cycle and an earlier peak (late 2024).
Credit: NOAA/NASA

Martian Shield Volcanos



Mars is home to the largest volcano in the solar system – Olympus Mons. Two and a half times the height of Mount Everest, and 100 times larger than Mauna Loa on Earth, the base of the shield volcano is nearly the size of the state of Arizona. The peak actually rises above the Martian atmosphere and is easily seen from space, when not obscured by clouds of water ice or shrouded by dust storms.

The image of Mars (above) was captured by the Hope orbiter, the United Arab Emirates and the Arab world's first venture into interplanetary space. The spacecraft was launched on July 19, 2020 aboard a Japanese rocket and arrived in orbit around the Red Planet on February 9, 2021. Its mission focuses on Martian weather in an effort to understand how it changes over time and if those changes contributed to the loss of the bulk of the planet's atmosphere.

Hope travels in a unique and highly elliptical orbit, completing one circuit around the planet's equator every 55 hours and coming as close as 12,000 miles (20,000 km) of the Martian surface and as far away as 27,000 miles (43,000 km). Its orbit allows the spacecraft's instruments to view the entire world and capture some spectacular images, such as the one of Olympus Mons and the three smaller shield volcanos Ascraeus Mons, Pavonis Mons, and Arsia Mons, seen on the limb, which was taken from an altitude of 8,100 miles (13,000) km.

Twenty-One Years of Living in Low-Earth Orbit

In the President's 1984 State of the Union Address, Ronald Reagan directed NASA to build an international space station within the next 10 years. The first segment; however, wouldn't be launched until the end of 1998 when the Russian Zarya module was placed into orbit. Thirty-six space shuttle flights and five Russian launches were required to complete the station - the last major components were delivered by the space shuttle Atlantis in 2011.

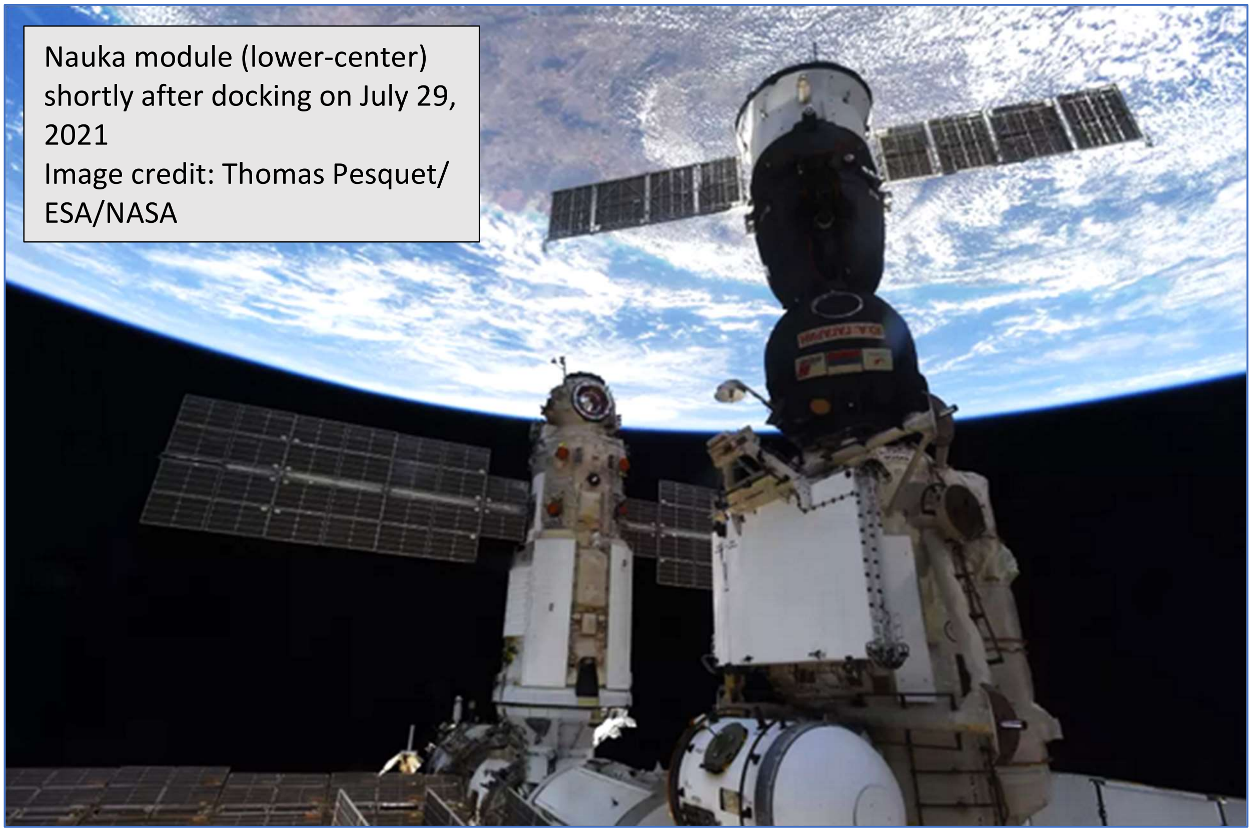
The start of continuous occupation of the International Space Station (ISS) began on November 2, 2000 when a Russian spacecraft Soyuz TM-31 delivered the Expedition 1 three-person crew (astronaut Bill Shepherd and cosmonauts Yuri Gidzenko and Sergei Krikalev) to the station. In 2000, the journey from launch pad at the Baikonur Cosmodrome to the ISS took two days – in October 2020, with continuous improvements in rendezvous techniques, a Soyuz spacecraft arrived at the ISS in just three hours.

In 2000, the ISS consisted of the Russian Zarya cargo and Zvezda service modules, U.S. Unity module and the Z1 (Zenith) truss that would be one of the future attachment points for solar arrays, thermal control radiators and external payloads. During the crew's 136-day stay (which ended in March 2001), station construction accelerated with components and equipment delivered by three space shuttles and two Russian Progress resupply vehicles. The first set of solar arrays was installed in December 2000 and the Destiny Laboratory Module, the primary research laboratory for the U.S., in February 2001. The European Space Agency's Columbus Laboratory module and the first Japanese Kibo laboratory module joined the station in 2008. Astronauts and cosmonauts have conducted more than 227 spacewalks in support of space station construction and maintenance since 1998.

The completed station is 357 feet (109 meters) from end to end (about the size of an American football field including the end zones). Orbiting about 250 miles (402 km) above the Earth at 17,500 mph (28,000 km/hour), astronauts experience 16 sunrises and sunsets during each orbit of the Earth. Four pairs of solar arrays, each spanning 240 feet (73.2 meters), provide 70 to 90 kilowatts of power for station operations. The station's habitable volume is 13,696 cubic feet (388 cubic meters), not counting visiting vehicles (eight spacecraft can be connected to the station at once). An international crew of six typically live and work on the station, hosting almost 3,000 research investigations from scientists and researchers in more than 100 countries. Areas of investigation include biology and biotechnology, Earth and space science, educational activities, human research, physical science and technology development. In 2005, Congress designated the U.S. portion of the station as a national laboratory to encourage its use by academic and private institutions.

The station is showing its age and NASA has recently embarked on a program to upgrade the power collection system (the first pair of solar arrays have been in operation since December 2000) which is showing signs of degradation. NASA has begun to install six new and smaller roll-out solar arrays to supplement the existing, larger arrays. Positioned in front of the current arrays, the new arrays will use the existing sun tracking, and power distribution systems. Once installed, they will provide a 20% to 30% increase in power for station operations – comparable to the power production of the original arrays when newly installed.

