Galactic Observer
John J. McCarthy Observatory

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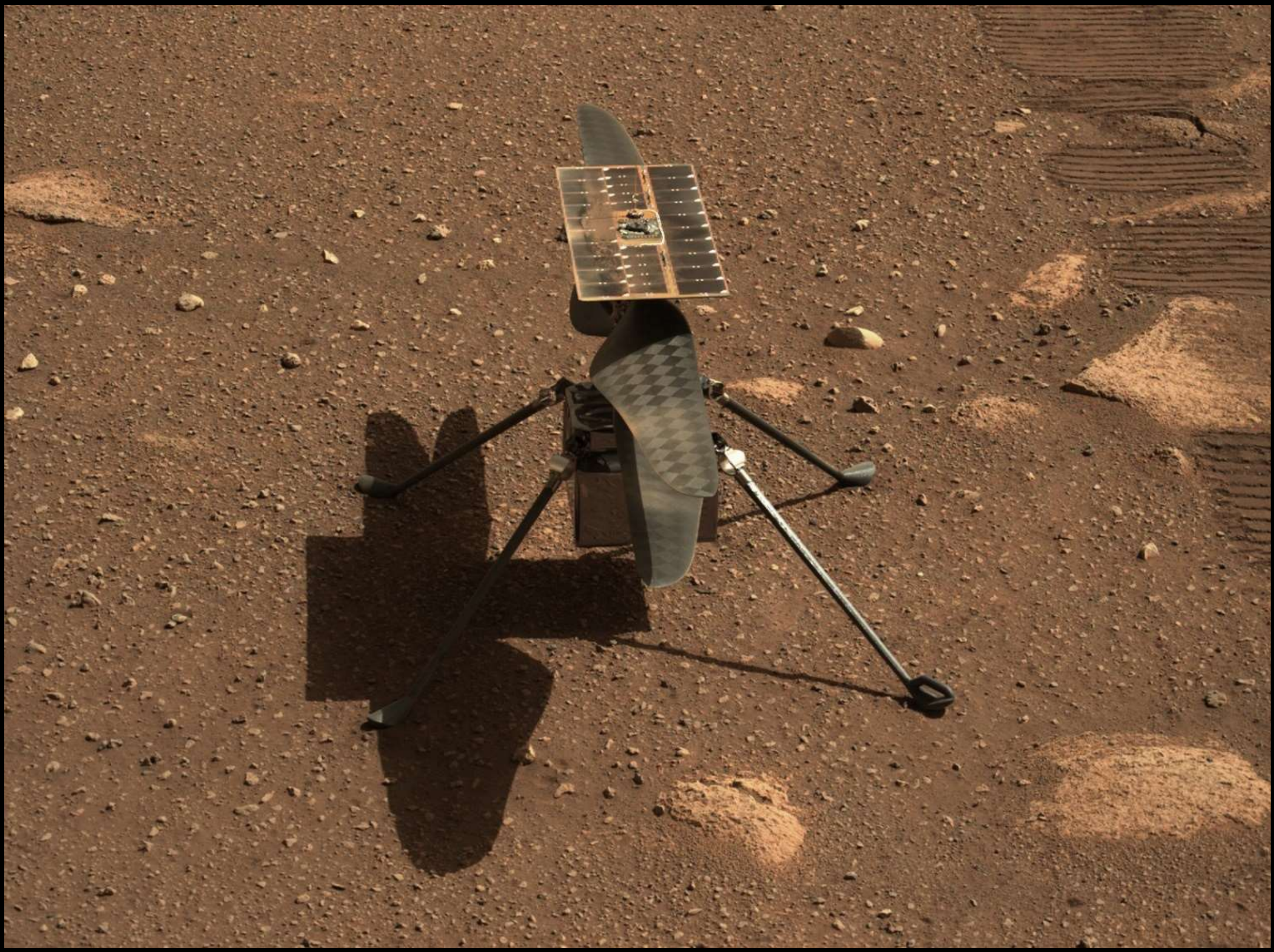

First Year of Flight

The Ingenuity helicopter photographed at Wright Brothers Field on April 5, 2021. The photo was acquired by the Perseverance rover's Mastcam-Z, a pair of zoomable cameras.

The helicopter, which rode to Mars in an enclosure attached to the underside of the rover, was dropped onto the surface two days earlier. Disconnected from the rover, and its power source, the diminutive helicopter was on its own to survive the harsh Martian environment. One year later, Ginny is still flying, having transitioned from a technology demonstration to an operational asset.

Credits: NASA/JPL-Caltech/ASU

April Astronomy Calendar and Space Exploration Almanac

Photo: Bill Cloutier

Ten years ago on April 17, 2012, the space shuttle orbiter Discovery was delivered to the National Air and Space's Museum's Udvar-Hazy Center in Chantilly, Virginia - transported by Shuttle Carrier Aircraft (SCA) No. 905 to the adjacent Dulles International Airport. Discovery was the first of three active orbiters retired from the shuttle fleet, with its final mission (STS-133) concluding in March 2011. From 1984 through 2011, the spacecraft spent 365 days in orbit, over 39 flights, circling the Earth 5,830 times and traveling a total of 148,221,675 miles. Its missions included deploying the Hubble Space Telescope and two follow-on servicing calls.

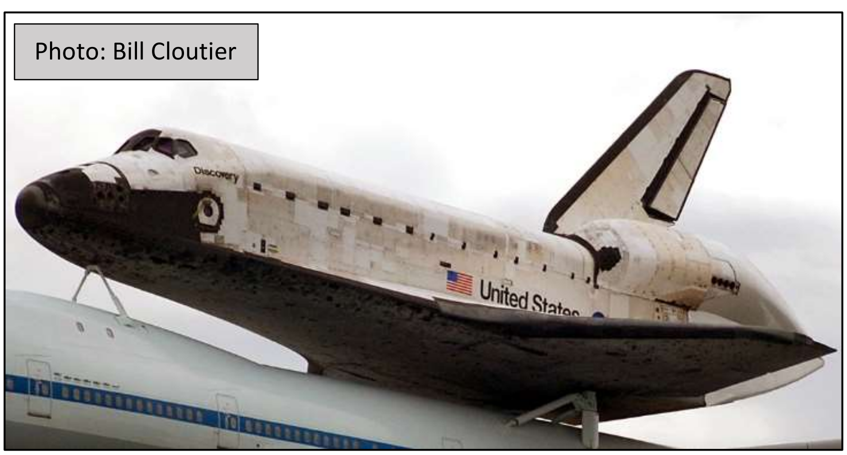
Photo: Bill Cloutier

SCA 905 was the first of two Boeing 747 aircraft used by NASA to ferry the shuttles from alternative landing sites back to the launch site at the Kennedy Space Center. Built in 1970, SCA 905 was acquired by NASA in 1974 from American Airlines. Structural modifications were made to the airframe to accommodate the orbiters and vertical stabilizers added to enhance stability. The retired jumbo jet is now the centerpiece of an exhibit at NASA's Johnson Space Center, paired with a full-scale mockup of the space shuttle.

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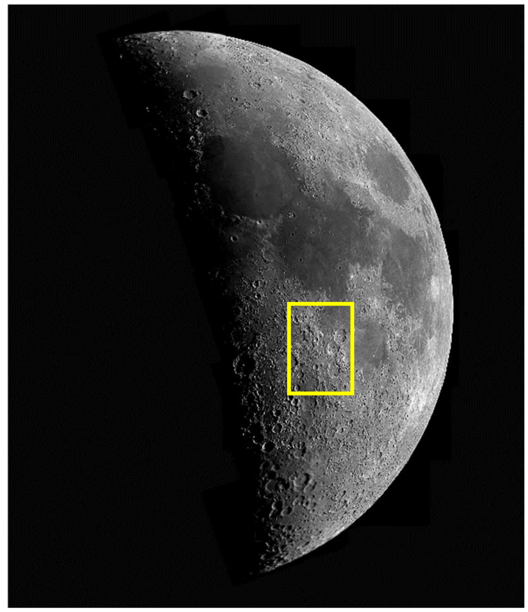
McCarthy Observatory
New Milford, CT

“Out the Window on Your Left”

It’s been almost 53 years since Neil Armstrong first stepped onto the Moon’s surface and more than 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).



Central lunar highlands and location of the Apollo 16 landing

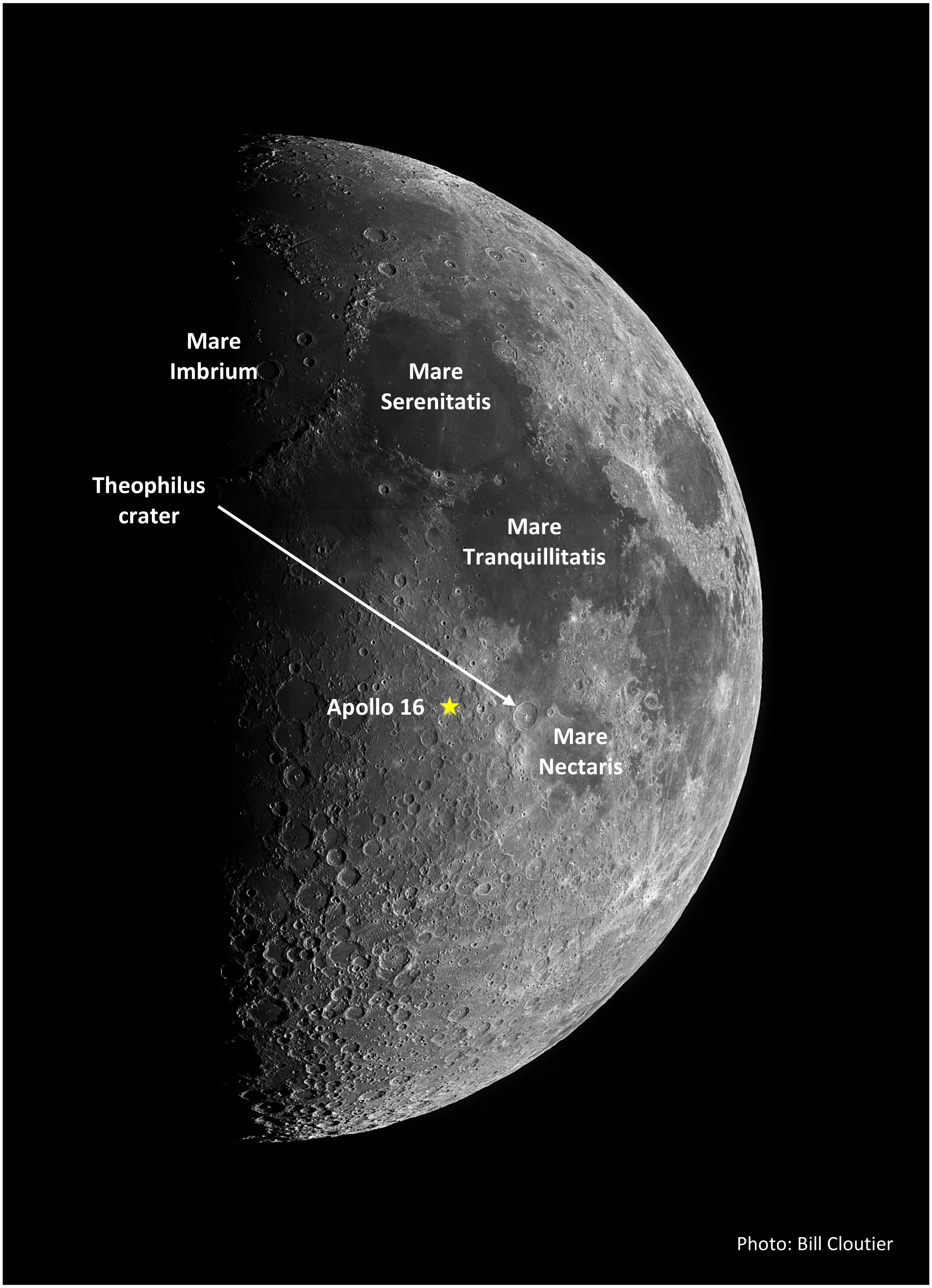
In April 1973, Commander John Young set the Apollo 16 lunar module (named Orion) down between two geologic units – the Cayley Plains and the Descartes Mountains, in the central lunar highlands. Apollo 16 was the second J-type mission, characterized by larger scientific payloads, extended surface time, and longer excursions with the lunar rover. During their stay, John Young put the battery-powered rover through its paces in a “Grand Prix” exercise - consisting of a series of S-turns, hairpin turns and hard stops.