Russia recently delivered the long-awaited-for Nauka module. The 43 foot long (13 meter), 20-tonne science module was originally scheduled to launch in 2007, but has been delayed due to budget issues and technical problems during development. Problems continued after launch when a computer glitch prevented an orbit-raising maneuver, but the module was finally docked to the ISS on July 29. Unfortunately, a few hours after docking, the module's thrusters began an uncontrolled firing – spinning the football-sized station 1-1/2 revolutions before ground controllers were able to regain control. Thrusters on other modules docked to the ISS were used to flip the station over to its normal configuration.



Nauka module (lower-center) shortly after docking on July 29, 2021
Image credit: Thomas Pesquet/ ESA/NASA

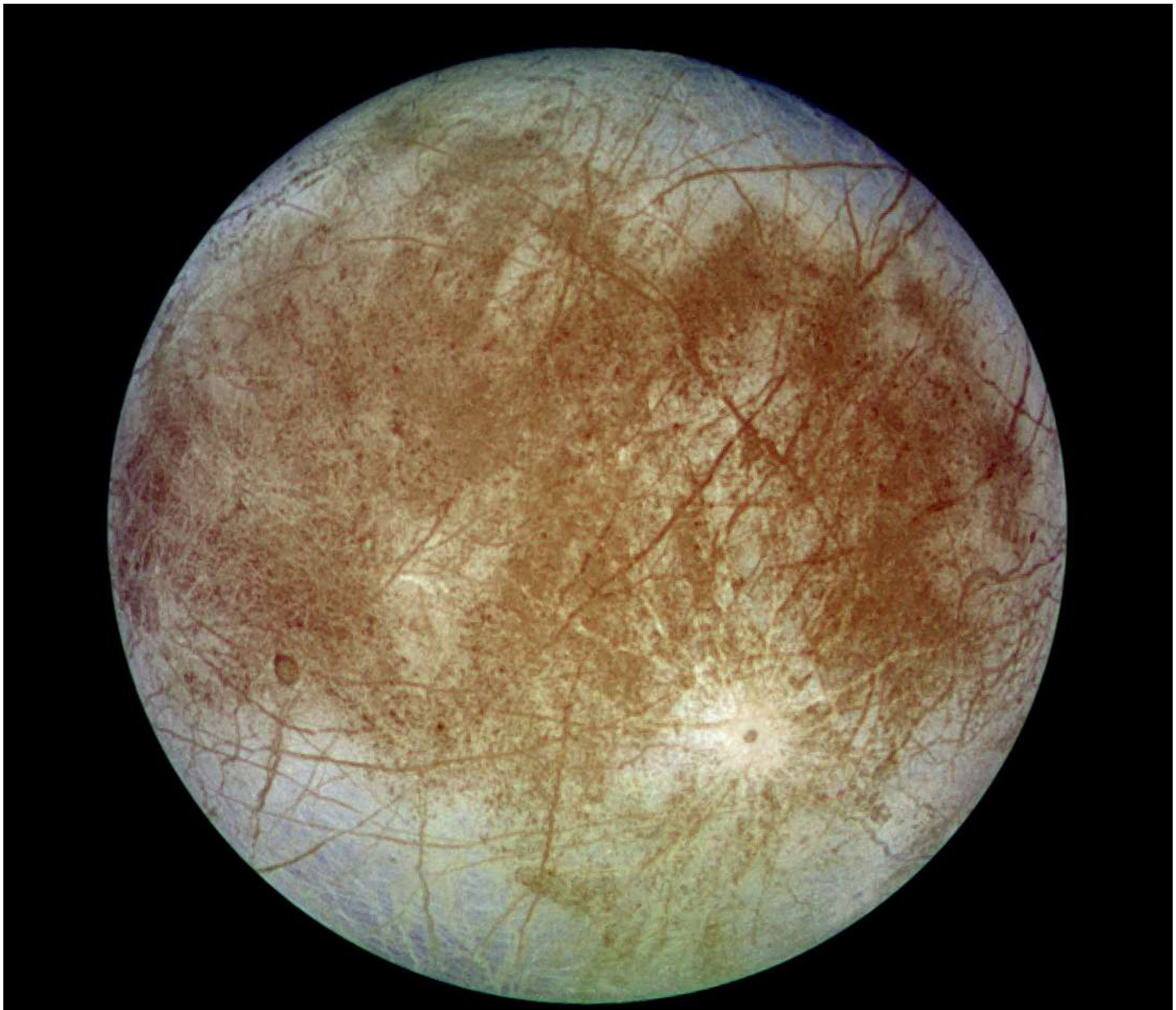
To make room for Nauka, Russia jettisoned the Pirs docking port. Docking capability should be restored with the launch of the Russian Prichal module in late November.

Axiom Space, Inc., a privately funded American space company is designing its own space station modules. NASA has given the company a contract to provide at least one habitable spacecraft to attach to the ISS. Axiom is also flying history's first private ISS mission. The 10-day mission is currently scheduled for February 21, 2022 with 3 paying passengers flying aboard a SpaceX Crew Dragon on a mission commanded by former NASA astronaut Michael López-Alegría.

Axiom's long-range ambitions are to deliver several components, including a node module, a research and manufacturing facility, a crew habitat, and a "large-windowed" module for viewing the Earth. According to their website, once fully assembled, Axiom's addition will nearly double the useable volume of the ISS. It is also the company's intention that, once the decision is made to decommission the ISS, the Axiom segment could be detached and, with the addition of a power module and airlock, be transformed into the first private/commercial space station. The first Axiom module could be launched as early as 2024, with two additional modules to follow (should the ISS continue to operate for another decade).

A Europa Enigma

Among the notable discoveries of NASA's Galileo mission during its eight years orbiting Jupiter was evidence for the existence of a saltwater ocean beneath the icy surface of the Jovian moon Europa. While that mission ended in 2003, there are plans to return to the moons of Jupiter with the European Space Agency's JUpiter ICy moons Explorer (JUICE) planned for launch in 2022, followed by NASA's Europa Clipper in 2024.

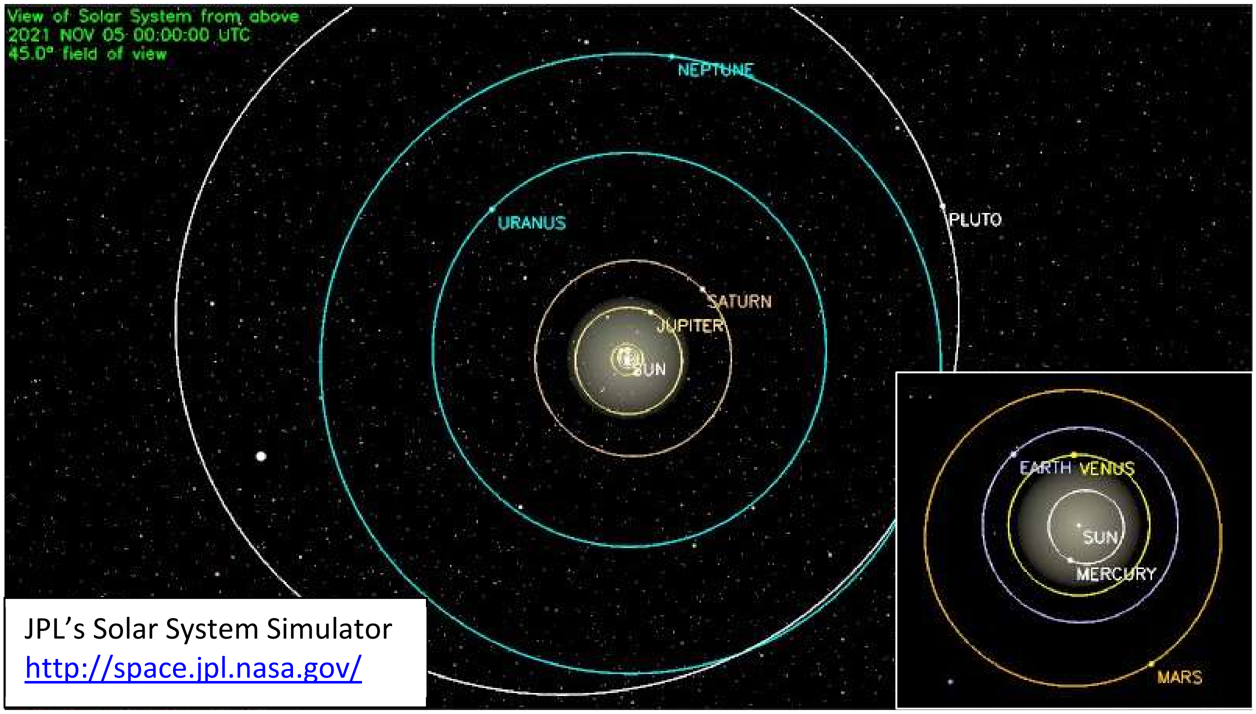


Trailing hemisphere of Europa, in approximate natural color. Credit: NASA/JPL/DLR

With Galileo's discovery, astronomers have trained their Earth-based telescopes, including the Hubble Space Telescope, at this Moon-sized moon of Jupiter to refine their science objectives for the 45 close-approach flybys planned for by the Europa Clipper spacecraft.

Hubble data has confirmed the long-term presence of water vapor in Europa's atmosphere; however, most surprising, the water vapor appears to be present in only the trailing hemisphere (opposite from the direction of travel around Jupiter). With a daytime temperature reaching a high of -260°F, the icy surface would sublimate (solid directly to gas), but why only in the trailing hemisphere is an enigma waiting for the two robotic explorers.

Uranus at Opposition



The Earth will come between Uranus and the Sun on November 4th (EDT), i.e., "Opposition." On that day, Uranus will rise as the Sun sets and will be visible throughout the night (highest in the southern sky after midnight). At magnitude 5.7, it can be spotted by keen eyes in the constellation Aries, near the head of the sea monster Cetus under ideal sky conditions. Uranus will be approximately 1.75 billion miles (2.8 million km) from Earth at Opposition.

William Herschel is credited with the discovery of Uranus in 1781 with his home-made telescope, although the planet had been observed, and recorded as a star by many observers including; Hipparchos in the 2nd century BC, the English astronomer John Flamsteed in 1690, and the French astronomer Pierre Le Monnier in the 1750s. Uranus was named for the Greek god of the sky, notwithstanding Herschel's preference to name the planet after his benefactor, King George III (Georgium Sidus).

Uranus is an ice giant and seventh planet from the Sun. The third largest planet in diameter, Uranus' spin axis is tilted more than 90° (the planet basically spins on its side). The tilt is likely the result of a collision with another planetoid billions of years ago. Thirteen faint rings surround the planet along with 27 small moons. A day on Uranus lasts about 17 earth-hours and it takes 84 earth-years to complete a single orbit around the Sun. Winters last 21 years with one half of the planet sunlit and the other in total darkness.

Methane in the atmosphere of Uranus gives the planet its blue-green color. Hydrogen, helium, water and ammonia are the other constituents of a slushy atmosphere that surrounds a rocky core. The planet is believed to have formed closer to the Sun before migrating out to its current position. The planet revealed few details when visited by the Voyager 2 spacecraft in 1986. However, more recent observations from the Hubble Space Telescope and other Earth-bound observatories have detected dark clouds and storms with bright cloud tops.

Leonid Meteor Shower

Almost everyone has seen a ‘shooting star;’ but not everyone knows what they are, where they come from and how best to view them. For those of you that remember that chilly November night in 2001 when the stars fell like rain, a meteor shower or meteor storm is truly unforgettable. As with that night, all you need are a comfortable chair and a warm blanket to enjoy the show.

Meteor showers occur when the Earth passes through a cloud of debris left behind by a comet. As a comet nears the Sun, the volatile gases warm and erupt along with trapped particles of rock and dust. Pushed away from the comet by the solar wind, this material forms the comet’s tail. Each time a comet crosses the Earth’s orbit it leaves behind a small cloud of debris. When the Earth passes through these clouds, the debris quickly heats up in the atmosphere, creating streaks of light across the night sky. The point in the sky where the meteors appear to originate is called the radiant. Meteor showers are identified by the constellation in which the radiant appears. As such, if you trace the path of the meteors in the early morning of November 17, you will notice that most seem to originate from a point in the constellation Leo, hence the name Leonids.

Why does the same meteor shower excite one year and disappoint the next? While comets are responsible for seeding Earth’s orbit with the makings of a meteor shower, most comets are not frequent visitors to the inner solar system. Comet Tempel-Tuttle (the source of the Leonid meteors) crosses Earth’s orbit once every 33 years. The resulting cloud is about 10 Earth diameters across and continues to drift along the comet’s path. Most years the Earth misses these clouds altogether. In those years the meteor shower is sparse. Other years, as in 2001, the Earth can interact with several clouds of debris from Comet Tempel-Tuttle. If the debris fields are dense (containing a lot of rock and dust) the show can be spectacular. However, as debris clouds age they stretch out and become less dense. The resulting encounter produces fewer and fewer meteors.

What can we expect this year? Typically, the shower produces an average of 15-20 meteors per hour during the peak period from a dark site (as long as the skies are clear). Unfortunately, this year, an almost full moon, which doesn’t set until almost 4 am EST, will wash out all but the brightest fireballs.

Danger: Space Debris

Estimates for the mass of material that falls on Earth each year range from 37,000-78,000 tons. Most of this mass would come from dust-sized particles and disintegrate in the Earth’s atmosphere. The moon is not so fortunate; the lunar surface is continually modified by the bombardment, as shown by the samples brought back from there by the Apollo astronauts. NASA is supporting projects that monitor the frequency of lunar impacts, anticipating that the information will be useful in designing more robust lunar structures and contingency plans for astronauts venturing out on the lunar surface.

NASA launched the Chandra X-ray Observatory in July 1999, placing it in an elliptical orbit that extends almost one-third the distance to the moon. In November 2003, the telescope’s operators placed the telescope in a safe configuration during its passage through four meteor shower streams. Despite an extremely low probability (one in a million) that the telescope would be hit by a meteoroid, that’s what apparently happened early on the morning of November 15th. Fortunately, there was no apparent damage to the more sensitive parts of the telescope.