Young and Charlie Duke spent over 20 hours on the surface, collecting approximately 212 pounds (96 kg) of rock and soil samples. Although geologists had expected the region to be covered by volcanic material, almost all of the rock samples collected by the astronauts turned out to be breccias (broken fragments of rock that have been cemented together into a matrix). The samples also contained bits of anorthosite (including two of the largest returned by the Apollo missions). Anorthosite crystallized in the magma ocean that covered the moon shortly after its accretion almost 4.5 billion years ago, forming the bulk of the early lunar crust.

The breccias that covered the landing area likely came from the nearby impact basins. While Nectaris is the closest large impact basin (less than 125 miles or 200 km from the landing site), the samples also included what is believed to be material from the much further but larger Imbrium basin, 620 miles or 1,000 km away. The samples allowed scientists to date the Nectaris impact basin-forming event at 3.92 billion years ago. Bits of basalt, that formed 3.79 billion years ago and that were interspersed with the breccias, likely originated from the mare that overlies the Nectaris impact basin. The basalt was likely ejected by a mare impact, for example, the one that created the 60-mile-diameter (100 km) Theophilus crater, lying 150 miles (250 km) to the east of the landing site.

Apollo 16 also released a small satellite into lunar orbit from the service module. It was intended to complement a similar satellite released by Apollo 15 eight months earlier. However, unlike the Apollo 15 satellite, which maintained a stable orbit, the orbit of the Apollo 16 satellite decayed rapidly, crashing into the lunar surface after just 35 days. It was later determined, that the inclination of the Apollo 16 satellite’s orbit was unstable due to mass concentrations (or mascons) hidden beneath the lunar surface.

Descartes Highlands



Rollout of Artemis 1

NASA's Space Launch System (SLS), rolled out of the Vehicle Assemble Building on March 17th. It was the first rocket to pass through the 456-foot-high doors (140 meter) on the cavernous building since the last shuttle mission in 2011. The SLS was carried to launch pad 39B (the one used by Apollo 10 in 1968) atop a 1960's-era crawler-transport – a trip that took almost 11 hours.

Photo Credit: NASA/Aubrey Gemignani

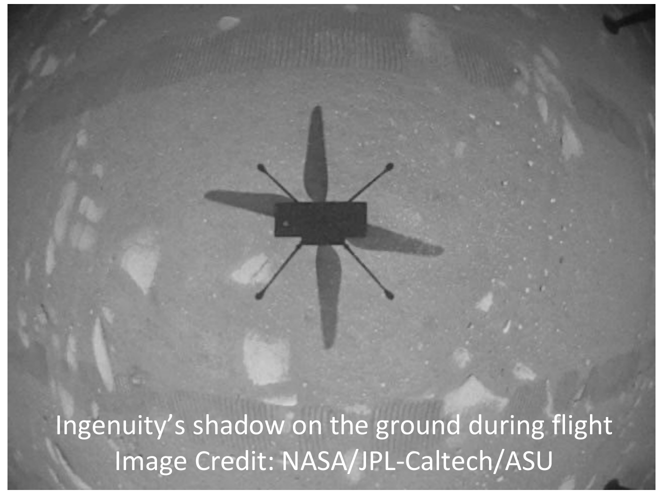
The 6.65-million-pound crawler-transporter, originally designed and built by Marion Power Shovel with components designed and built by Rockwell International, was significantly upgraded to carry the heavier SLS rocket and mobile launch pad over the 4.2-mile (6.8-km) distance. The colossal machine, the size of a baseball diamond infield, can carry up to 18 million pounds and keep the load level as it climbs up the 5 percent grade to the launch complex.

The SLS, topped by the Orion spacecraft, was moved to the pad for a final prelaunch test known as a "wet dress rehearsal." While at the pad, the launch team at the Kennedy Space Center will load and drain the SLS propellant tanks and conduct a full countdown in preparation of an unmanned launch later this spring.

NASA's return to the Moon program is called Artemis, named after the twin sister of Apollo (she is also the goddess of the Moon). The SLS, with 8.8 million pounds of thrust during liftoff, will send the Orion spacecraft to the Moon and beyond on its first mission. The service module, provided by the European Space Agency, will provide power for spacecraft and propulsion during its stay in lunar orbit and a foray into deep space (about 40,000 miles or 70,000 km beyond the Moon). After about 3 weeks, Orion will execute a high-speed return back into the Earth's atmosphere (at 25,000 mph or 11 kms), splashing down off the coast of Baja, California.

Photo Credit: NASA/Aubrey Gemignani

Aloft in Butterscotch Skies


Ingenuity's shadow on the ground during flight
Image Credit: NASA/JPL-Caltech/ASU

NASA's Perseverance rover landed in Jezero crater on February 18, 2021. The rover's mission: to search for signs of ancient microbial life and collect core samples of Martian rock and soil for retrieval and return to Earth by a future mission. In the first month on the surface, the rover's arm and science instruments were deployed, systems activated and checked out, interplanetary cruise software changed out to a surface operating version, and an assessment of the surroundings conducted.

In addition to seven science instruments, Perseverance brought along two technology demonstrations; one that would assess the capacity of extracting oxygen from the primarily carbon-dioxide atmosphere, and the other to see if flight was possible in such a rarified atmosphere. The four-pound (Earth weight) helicopter, named Ingenuity, rode to Mars in an enclosure bolted to the underside of the rover. Between March 26 and April 3, the helicopter was deployed in a choreographed sequence that was completed when it dropped the final 4 inches (10 cm) onto the ground at a place that would be known as "Wright Brothers Field."

NASA allotted just 30 Martian days or Sols for the technology demonstration. That clock started on April 3rd. The date also marked the first time that Ingenuity, now disconnected from the rover's power system, had to survive the harsh Martian weather on its own. Sixteen days later, on Monday, April 19th, Ingenuity made history when it became the first aircraft to make a powered, controlled flight on another planet. The solar-powered helicopter executed a flawless flight plan, climbing to an altitude of about 10 feet (3 meters), where it hovered, turned 90 degrees, so that its color camera was pointed towards the Perseverance rover parked about 211 feet (64.3 meters) away, before descending and landing. Three days later, the Jet Propulsion Laboratory (JPL) helicopter team accomplished a second successful flight, this time flying a bit higher and moving laterally for the first time.

On April 30th, after four flights that exceeded all expectations, NASA announced a 30-sol extension and a transition from testing to operations. On Flight 5, Ingenuity took to the air and didn't return to Wright Brothers Field, but moved on to new location, approximately 423 feet (129 meters) away. Almost one year later, and several mission extensions, the helicopter has flown 23 times, covering 3.15 miles (5.1 km) in 42.7 cumulative minutes of flight time. With its new mission as a forward scout, Ingenuity's cameras have provided scientists images of possible targets to sample, searched for routes of safe passage for the rover, and explored areas inaccessible to Perseverance due to rugged or dune-filled topography.

Flying on Mars has not been easy. The flights have had to be relatively short (less than 3 minutes and 1,000 feet or 300 meters) so that the motor doesn't overheat with essentially no air for cooling, despite the frigid temperatures. The density of the Martian atmosphere is typically about 1 percent that of Earth's at sea level. To compensate, Ingenuity's rotors were designed to operate at a much higher speed (2,537 rpm) than its Earthly counterparts. Ingenuity typically flies at mid-day, after recharging its batteries in the morning from the small solar panel mounted on top of the vehicle. Mid-day flights also allow time for recharging after flight and before the cold night sets in (which can drop down to a hundred degrees below zero). Mid-day flights can be challenging as this is also the time of day when the winds are at their strongest in the crater, problematic for an aircraft that only weighs a pound and a half on Mars. Flight control and aerodynamic performance have been a learning process for the helicopter team since Ingenuity is now operating well beyond its 30-day window and, therefore, encountering conditions and situations that were not anticipated for a brief technology demonstration. The seasonal changes and the adverse weather conditions on the Red Planet, as well as the different types of terrain traversed since the helicopter left the safe confines of Wright Brothers Field, have kept the JPL team busy as they continue to innovate to keep Ingenuity in the air – while working remotely from tens of millions of miles or more.

Over the course of 2021, spring in Jezero Crater progressed into summer. Warmer summertime temperatures reduced the already low air density in the crater, making it even more difficult to fly. The challenge was addressed by the helicopter team, after some testing, by increasing the rotor speed to 2,700 rpm (higher than any speed attempted back on Earth). Autumn began in February of 2022 with winter, and the dusty season, on the horizon.