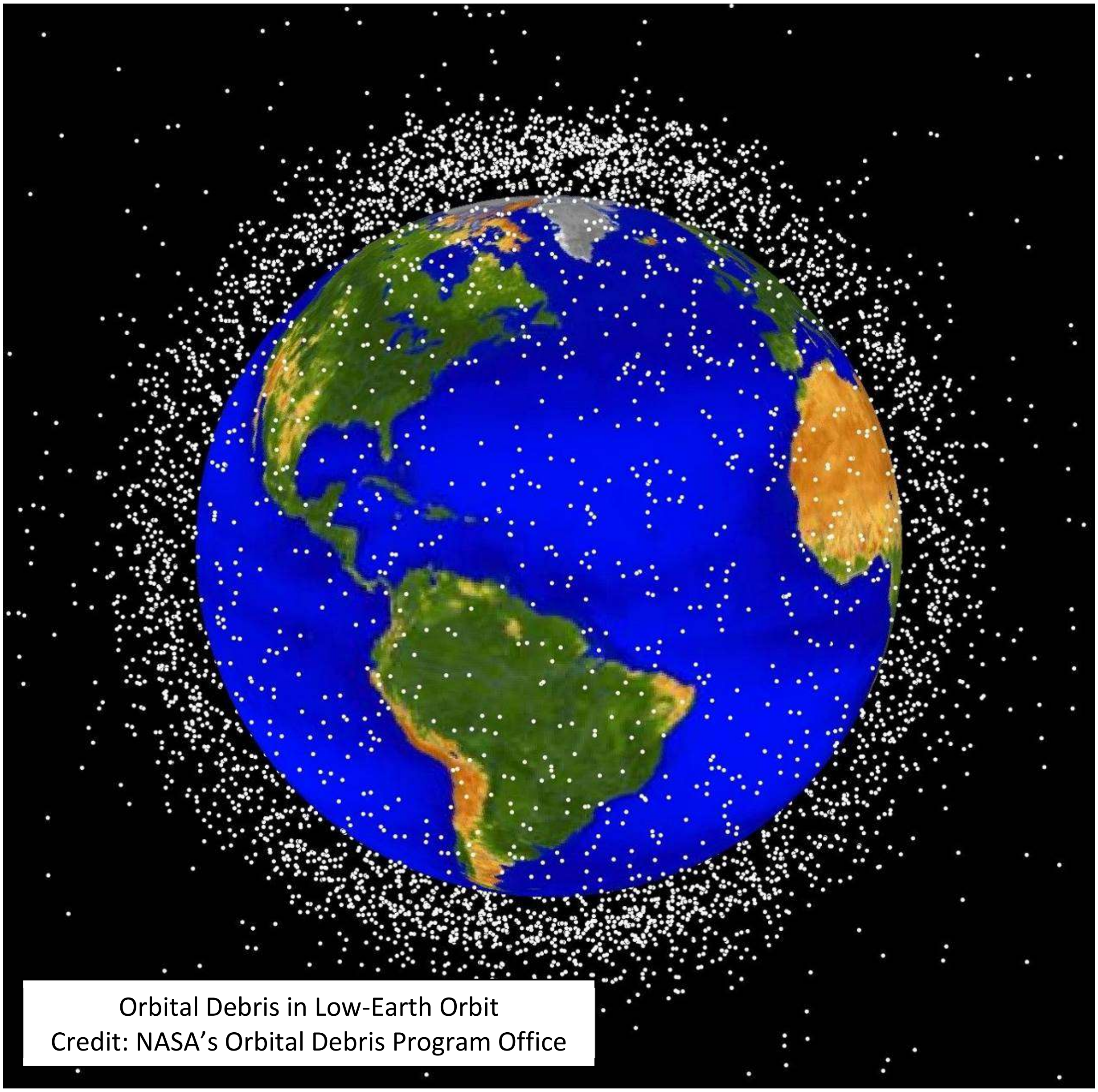
In 2006, the right-hand payload bay door radiator of the space shuttle Atlantis was hit by space debris. The object blasted its way through the metal skin and aluminum honeycomb material inside before exiting the other side. The resulting hole missed the Freon coolant lines inside the panel and did not endanger the crew. (The radiators were only deployed once the shuttle is in space and were stored in the cargo bay during reentry.) However, the impact illustrates the danger presented by space debris to spacecraft and their human occupants.

The Hubble Space Telescope's Wide Field Planetary Camera 2 was returned to Earth as part of the telescope's servicing mission in 2009 (STS-125). Attached to the camera was a large radiator (2.2 m by 0.8 m). The radiator had been in space since the camera was installed in 1993, and its large flat surface provided an excellent measure for determining impact rates for orbital debris at the telescope's altitude (between 560 and 620 km). Initial analysis of the radiator found a total of 685 micrometeoroid and orbital debris impact features (larger than about 0.3 mm).

It is estimated that tens of millions of man-made objects also orbit the Earth, the vast majority smaller than 1 centimeter in size. The objects come from derelict spacecraft, exploding rocket boosters, discarded motors, deterioration of man-made structures including thermal blankets and solar panels, as well as from accidental and deliberate collisions. The objects orbit the Earth in many different directions, altitudes, and velocities, traveling up to 30,000 miles an hour or 20 times faster than a rifle bullet. At these speeds, it doesn't take a very large object to inflict considerable damage to another object, including the International Space Station (ISS). The space shuttle windows were hit by small pieces of debris 32 times during an average mission. Micrometeorites were involved in approximately one-third of the collisions. The grains of sand are generally less dense than man-made debris, and therefore, relatively harmless. The remaining two-thirds do have some penetrating power and are primarily bits of aluminum, followed by paint, steel, and copper.

More than 23,000 pieces of orbital debris, or "space junk," are tracked by the Department of Defense's global Space Surveillance Network (SSN) sensors; most are larger than 10 centimeters (4 inches). This is more than double the number of objects tracked twenty years ago. (There may be 500,000 debris fragments greater than one centimeter in size and over a 100 million fragments smaller than a millimeter). While the United States and Russia are the largest contributors to the swarm of man-made objects, newer space faring nations, in particular China, have added to the problem (particularly after China's intentional destruction of its Fengyun 1C weather satellite, the single largest debris producing event). Debris in low-Earth orbit will eventually fall back to the surface; however, objects higher than 800 kilometers (480 miles) can continue to circle the planet for decades and even centuries.

Until a solution can be found to cleaning up the debris (that is both technically feasible and economical), NASA has developed guidelines it hopes other nations will adopt to minimize the creation of even more debris. In the meantime, surveillance of the existing debris (only practical for the larger objects) will allow spacecraft that can maneuver to avoid future collisions, and more importantly, the loss of life. For additional information, NASA publishes the "Orbital Debris Quarterly News," complete with a "satellite box score." The newsletter (past and present) is available at http://orbitaldebris.jsc.nasa.gov/newsletter/newsletter.html.



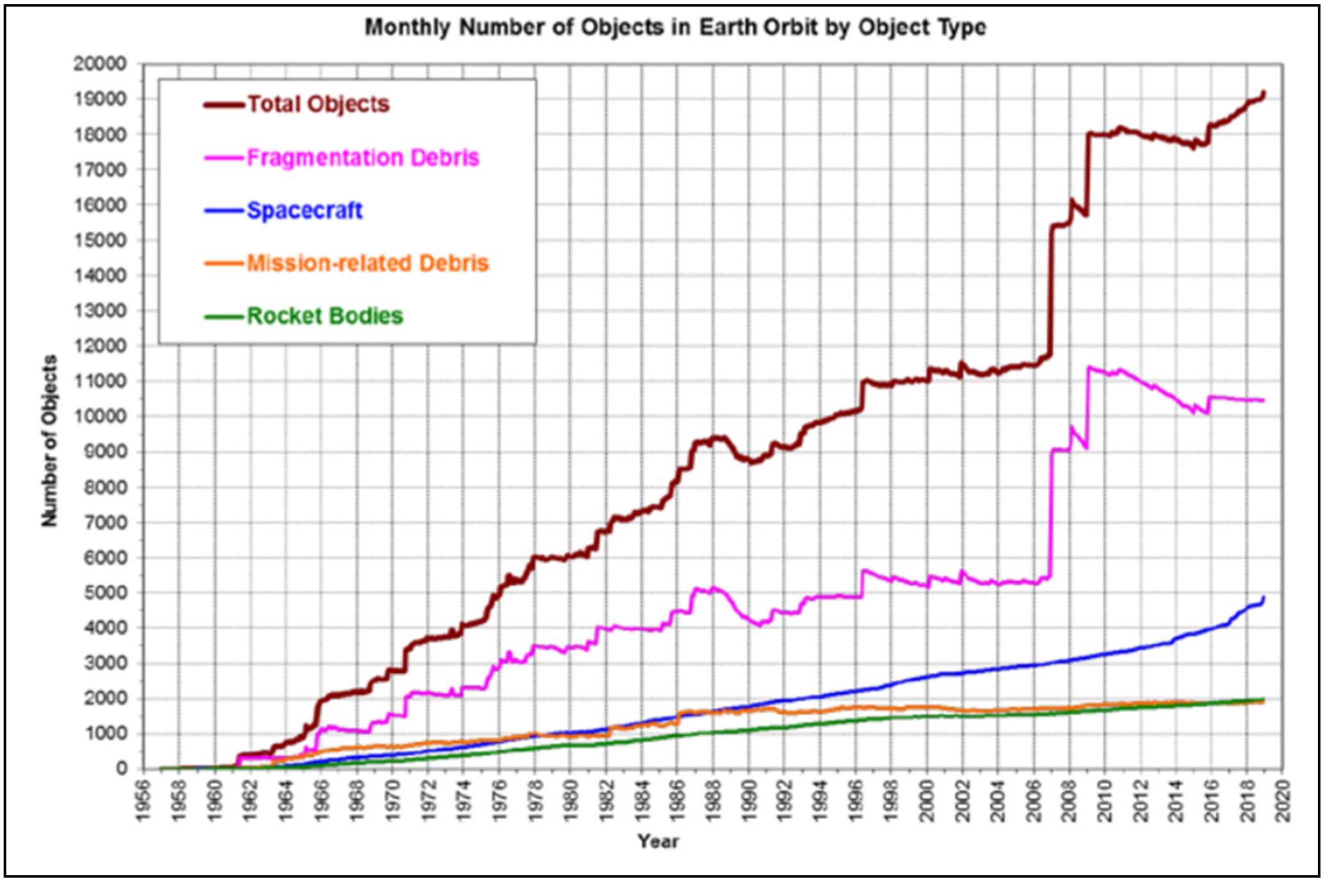
Orbital Debris in Low-Earth Orbit
Credit: NASA's Orbital Debris Program Office

The ISS conducted two collision avoidance maneuvers in 2020, in April and July. The April maneuver was executed to avoid a potential collision with a fragment from the Fengyun-1C satellite, while the July maneuver was in response to a potential collision with a fragment from a Russian Proton rocket ullage motor that had exploded. The ISS has conducted a total of 27 collision avoidance maneuvers since 1999.

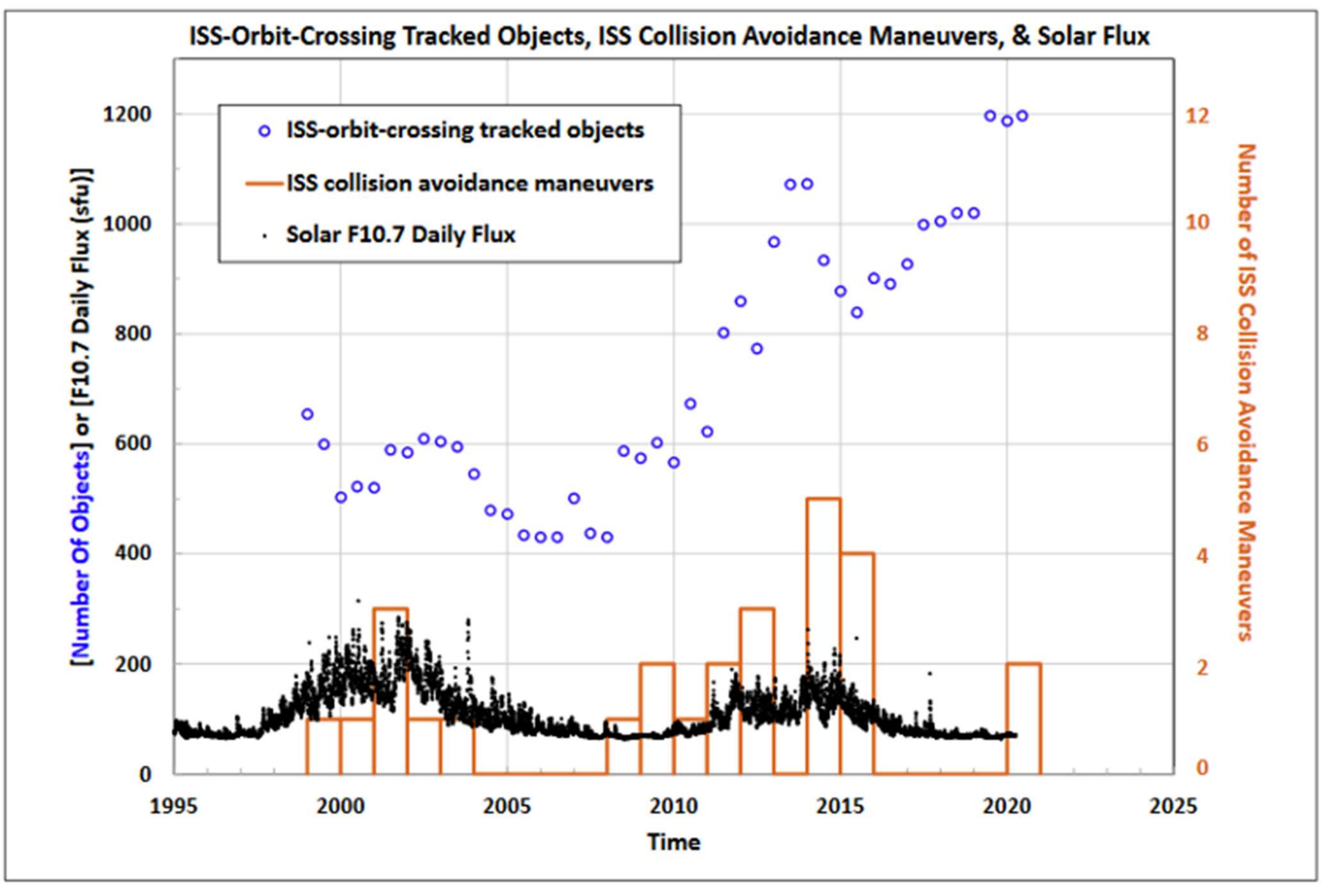
The diagrams on the following page are from:

1. Anz-Meador, P., "Root Cause Classification of Breakup Events 1961-2018," International Orbital Debris (IOC) Conference, December 2019

2. NASA Orbital Debris Quarterly News, Volume 24, Issue 3, August 2020 (solar radio flux at 10.7 cm or 2800 MHz is an excellent indicator of solar activity)



Monthly Number of Objects in Earth Orbit by Object Type
Total Objects
Fragmentation Debris
Spacecraft
Mission-related Debris
Rocket Bodies
Number of Objects
Year



ISS-Orbit-Crossing Tracked Objects, ISS Collision Avoidance Maneuvers, & Solar Flux
ISS-orbit-crossing tracked objects
ISS collision avoidance maneuvers
Solar F10.7 Daily Flux
[Number Of Objects] or [F10.7 Daily Flux (sfu)]
Number of ISS Collision Avoidance Maneuvers
Time

Saturn

Saturn reached Opposition in early August when the ringed-world was closest to Earth. Since that time, the distance between the Earth and Saturn has been steadily increasing with Earth's higher orbital velocity. Saturn is still well placed in evening sky, just to the west of Jupiter in the constellation Capricornus and east of the Milky Way. The planet's north pole is tilted towards the Earth and its rings inclined at an angle of 18° to our line of sight (less than their maximum inclination in 2017, but still a nice presentation).