Air density became an issue again in January when a late summer global dust storm developed (storms are typically more prevalent in the winter), obscuring the skies over Jezero Crater. Perseverance's weather station recorded a 7% decrease in air density and about an 18% decrease in sunlight during the storm. The dusty atmosphere decreased the helicopter's ability to charge its batteries with less sunlight available and dust coating the surface of the solar panel. The helicopter was already pushing the limits of flight operations on Mars, so the JPL team decided to ground the rotorcraft for the month, until the skies cleared.

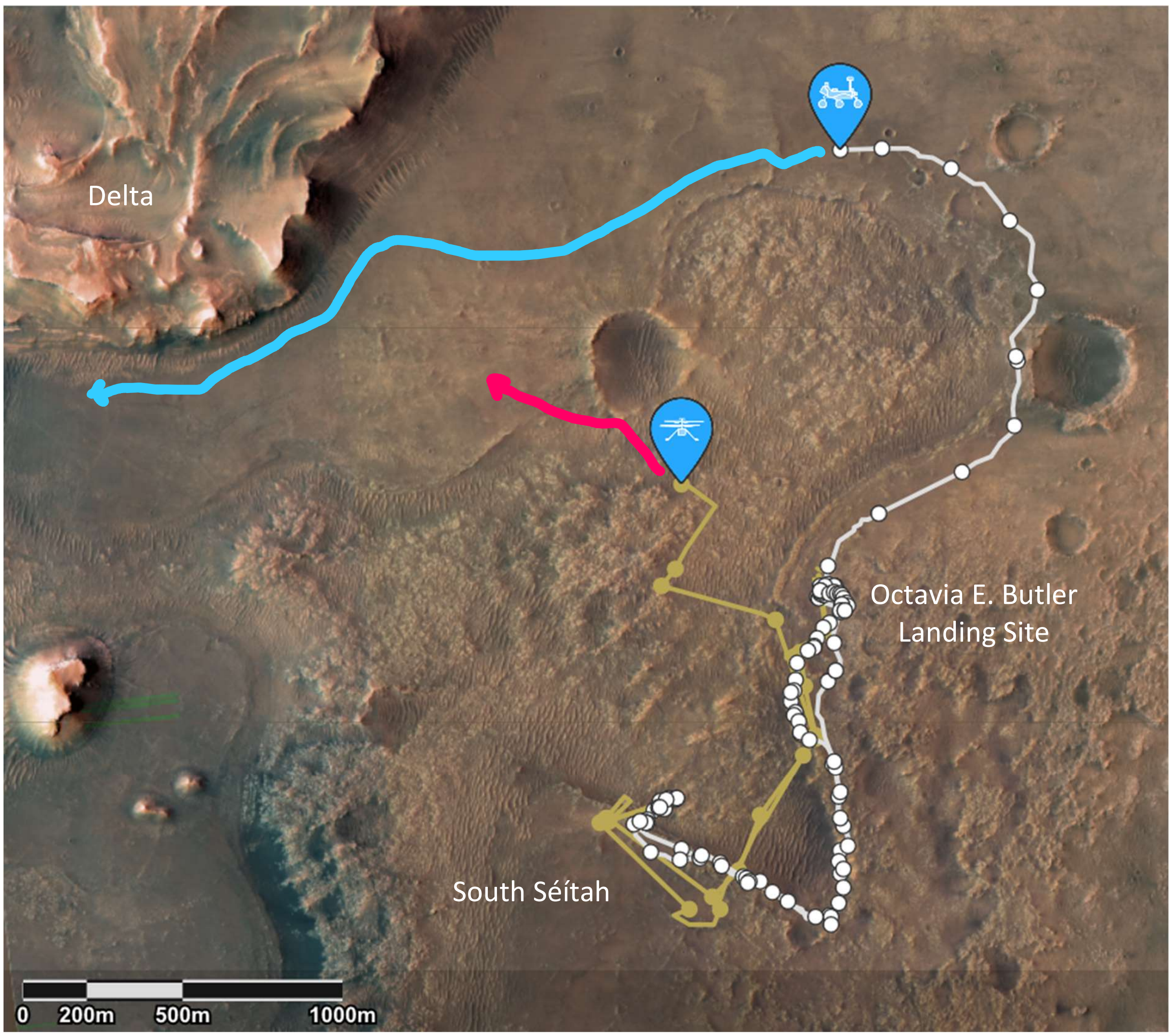
All in all, Ingenuity weathered the storm. Dust and sand did accumulate on the helicopter's swashplate assemblies (used to control the pitch of the rotor blades) as seen from their unusually high levels of resistance. This was also consistent with the dust and sand seen on the upper deck of the rover. Fortunately, the JPL team was able to clear the servo actuators with repeated actuation, using a technique tested earlier in the program.

The helicopter communicates to Earth through the rover, requiring a line-of-sight to be maintained. During Flight 17 in December, Ingenuity lost sight of the rover due to the elevated terrain between the two vehicles. Fortunately, the loss of communications didn't prevent the helicopter from landing safely.

Several flights have experienced anomalies that, in the end, will be used to improve the design of the next generation of flying machines. In general, the issues have been associated with the complexities of operating outside the helicopter's original flight envelope. Ingenuity's flight software was designed for level ground with discrete navigation markers. During flight, the helicopter's navigation camera images the ground, taking 30 pictures a second. Its software then timestamps the image and predicts what the camera should be seeing as it moves forward (for examples, changes in positions of surface features like rocks and ripples in the sand). On Flight 6, a single dropped frame resulted in all subsequent images being assigned the wrong time. This produced large oscillations in the vehicle and an erratic flight path as the software was operating on incorrect information.

While the rugged terrain in Jezero Crater has been a challenge on some flights, Flight 18 encountered a featureless, sandy surface. The absence of navigation aids threatened to end the flight prematurely. Still, Ingenuity was able to land safely and await further instructions.

So, what's next? After landing, scientists decided to explore an intriguing area just to the south, rather than heading directly to the delta. The rover has since finished up its work in the "South Séítah" geologic unit and returned to the landing site. The rover is now driving counterclockwise around the dunes that lay between it and the delta. Ingenuity will fly ahead, reconning areas of interest. Despite the number of off-the-shelf components used to build the rotorcraft and the harsh operating conditions, the helicopter's flight electronics and battery remain healthy and NASA has recently extended Ingenuity's mission to September. "Ginny's" success in Jezero crater has paved the way for future aerial sidekicks.



Path of the Perseverance rover (white) and Ingenuity (gold) since landing. After an excursion to South Séítah, both vehicles are now moving towards the delta. Blue line indicates a possible future route for the rover to the delta and, eventually, up onto the delta to the crater wall. The pink line indicates one possible route for the helicopter to reach the delta. Credit: NASA/JPL-Caltech/University of Arizona/USGS

Casualty of War

The photo may look like a replicate of page one, but it’s actually the Soviet version of their space shuttle (Buran) atop the heavy-lift aircraft, the Antonov An-225. The 640-ton, six engine An-225 was the world’s largest aircraft (and heaviest), able to carry 300,000 pounds more than the US military’s Boeing C-17.

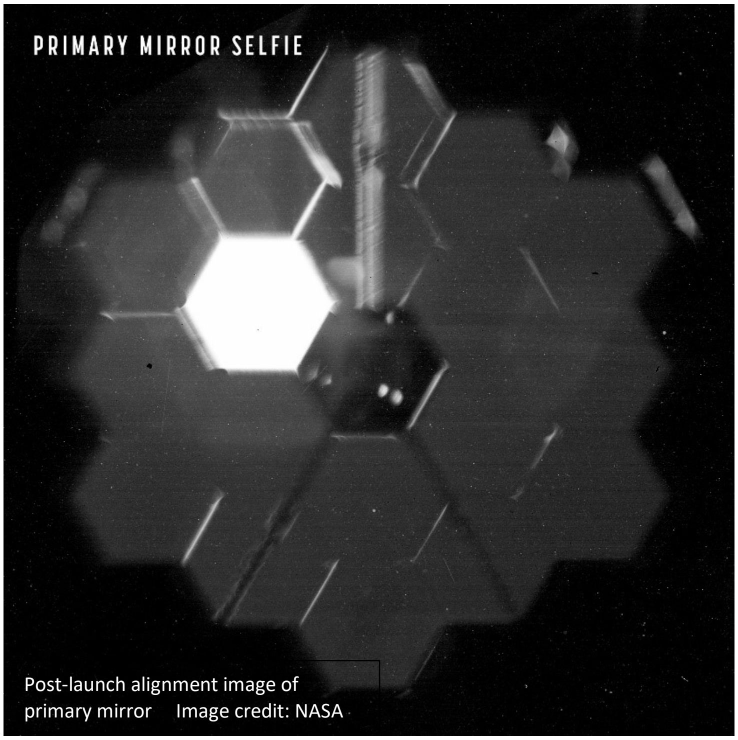
The AN-225 was built in 1985 to deliver the Soviet Union’s Energia rocket boosters and Buran-class space shuttle orbiters to their launch site. It was similar, but much larger than the modified Boeing 747 jetliners used by NASA to transport its shuttles. Two aircraft were planned, but only one completed before the fall of the Soviet Union in 1991. Mothballed for eight years, the AN-225 underwent an extensive restoration before being placed in commercial service in 2001.

Repainted and rebranded, the Antonov An-225 "Mriya" ("Dream") was flying out of the Ukraine. The aircraft has been used to deliver military equipment, disaster relief supplies, as well as commercial payloads. In many instances, Mriya was the only option for transporting massive equipment, such as gas and wind turbines, turbine blades and transformers.