Image: Marc Polansky

Jupiter

Jupiter was also closest to the Earth in August. In November, Jupiter shines brightly in the southern sky after sunset (more than 18 times brighter than Saturn). The largest planet in the solar system is also in the constellation Capricornus and just to east of Saturn.


Image: Marc Polansky

	Rise and Transit Times (EDT)			
	November 1		November 31	
Planet	Rise	Transit*	Rise	Transit*
Saturn	1:51 pm	6:41 pm	11:01 am	3:54 pm
Jupiter	2:36 pm	7:43 pm	11:48 am	4:59 pm

* The celestial meridian is an imaginary the line that connects the north and south points of the horizon with the observer's zenith (point directly overhead). A planet is highest in the sky when it crosses or transits the meridian.

Jovian Moon Transits

On nights of good visibility, the shadow(s) of Jupiter's moon(s) can be seen on the cloud tops as they cross (transit) the planet's disk. Only events that are visible before the planet gets too low in the western sky are included. A more complete listing can be found in Sky & Telescope's monthly magazine.

Date	Moon	Transit Begins	Transit Ends
5th	Io	7:01 pm	9:18 pm
8th	Europa	5:26 pm	8:13 pm
12th	Io	7:57 pm	10:13 pm
15th	Europa	8:02 pm	10:50 pm
23rd	Ganymede	6:08 pm	9:39 pm
23rd	Callisto	6:52 pm	11:03 pm
28th	Io	6:18 pm	8:34 pm

Great Red Spot Transits

The Great Red Spot is a large, long-lived cyclone in the upper Jovian atmosphere. The Earth-size storm will cross the center line of the planetary disk on the following evenings during the hours between 8 pm to midnight local time.

Date	Transit Time	Date	Transit Time
1st	10:35 pm	16th	7:03 pm
4th	8:06 pm	18th	8:42 pm
6th	9:44 pm	20th	10:21 pm
8th	10:23 pm	23rd	7:52 pm
11th	7:54 pm	25th	9:31 pm
13th	9:33 pm	28th	7:02 pm

November Nights

The late Harvard University astronomer Harlow Shapley was born in November 1885. One of his many accomplishments was accurately measuring the distance to globular star clusters and their position around the Milky Way Galaxy. While warm summer nights are usually reserved for hunting globulars, the autumnal sky contains several impressive clusters including M15 in Pegasus and M2 in Aquarius. M30 in Capricorn is also visible in the southwest sky in the evening.

On the eastern side of the Great Square of Pegasus is the constellation Andromeda. Within this constellation and visible to the unaided eye on a dark night is the Andromeda Galaxy (M31), a massive pinwheel of 500 billion suns. Larger than the Milky Way, the Andromeda Galaxy is currently rushing towards us at 75 miles per second. Fortunately, it is approximately 2½ million light years (14.7 million trillion miles) distant, so it will be some time before the two galaxies merge. Visible through a telescope are Andromeda's two companion galaxies, M32 and M110. While M32 can be mistaken for a bright star due to its close proximity to the core of the Andromeda Galaxy, M110 is a bit easier, being further away and larger than M32.

Located not far from M31 is the Triangulum or Pinwheel Galaxy (M33). Smaller and less massive than the Milky Way, this galaxy can be a challenge to see on less-than-ideal nights, due to its low surface brightness. However, through a large telescope on a dark, steady night, the view looking face-on at this giant pinwheel can be spectacular. The large spiral arms of M33 are filled with star-forming regions that almost appear to be gliding through space.

Sunrise and Sunset (from New Milford, CT)

Sun	Sunrise	Sunset
November 1st (EDT)	07:25	17:48
November 15th (EST)	06:42	16:33
November 30th	07:00	16:24

Astronomical and Historical Events

1st	Aten Asteroid *2340 Hathor* closest approach to Earth (0.161 AU)
1st	History: launch of the Wind spacecraft, designed to monitor the solar wind (1994)
1st	History: opening of the Arecibo Observatory (radio telescope) in Arecibo, Puerto Rico (1963)
2nd	Apollo Asteroid 2017 TS3 near-Earth flyby (0.036 AU)
2nd	Aten Asteroid 2009 WY7 near-Earth flyby (0.049 AU)
2nd	Kuiper Belt Object 42301 (2001 UR163) at Opposition (52.732 AU)
2nd	History: flyby of Asteroid 5535 Annefrank by the Stardust spacecraft (2002)
2nd	History: first light at the 100-inch telescope on Mount Wilson (1917)
3rd	Taurids Meteor Shower peak (associated with the comet Encke)
3rd	Comet *10P/Tempel* closest approach to Earth (1.610 AU)
3rd	History: launch of Mariner 10 to Venus and Mercury; first mission to use the gravitational pull of one planet (Venus) to reach another (Mercury) (1973)
3rd	History: launch of Sputnik 2 and a dog named Laika (1957)
4th	New Moon
4th	Aten Asteroid 2005 VL1 near-Earth flyby (0.044 AU)
4th	Apollo Asteroid *25143 Itokawa* closest approach to Earth (0.697 AU)
4th	Kuiper Belt Object *15760 Albion* (1992 QB1) at Opposition (40.489 AU)
4th	History: Deep Impact's closest approach to the nucleus of Comet 103P/Hartley 2 (2010)
4th	History: launch of the Soviet Venus lander Venera 14 (1981)
5th	Uranus at Opposition
5th	Moon at perigee (closest approach to Earth)
5th	Atira Asteroid 2021 BS1 closest approach to Earth (0.573 AU)
5th	History: Parker Solar Probe's first close encounter with the Sun's corona (0.17 AU) (2018)
5th	History: launch of India's Mars Orbiter Mission (MOM) from the Satish Dhawan Space Centre (2013)
5th	History: Chinese spacecraft Chang'e 1 enters orbit around Moon (2007)
6th	Apollo Asteroid 2020 KA near-Earth flyby (0.038 AU)
6th	History: launch of Lunar Orbiter 2, Apollo landing site survey mission (1966)
7th	End of Daylight Savings Time - set clocks back one hour at 2 a.m.
7th	Kuiper Belt Object 472271 (2014 UM33) at Opposition (42.276 AU)
7th	Kuiper Belt Object 2014 UZ224 at Opposition (88.414 AU)
7th	History: launch of Mars Global Surveyor (1996)
7th	History: launch of Surveyor 6 moon lander (landed two days later). On November 17th, the lander's small vernier engines were fired for 2½ seconds, lifting the lander off the lunar surface 10 to 12 feet and almost 8 feet sideways. This lunar "hop" was the first powered takeoff from the lunar surface. It also provided NASA a view of the original landing site and a baseline for acquiring stereoscopic images of its surroundings. (1967)
7th	History: French astronomer Pierre Gassendi first to observe a transit of the planet Mercury across the Sun's disk (1631)
7th	History: a 300-pound stony meteorite falls in a wheat field outside the walled town of Ensisheim in Alsace (now part of France) (1492)
8th	Centaur Object 2015 JH1 at Opposition (11.191 AU)
8th	Kuiper Belt Object 2014 US277 at Opposition (77.096 AU)

Astronomical and Historical Events (continued)