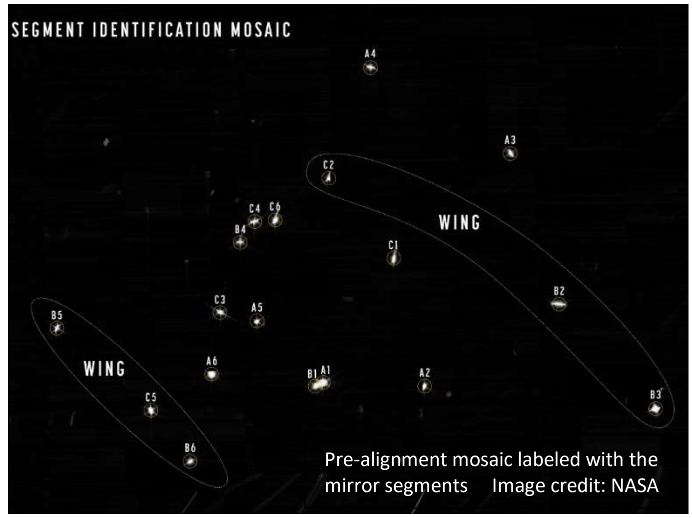
Unfortunately, Mriya was parked in a hanger undergoing repairs at an airport located to the northwest of Ukraine's capital city of Kyiv when Russia launched its attack on the country. According to sources in Ukraine, the aircraft was destroyed by the Russian invaders.

The destruction of the AN-225 closes a cold war chapter on Soviet space exploration and their attempt to develop a reusable orbital vehicle in response to the US space shuttle. In 2002, the only Buran to fly into space was destroyed when the hanger in which it was stored collapsed.

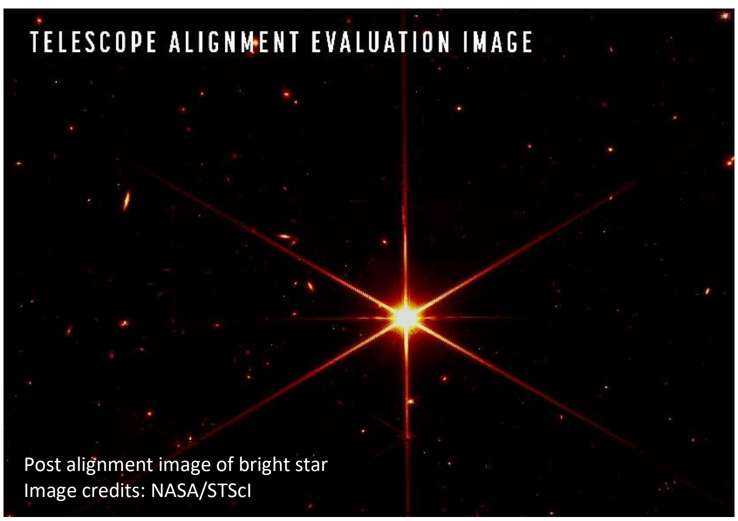
Webb Alignment Progress



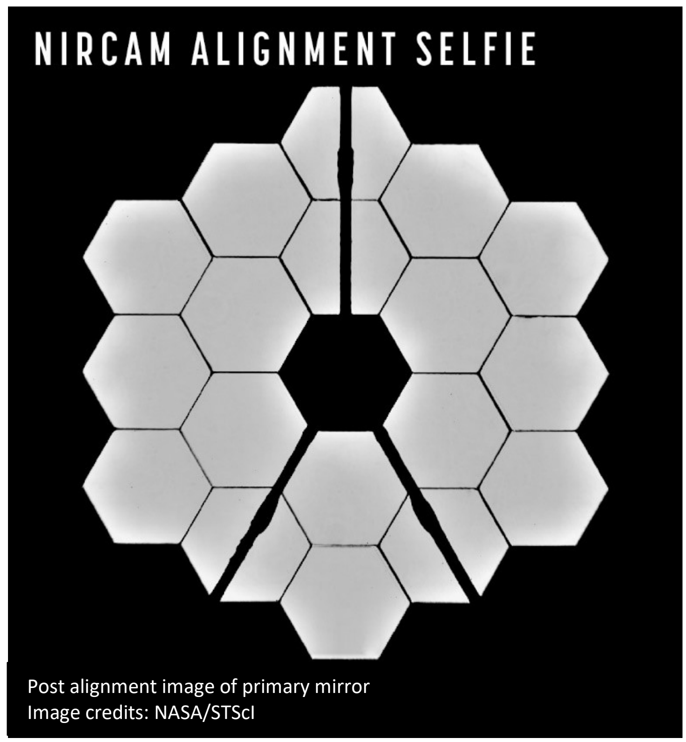
Post-launch alignment image of primary mirror Image credit: NASA



Pre-alignment mosaic labeled with the mirror segments Image credit: NASA



Post alignment image of bright star
Image credits: NASA/STScI



Post alignment image of primary mirror
Image credits: NASA/STScI

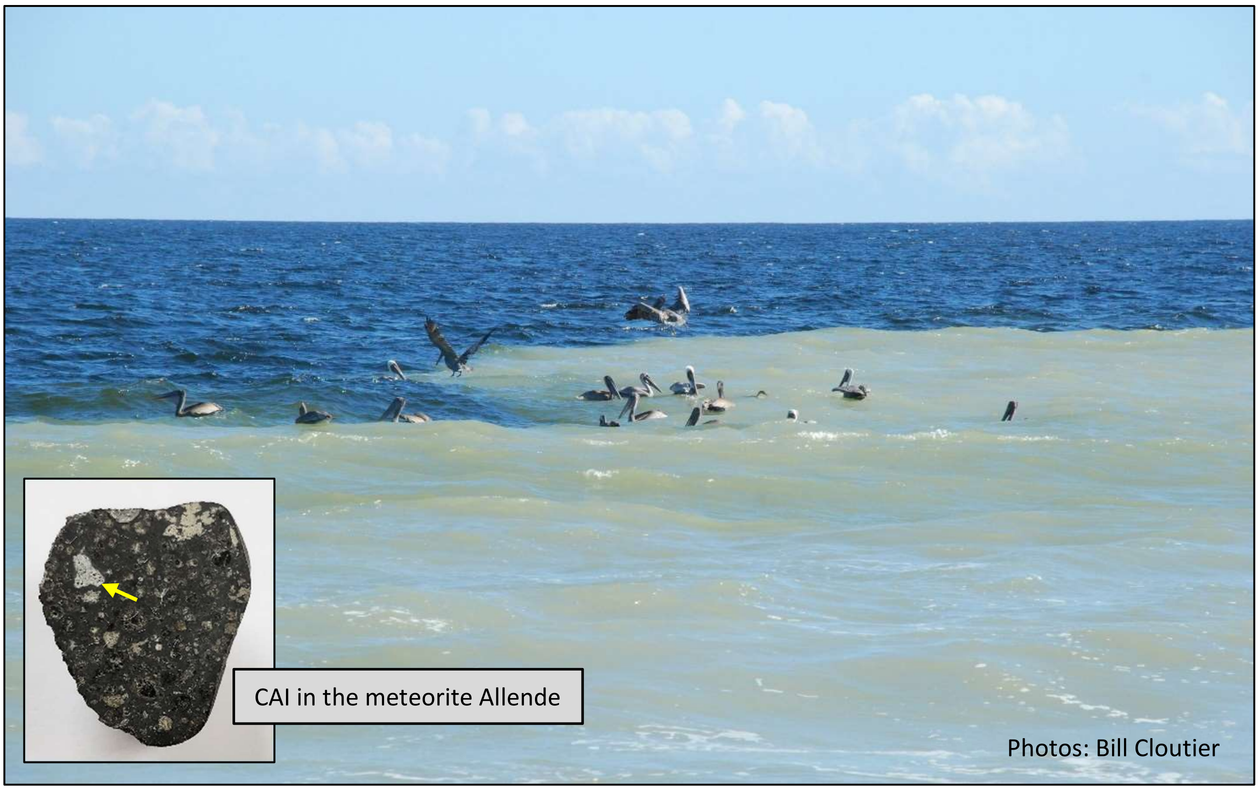
On March 11th the James Webb Space Telescope team announced that they had completed the "fine phasing" stage of alignment. In the process, which used the telescope's Near-Infrared camera (NIRCam), the eighteen mirror segments were aligned to work as one. The team was then able to confirm that the primary mirror is able to deliver unobstructed light to the instrument with performance at, or above, expectations. Over the next six weeks, the telescope's other three detectors (Near-Infrared Spectrograph, Mid-Infrared Instrument, and the Fine Guidance Sensor/Near InfraRed Imager and Slitless Spectrograph) will be aligned with the light path.

The image (top left) shows the post-launch alignment with only one mirror segment (illuminated segment) pointed at a bright star. Unaligned, the bright star shows up as 18 randomly placed images (top right). Post-fine phasing images (lower images), show the alignment results.

Water, Water Everywhere, But Where Did It Come From?

Scientists are using meteorites to piece together the history of the early solar system and to look for clues to enduring questions such as the source of Earth's water.

Our Sun formed about 4.6 billion years ago from the collapse of a giant rotating molecular cloud of gas and dust called the solar nebula. Rocky planets, like Earth, are believed to have formed from the remnants of the solar nebula, inside an "accretion disk," and relatively close to the newborn Sun. Conditions inside the disk were believed to be too hot for liquid water, so the Earth was believed to have been born dry, with water delivered at a later time by comets and water-rich asteroids from the outer solar system.