8th History: launch of the ill-fated Phobos-Grunt spacecraft from the Baikonur Cosmodrome in Kazakhstan. Destined for the Martian moon Phobos, the spacecraft never left Earth orbit and eventually re-entered the atmosphere. (2011)
8th History: meteorite hits a house in Wethersfield, Connecticut (1982)
8th History: launch of Pioneer 9 into solar orbit (1968)
8th History: launch of Little Joe rocket, qualifying flight for the Mercury spacecraft (1960)
8th History: Edmund Halley born, English astronomer who calculated the orbit and predicted the return of the comet now called Comet Halley (1656)
9th Apollo Asteroid 2019 XS near-Earth flyby (0.004 AU)
9th Plutino *47171 Lempo* (2 moons) at Opposition (29.777 AU)
9th History: launch of the Venus Express spacecraft; ESA Venus orbiter (2005)
9th History: launch of OFO-1 (Orbiting Frog Otolith) - two bullfrogs launched in an experiment to monitor the adaptability of the inner ear to sustained weightlessness (1970)
9th History: launch of the first Saturn V rocket, Apollo 4 (1967)
10th Kuiper Belt Object 120348 (2004 TY364) at Opposition (37.860 AU)
10th Plutino 144897 (2004 UX10) at Opposition (38.441 AU)
10th History: launch of Luna 17, Soviet Moon rover mission (1970)
10th History: launch of USSR spacecraft Zond 6; Moon orbit and return (1968)
10th History: Waseda Meteorite Fall; hits house in Japan (1823)
11th First Quarter Moon
11th Atira Asteroid 164294 (2004 XZ130) closest approach to Earth (0.627 AU)
11th Kuiper Belt Object 55637 (2002 UX25) at Opposition (39.101 AU)
11th Kuiper Belt Object 84522 (2002 TC302) at Opposition (42.760 AU)
11th History: launch of Gemini 12 with astronauts James Lovell and Edwin Aldrin (1966)
11th History: Tycho Brahe discovers a new star in the constellation Cassiopeia shining as bright as Jupiter; later determined to be a supernova - SN1572 (1572)
12th Kuiper Belt Object 2014 ST373 at Opposition (50.801 AU)
12th History: Philae lander (Rosetta mission) touches down on Comet 67P/*Churyumov-Gerasimenko* (2014)
12th History: launch of STS-2, second flight of the Space Shuttle Columbia (1981)
12th History: flyby of Saturn by the Voyager 1 spacecraft (1980)
12th History: Seth Nicholson born, American astronomer who discovered four of Jupiter's moons, a Trojan asteroid, and computed orbits of several comets and of Pluto (1891)
13th Second Saturday Stars – Virtual Open House at the McCarthy Observatory (7:00 pm)
13th Apollo Asteroid 2004 UE near-Earth flyby (0.029 AU)
13th Amor Asteroid *189011 Ogmios* closest approach to Earth (0.442 AU)
13th Centaur Object *49036 Pelion* at Opposition (20.511 AU)
13th History: launch of HEAO-2, the second of NASA's three High Energy Astrophysical Observatories; renamed Einstein after launch, it was the first fully imaging X-ray space telescope (1978)
15th History: launch of SpaceX's Crew-1 from the Kennedy Space Center, Florida, to the International Space Station.
14th History: dedication of the New Milford Solar System Scale Model (2009)
14th History: Mariner 9 arrives at Mars; first spacecraft to orbit another planet (1971)

<u>Astronomical and Historical Events</u> (continued)

14th History: launch of Apollo 12, with astronauts Pete Conrad, Richard Gordon and Alan Bean to the moon's Ocean of Storms and near the robotic explorer Surveyor 3 (1969)
14th History: discovery of the Great Comet of 1680 or Kirch's Comet by Gottfried Kirch (1680)
15th Aten Asteroid 2010 VK139 near-Earth flyby (0.016 AU)
15th Apollo Asteroid 2016 VR near-Earth flyby (0.020 AU)
15th Apollo Asteroid 2019 VL5 near-Earth flyby (0.022 AU)
15th Kuiper Belt Object *474640 Alicanto* at Opposition (47.455 AU)
15th History: William Herschel born, German-English astronomer, credited with the discovery of Uranus, two of its moons, two of Saturn's moons and catalogued the heavens (1738)
15th History: ESA's spacecraft SMART-1 enters lunar orbit; first ESA Small Mission for Advanced Research in Technology; travelled to the Moon using solar-electric propulsion and carrying a battery of miniaturized instruments (2004)
15th History: the only orbital launch of the Russian space shuttle Buran; the unmanned shuttle orbited the Earth twice before landing (1988)
15th History: launch of Intasat, Spain's first satellite (1974)
16th Apollo Asteroid *136795 Tatsunokingo* closest approach to Earth (1.352 AU)
16th Apollo Asteroid 2008 HU4 closest approach to Earth (1.992 AU)
16th Binary Plutino *341520 Mors-Somnus* at Opposition (27.993 AU)
17th Leonids Meteor Shower peak (associated with the comet Tempel-Tuttle)
17th Kuiper Belt Object 2012 VP113 at Opposition (83.297 AU)
17th History: Surveyor 6 performs a "hop" maneuver, moving approximately 8 feet (2.5 meters) away from its original landing area – enabling scientists to validate surface properties (1967)
17th History: launch of Soyuz 20, a 90-day, long duration mission that carried a biological payload (tortoises) that docked with the Salyut 4 space station. The tortoises returned to Earth in good health (1975)
17th History: Soviet lunar lander Luna 17 deploys first rover - Lunokhod 1 (built by the Kharkov state bicycle plant); operated for 11 months, photographing and mapping the lunar surface and analyzing the regolith (1970)
18th Apollo Asteroid *2329 Orthos* closest approach to Earth (1.505 AU)
18th History: launch of the Mars Atmosphere and Volatile EvolutioN (MAVEN) spacecraft (Mars Orbiter) from the Cape Canaveral Air Force Station (2013)
18th History: launch of the COBE spacecraft; observed diffuse cosmic background radiation (1989)
19th Full Moon (Beaver Moon)
19th Partial Lunar Eclipse (enters umbra around 2:18 am – exits around 5:47 am)
19th Apollo Asteroid *5143 Heracles* closest approach to Earth (0.306 AU)
19th Apollo Asteroid 2015 TB145 closest approach to Earth (0.537 AU)
20th Moon at apogee (furthest distance from Earth)
20th Apollo Asteroid 2016 JG12 near-Earth flyby (0.037 AU)
20th Jupiter Trojan 3548 Eurybates at Opposition (3.755 AU) – scheduled to be visited by the Lucy spacecraft in August 2027
20th History: the Japan Aerospace Exploration Agency's Hayabusa spacecraft lands on Asteroid 25143 *Itokawa* for sample collection (2005) (JST)

<u>Astronomical and Historical Events</u> (continued)

20th	History: launch of the Swift spacecraft; first-of-its-kind multi-wavelength observatory dedicated to the study of gamma-ray bursts (2004)
21st	Parker Solar Probe, 10th Perihelion
21st	Apollo Asteroid 2021 KH2 near-Earth flyby (0.049 AU)
21st	Plutino 455502 (2003 UZ413) at Opposition (43.539 AU)
21st	Kuiper Belt Object *90377 Sedna* at Opposition (83.147 AU)
21st	History: launch of Sentinel 6-Michael Freilich, a joint mission between the European Space Agency, NASA, NOAA, CNES and Eumetsat - continuing the work done by the Jason series of satellites on monitoring sea level.
22nd	Apollo Asteroid *3361 Orpheus* near-Earth flyby (0.039 AU)
22nd	Asteroid *1862 Apollo* closest approach to Earth (0.212 AU)
23rd	Kuiper Belt Object 523645 (2010 VK201) at Opposition (47.182 AU)
23rd	History: launch of the Chang'e 5 spacecraft - China's first lunar sample return (2020)
23rd	History: launch of the European Space Agency's first satellite, Meteosat 1 (1977)
23rd	History: launch of Tiros II weather satellite (1960)
24th	Scheduled launch of the Russian Prichal nodal module to the International Space Station
24th	Scheduled launch of the Double Asteroid Redirection Test (DART) spacecraft from the Vandenberg Space Force Base, California – targeting the moon of the asteroid Didymos
24th	Apollo Asteroid 2014 WF201 near-Earth flyby (0.034 AU)
24th	Amor Asteroid *3288 Seleucus* closest approach to Earth (1.728 AU)
24th	History: first observations of a transit of Venus (1639)
25th	Aten Asteroid 2009 WB105 near-Earth flyby (0.039 AU)
25th	Aten Asteroid 2019 BB5 near-Earth flyby (0.048 AU)
25th	Plutino 84719 (2002 VR128) at Opposition (39.623 AU)
25th	History: Albert Einstein publishes his General Theory of Relativity (1915)
25th	History: William Dawes discovers Saturn's C Ring (1850)
26th	Solar Orbiter Earth flyby, along with 3 additional Venus flybys, will bring the spacecraft's orbit to an inclination of 25° degrees
26th	Comet *10P/Tempel* at Opposition (1.677 AU)
26th	Apollo Asteroid *3838 Epona* closest approach to Earth (0.577 AU)
26th	History: landing of NASA's InSight spacecraft on Mars' western Elysium Planitia (2018)
26th	History: Mars Cube One 1 & 2, Mars flyby (launched with InSight to monitor landing) (2018)
26th	History: launch of the Mars Science Laboratory (MSL) aboard an Atlas 5 rocket from the Cape Canaveral Air Force Station (2011)
26th	History: discovery of Mars meteorites SAU 005 and SAU 008 (1999)
26th	History: launch of France's first satellite, Asterix 1 (1965)
26th	History: launch of Explorer 18; studied charged particles and magnetic fields in and around the Earth – Moon (1963)
26th	History: discovery of the Orion Nebula by French astronomer Nicolas-Claude Fabri de Peiresc (1610)
27th	Last Quarter Moon
27th	History: Soviet spacecraft Mars 2 arrives at Mars; lander crashes, becoming first human artifact to impact the surface of Mars (1971)
28th	Comet 17P/Holmes closest approach to Earth (2.012 AU)
28th	History: launch of Algeria's first satellite, Alsat 1 (2002)

Astronomical and Historical Events (continued)

- 28th History: discovery of first Pulsar by Jocelyn Bell and Antony Hewish (1967)
- 28th History: launch of Mariner 4; first spacecraft to obtain and transmit close range images of Mars (1964)
- 29th Aten Asteroid 1994 WR12 near-Earth flyby (0.041 AU)
- 29th Dwarf Planet *Ceres* closest approach to Earth (1.761 AU)
- 29th Asteroid *12561 Howard* closest approach to Earth (2.374 AU)
- 29th History: discovery of Y000593 Mars meteorite in Antarctica (2000)
- 29th History: launch of Australia's first satellite, Wresat 1 (1967)
- 29th History: launch of Mercury 5 with Enos the chimpanzee (1961)
- 30th Amor Asteroid *7358 Oze* closest approach to Earth (0.749 AU)
- 30th Apollo Asteroid *3200 Phaethon* closest approach to Earth (1.255 AU)
- 30th Asteroid *2062 Aten* closest approach to Earth (1.705 AU)
- 30th Apollo Asteroid *2212 Hephaistos* closest approach to Earth (2.869 AU)
- 30th Kuiper Belt Object 523759 (2014 WK509) at Opposition (51.053 AU)
- 30th History first telescopic observations of the Moon by Galileo Galilei (1609)

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

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

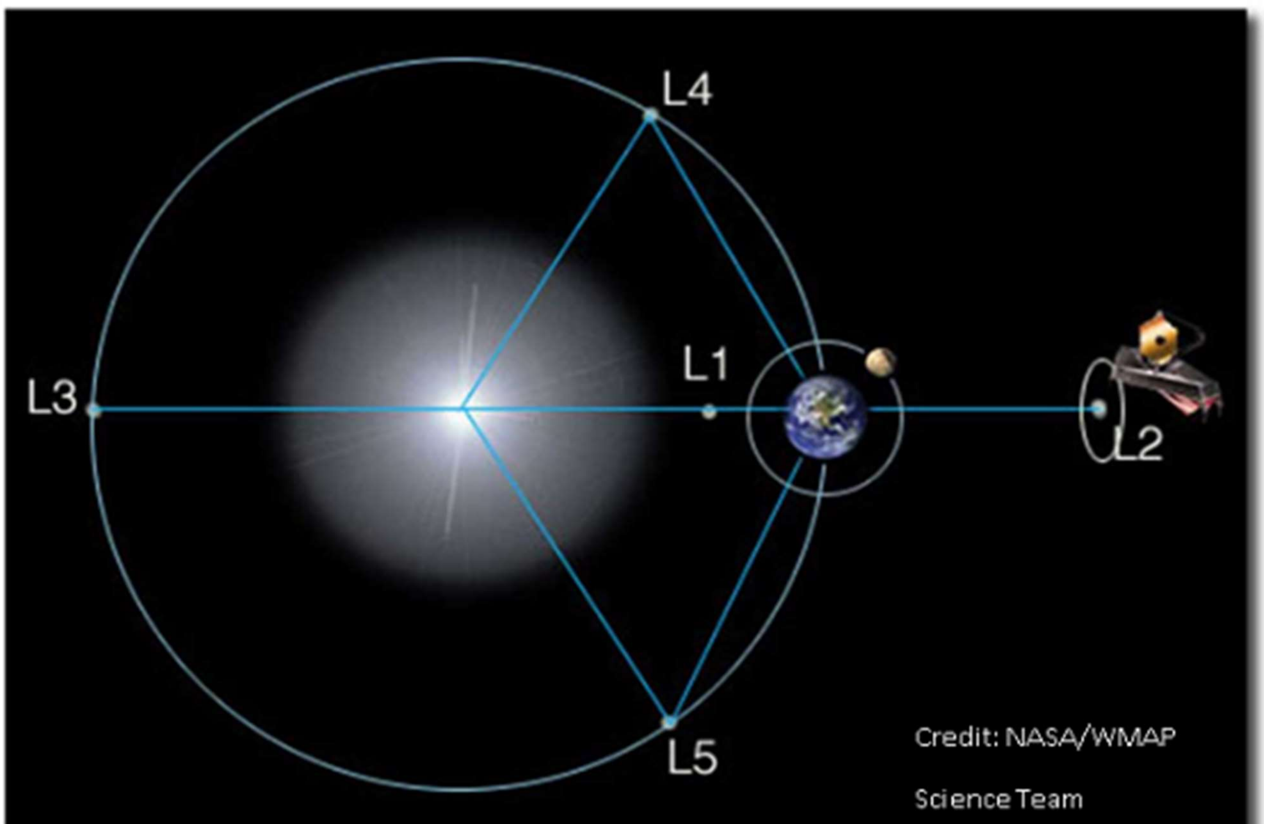
For the latest on what's happening on the Sun and the current forecast for flares and aurora, check out www.spaceweather.com

NASA's Global Climate Change Resource

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

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).



Mars – Mission Websites

Mars 2020 (Perseverance rover): https://mars.nasa.gov/mars2020/

Mars Helicopter (Ingenuity): https://mars.nasa.gov/technology/helicopter/

Mars Science Laboratory (Curiosity rover): https://mars.nasa.gov/msl/home/

Mars InSight (lander): https://mars.nasa.gov/insight/

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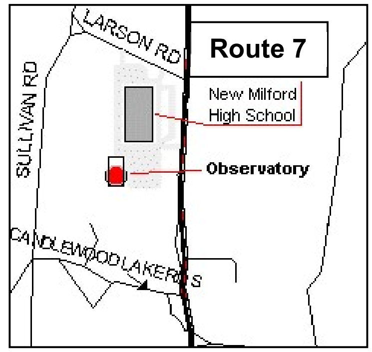

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