CAI in the meteorite Allende

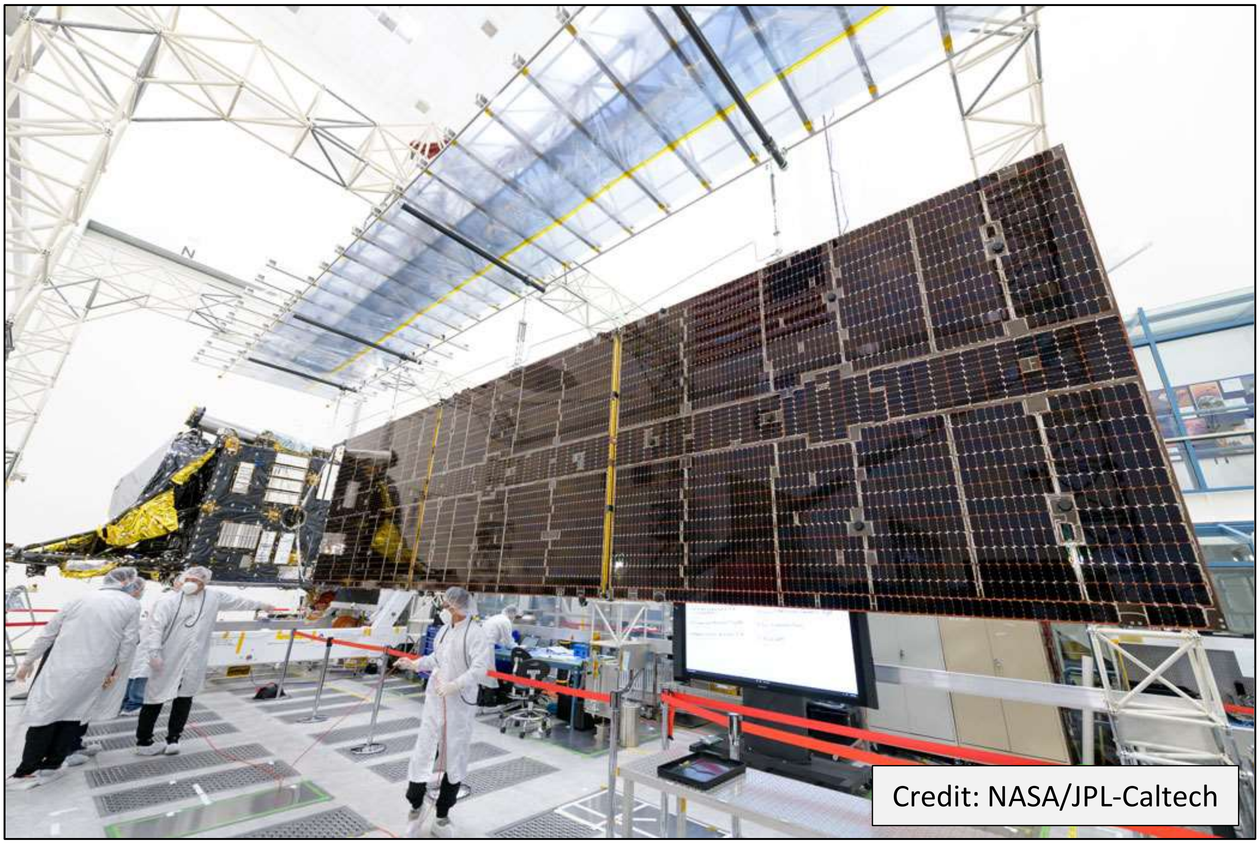
Photos: Bill Cloutier

Calcium-aluminum-rich inclusions (CAIs) were some of the first solids to condense out of the solar nebula. CAIs generally form on the inner edge of the accretion or protoplanetary disk. Researchers studying minerals inside the CAIs in primitive meteorites have found evidence that those containing oxidized iron formed in the presence of water vapor, with a hydrogen isotopic signature comparable to water found on Earth. This suggests, to researchers, that the Earth formed in a "wet" environment, with water from the interstellar medium drawn in as the solar nebula collapsed. If so, the water vapor would have been incorporated into the materials from which the Earth was formed.

In a separate study, researchers were able to measure the hydrogen content of Sahara 97096, an enstatite chondrite (meteoritic material similar in composition to rocks found on Earth). They found the isotopic hydrogen to be similar to that in Earth's mantle and with an abundance that could explain the presence of all of Earth's water. As with the previous study, the findings suggest that water was available in the rocky material from which our planet formed, without the need for a significant, external delivery from the outer solar system. To be continued …

Psyche Gets Its Wings

NASA's Psyche spacecraft is one step closer to its final launch configuration with the installation of its two massive, cross-shaped solar arrays. One of the two 37-foot-long (11.3-meter-long) arrays was recently unfolded in the Jet Propulsion Laboratory's (JPL's) High Bay 2 clean room (only one can be deployed at a time due to their size and only the center panels).


Credit: NASA/JPL-Caltech

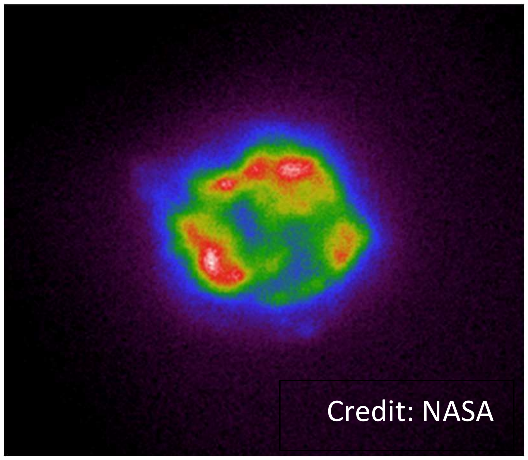
The solar arrays will provide power to the spacecraft and its science instruments during the 3½-year, 1.5-billion-mile (2.4-billion-km) journey to the Psyche asteroid and the two years in orbit around the metal-rich world. Psyche's solar arrays are highly efficient, lightweight and radiation resistant. They are designed to work in the very low-light conditions that the spacecraft will encounter at the far edge of the asteroid belt. The Psyche asteroid orbits the Sun at a distance ranging from 235 million to 309 million miles (378 million to 497 million km), 2½ to 3 times further than Earth's distance from the Sun. Near Earth, the solar arrays generate 21 kilowatts, but at Psyche, power production falls to only about 2 kilowatts.

After the deployment test at JPL, the arrays were restowed into their folded configuration against the spacecraft chassis. The 800 square feet (75 square meters), five-panel, cross-shaped solar arrays will eventually be removed from the chassis and returned to Maxar Technologies in Palo Alto (the supplier of the spacecraft bus) for full deployment testing before being reinstalled on the spacecraft later this spring.

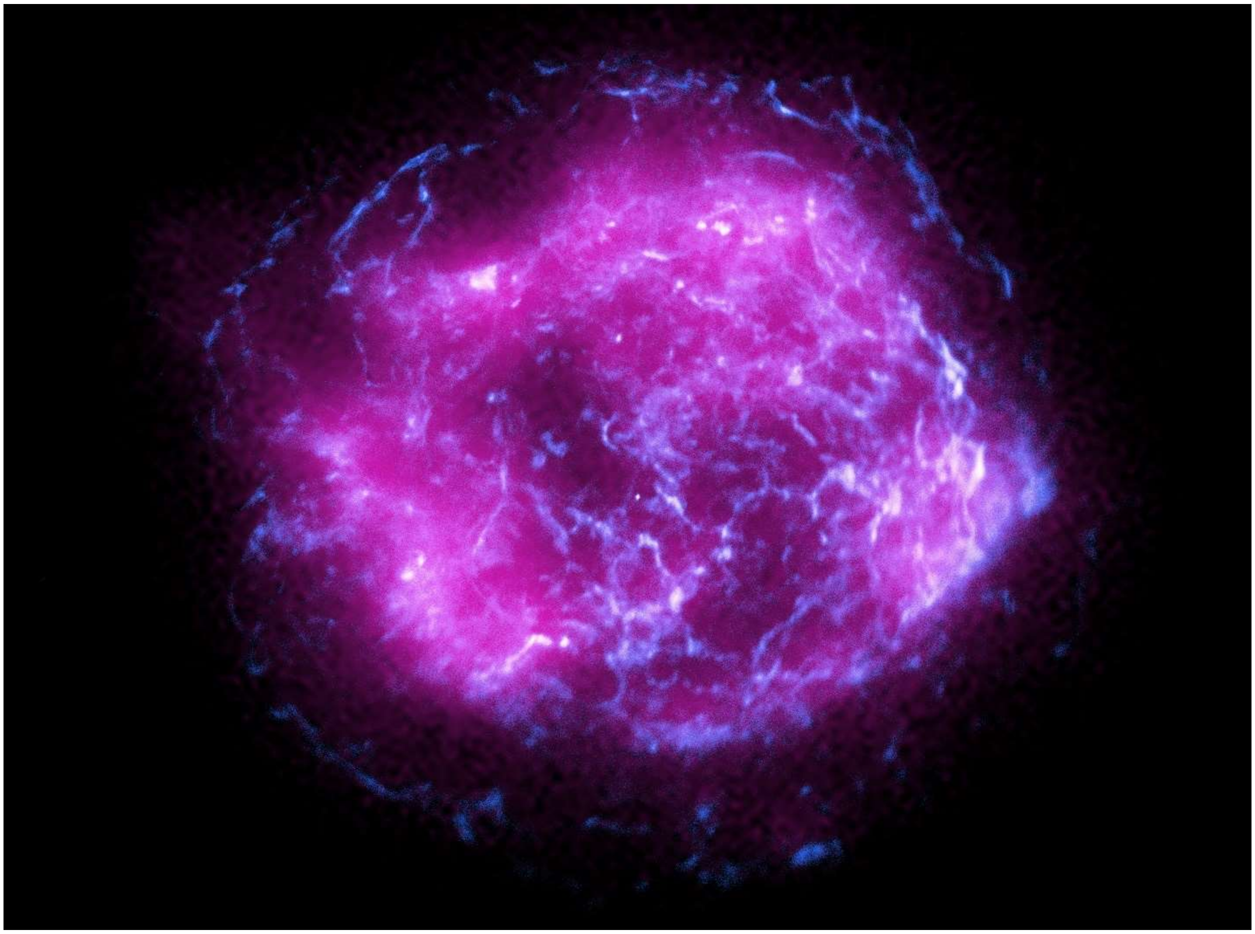
Launch window for the spacecraft opens on August 1st. It will be launched from the Kennedy Space Center atop a SpaceX Falcon Heavy rocket. The journey to the asteroid will include a gravity assist from the planet Mars.

IXPE First Science Image

NASA's Imaging X-ray Polarimetry Explorer (IXPE), launched on December 9, 2021, has returned its first science image. IXPE's first target was Cassiopeia A, a supernova remnant (it was also the first target of NASA's Chandra X-Ray Observatory launched in 1999). The two orbiting telescopes are equipped with different types of detectors, with IXPE able to map the intensity of X-rays and the orientation of the X-ray light as it travels through space. In the image on the right, colors ranging from cool purple and blue to red and hot white correspond with the increasing brightness of the X-rays.



IXPE orbits 370 miles (600 km) above Earth's equator. The mission is a collaboration between NASA and the Italian Space Agency, with partners and science collaborators in 12 countries.



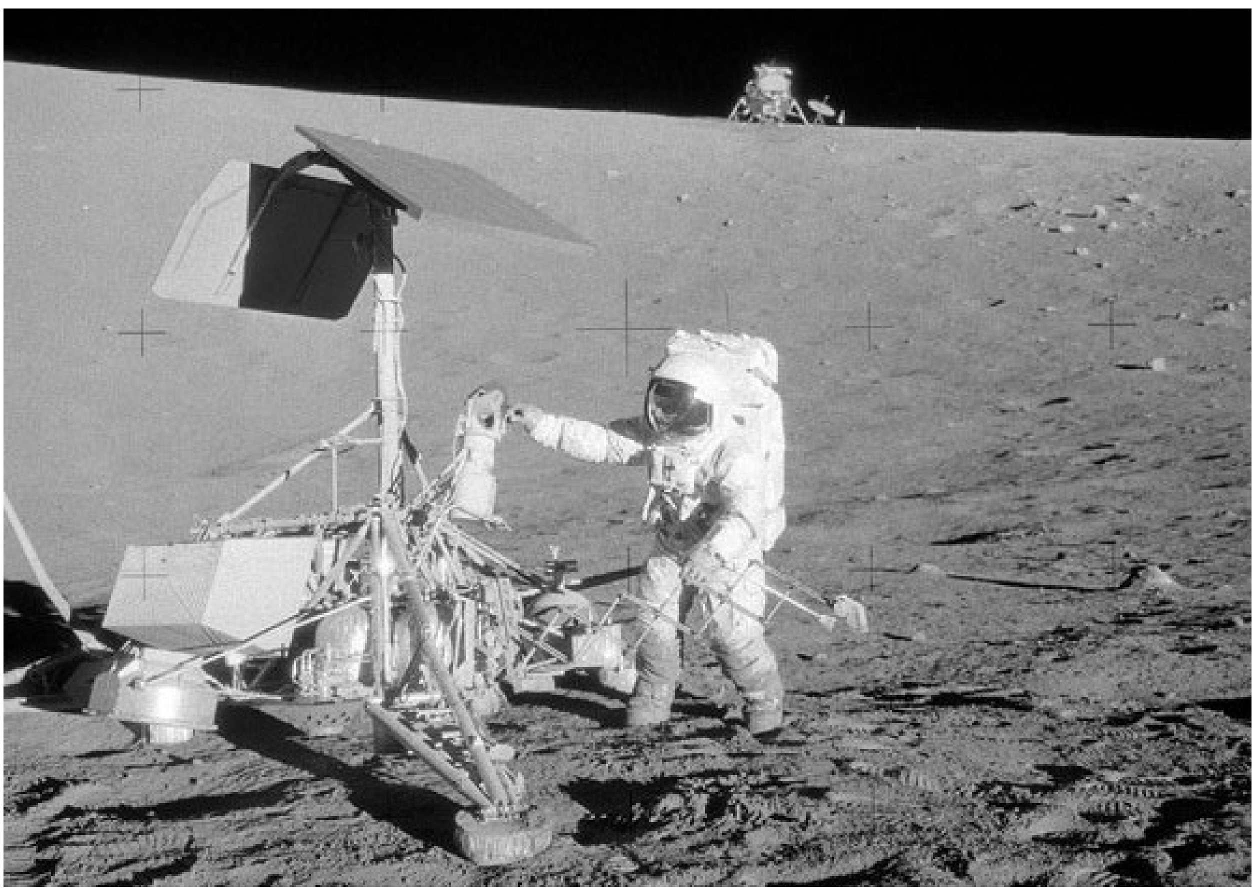
This image combines some of the first X-ray data collected by IXPE, shown in magenta, with high-energy X-ray data from the Chandra X-Ray Observatory, in blue.

Credits: NASA/CXC/SAO/IXPE

Home World

The Surveyor 3 spacecraft was launched on April 17, 1967, and was the second of the Surveyor series to successfully soft-land on the moon. The robotic spacecraft landed three days later inside an eroded crater in Oceanus Procellarum (Ocean of Storms), 230 miles (370 km) south of the crater Copernicus. The robotic lander returned 6,000 photographs of its surroundings including the first photo of Earth taken from the lunar surface. Surveyor 3 also provided data on the lunar soil, including its ability to support the weight of the Apollo lunar landing module, soil reflectivity and thermal properties.

The Apollo 12 astronauts removed several parts from the Surveyor 3 spacecraft during their mission to Oceanus Procellarum. Its camera is now on display in the Smithsonian National Air and Space Museum in Washington, D.C.

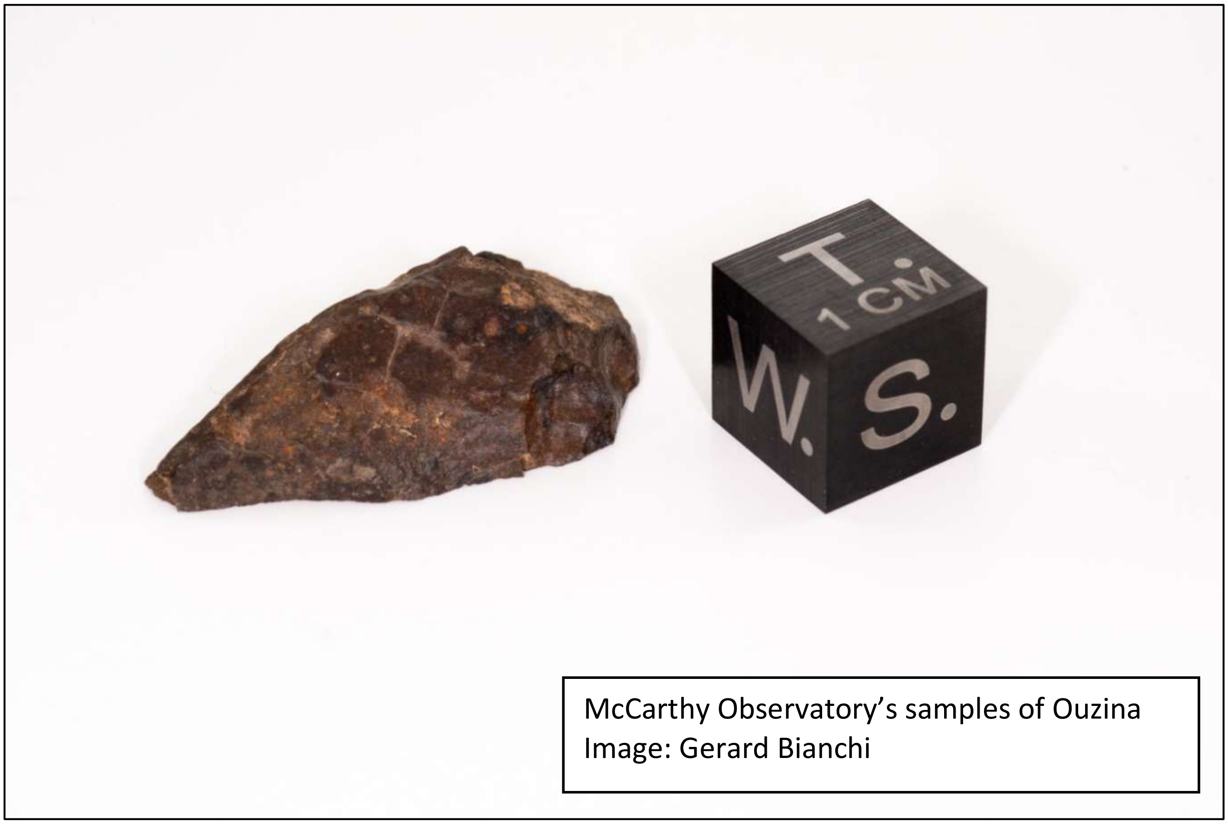


Apollo 12 astronaut Pete Conrad examines Surveyor 3's camera on November 20, 1969 before it was removed for its return to Earth

Image Credit: NASA/Apollo 12 astronaut Alan Bean

Meteorite Spotlight - Ouzina

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.



McCarthy Observatory's samples of Ouzina
Image: Gerard Bianchi

The Ouzina meteorite is a single stone found by a Bedouin in Morocco, near the Algerian border, in 1999. The 642-gram stone (1.42 pounds) is classified as Rumuruti chondrite. This group of stony meteorites is unique in that they don't belong to any of the major classes of chondrites. Meteorites like Ouzina are characterized by abundant and brightly colored chondrules, including sulfide chondrules that formed in the "protoplanetary disk," from which the planets would eventually accrete.

Scientists believe the Rumuruti meteorites may have come from the parent asteroid's regolith (the loose deposit of material the covers the minor planet's outer rocky surface). As such, they are comprised of a dusty matrix that cements together fragments of broken rock and mineral inclusions. Oxidization in the meteorite suggests the presence of water on the parent body. The breakup of the asteroid or collision, which produced the Ouzina meteorite, is believed to have occurred somewhere between 15 and 25 million years ago.

The McCarthy Observatory's sample of Ouzina is a 3.6-gram end cut of the meteorite.

Earth Day 2022

Setting aside a day to focus on spaceship Earth, its natural environment and the impact that humans have had on its fragile biosphere, was the idea of U.S. Senator Gaylord Nelson after witnessing the aftermath of the 1969 Santa Barbara oil spill (a well blowout in an off-shore drilling platform that spilled an estimated 80,000 to 100,000 barrels along the southern California coastline). In the first Earth Day, on April 22, 1970, 20 million Americans participated in country-wide events. The public awakening was credited for the establishment of the Environmental Protection Agency and the passage of important clean air and water legislation.

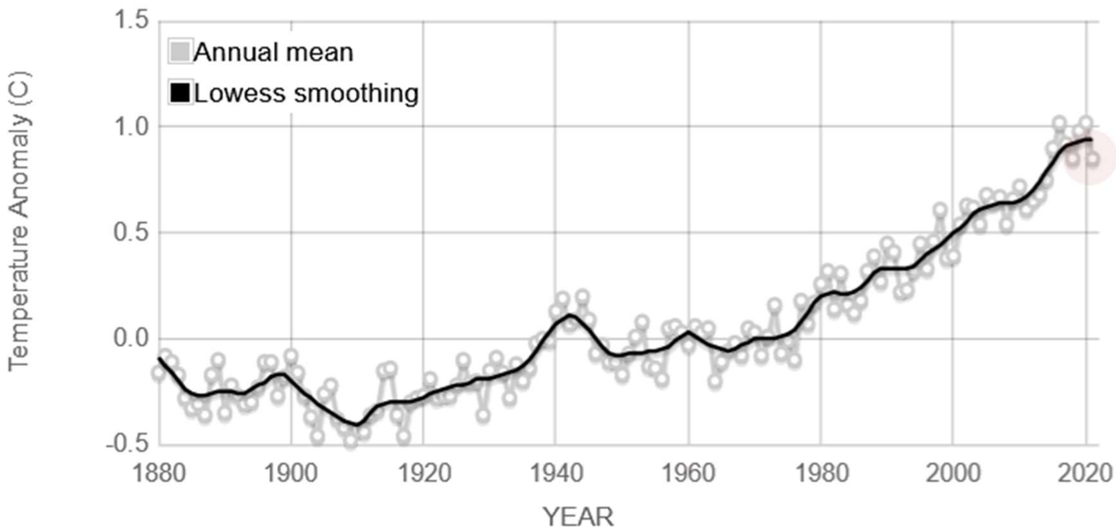
ISS Photo of Earth's Limb
Credit: NASA

Sunset image of the Earth's limb taken from the International Space Station showing several layers of the Earth's atmosphere (the Earth's atmosphere has several distinct layers). The majority (75% by mass and 99% of the water vapor) of the atmosphere (troposphere), highlighted in yellows and oranges, extends 5 to 10 miles above the surface (wider at the equator). Above the troposphere (pink and white region) is the stratosphere which extends to an altitude of 31 miles. Overlying layers - the mesosphere, thermosphere and exosphere become progressively thinner as the Earth's atmosphere transitions to the vacuum of space.

Earth Day 2022 finds the threats to the environment infinitely more challenging than an oil spill and their consequences potentially irreversible. Unlike a breached oil well, there are no quick fixes or easy answers if we do decide to address the source(s) of Earth's rapidly changing climate. Earth's health report is presented in the following graphs. It's not that the climate is changing - change is inevitable in such a complex, dynamic system over eons - it's the rate of change over such a short period of time that should be reawakening public consciousness.

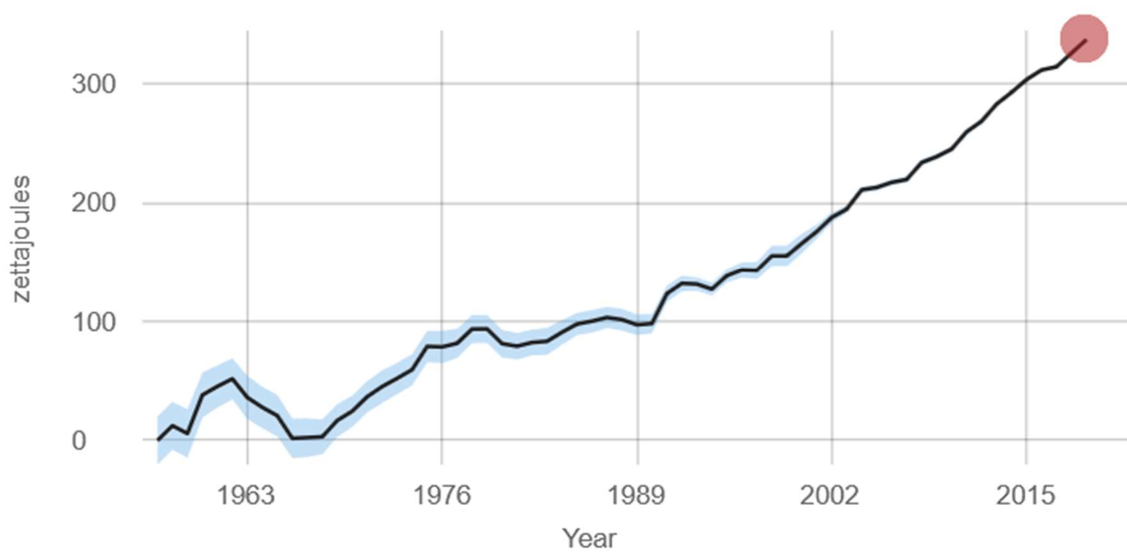
GLOBAL LAND-OCEAN TEMPERATURE INDEX

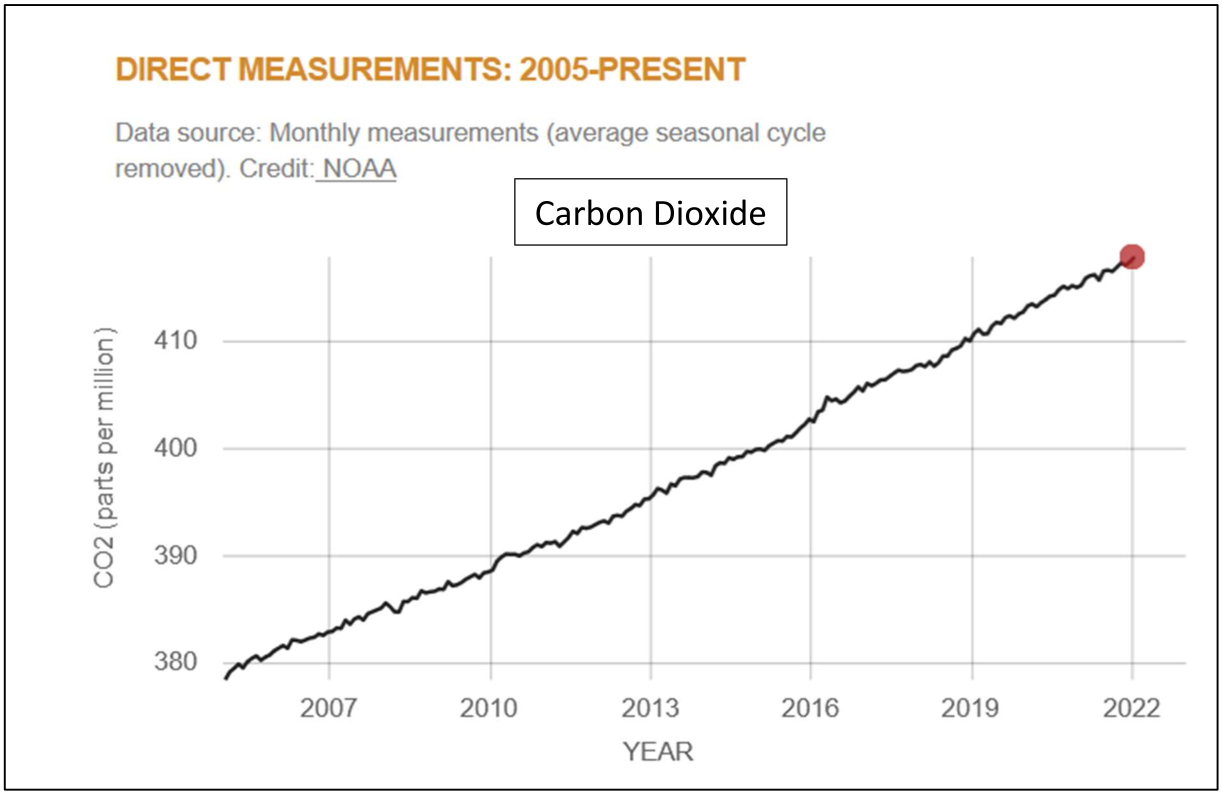
Data source: NASA's Goddard Institute for Space Studies (GISS).
Credit: NASA/GISS

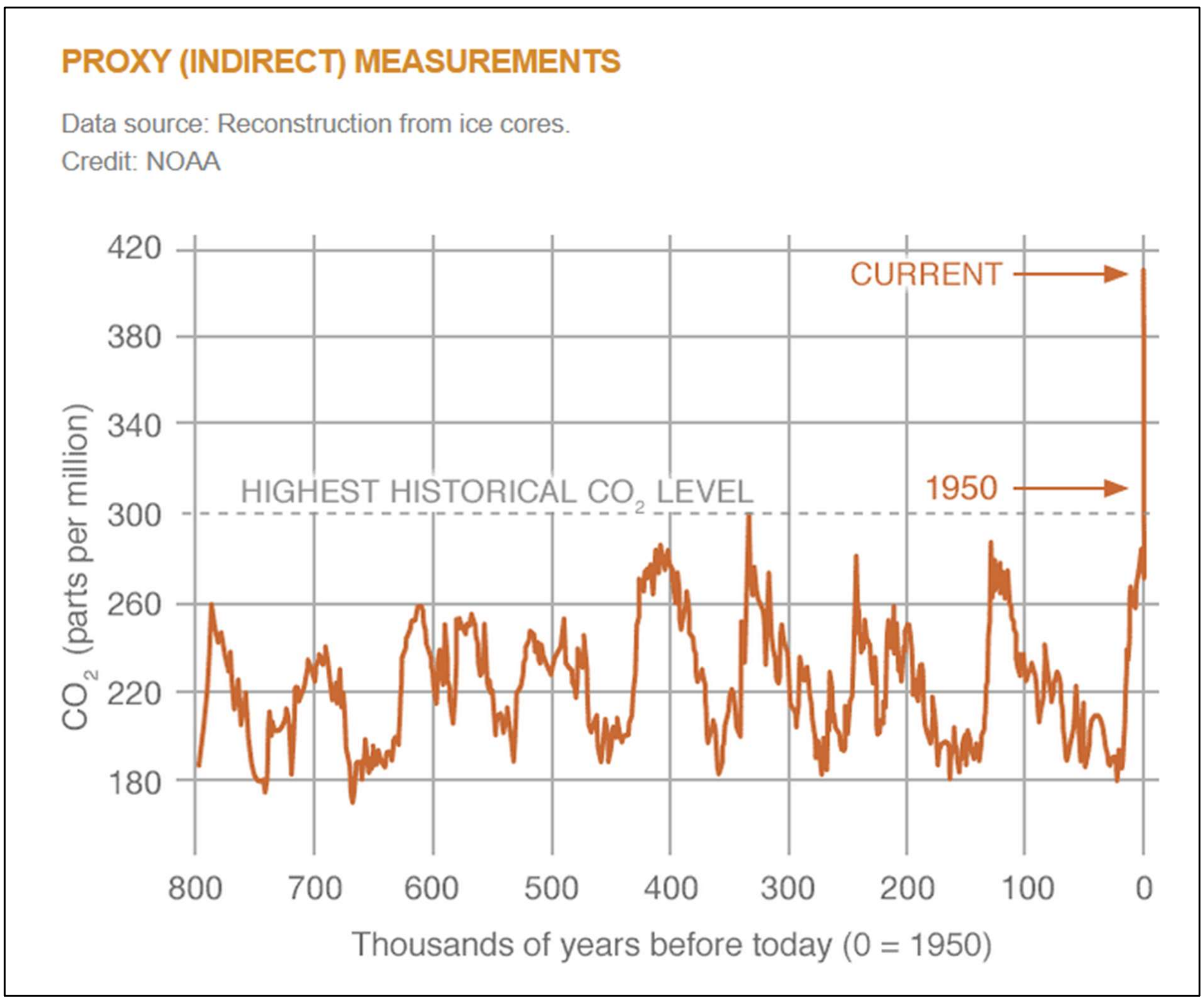


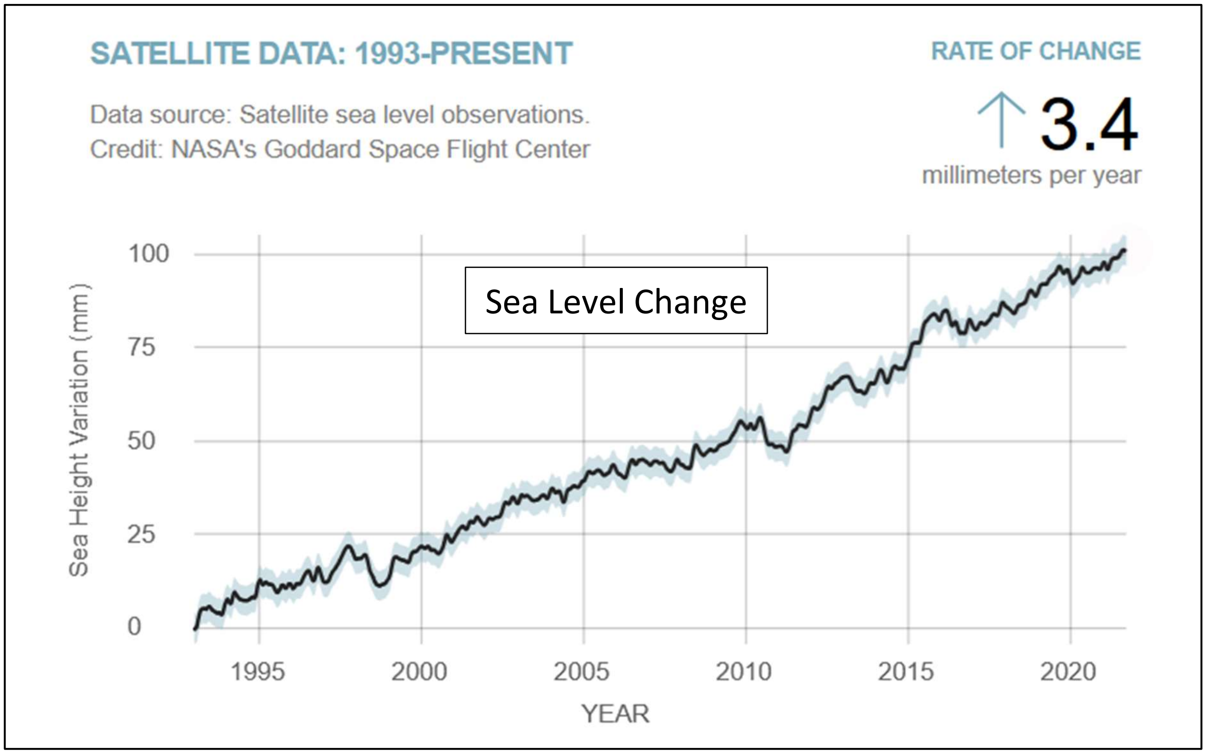
OCEAN HEAT CONTENT CHANGES SINCE 1955 (NOAA)

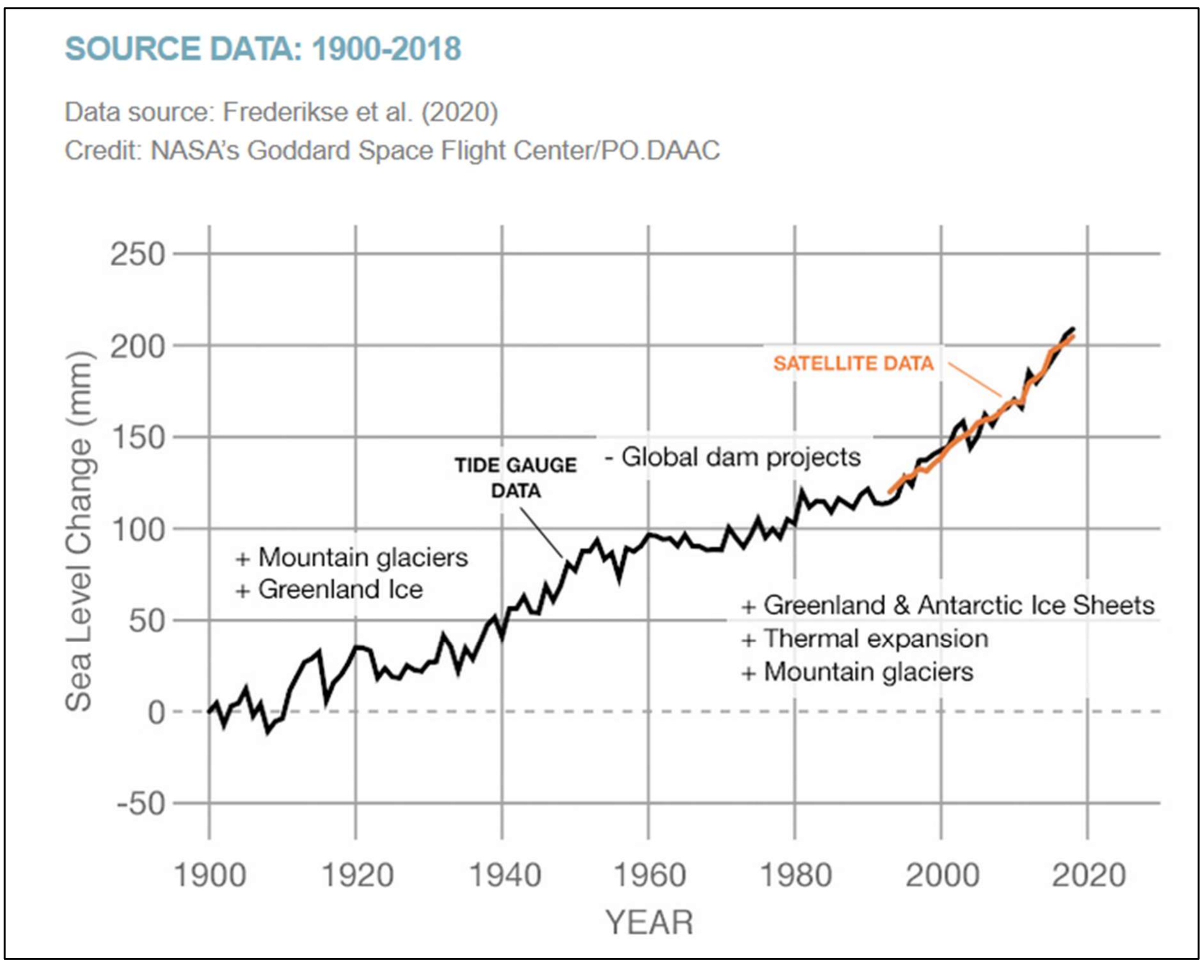
Data source: Observations from various ocean measurement devices, including conductivity-temperature-depth instruments (CTDs), Argo profiling floats, and eXpendable BathyThermographs (XBTs). Credit: NOAA/NCEI World Ocean Database

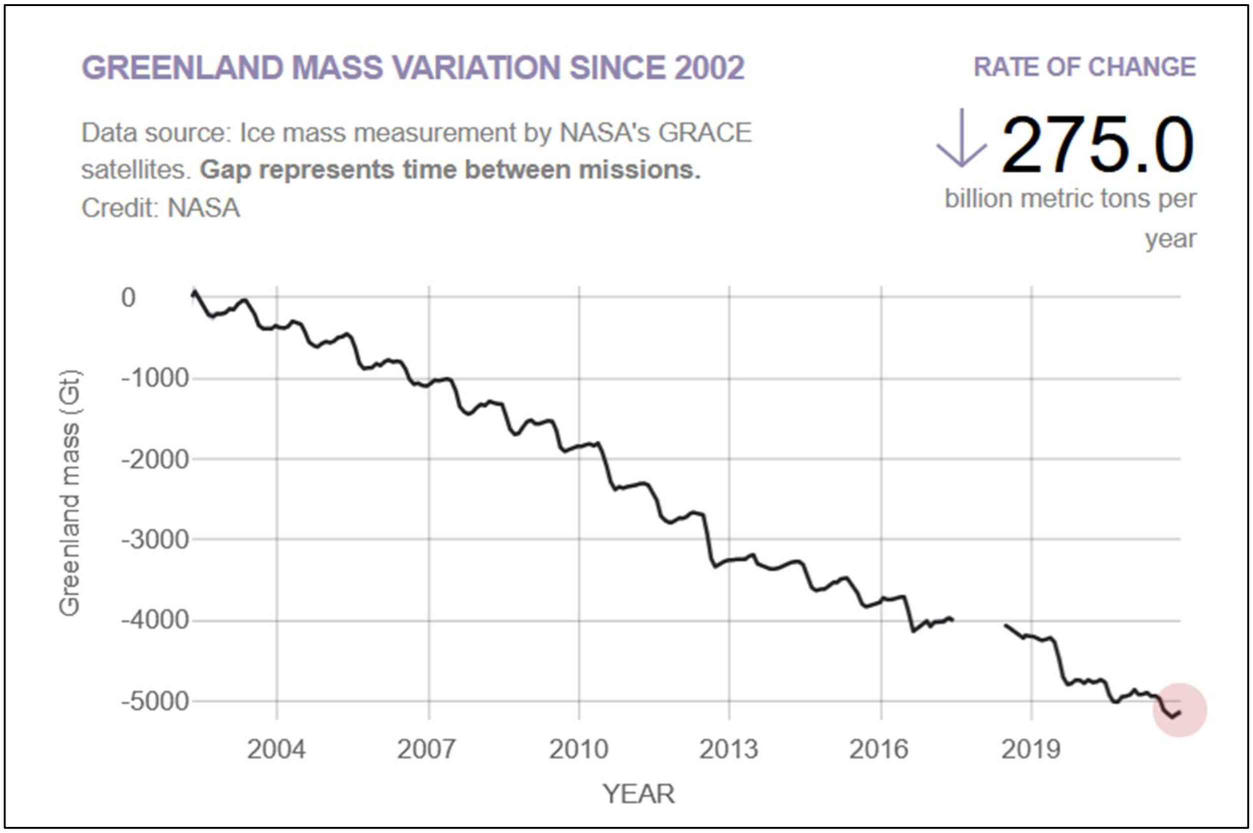


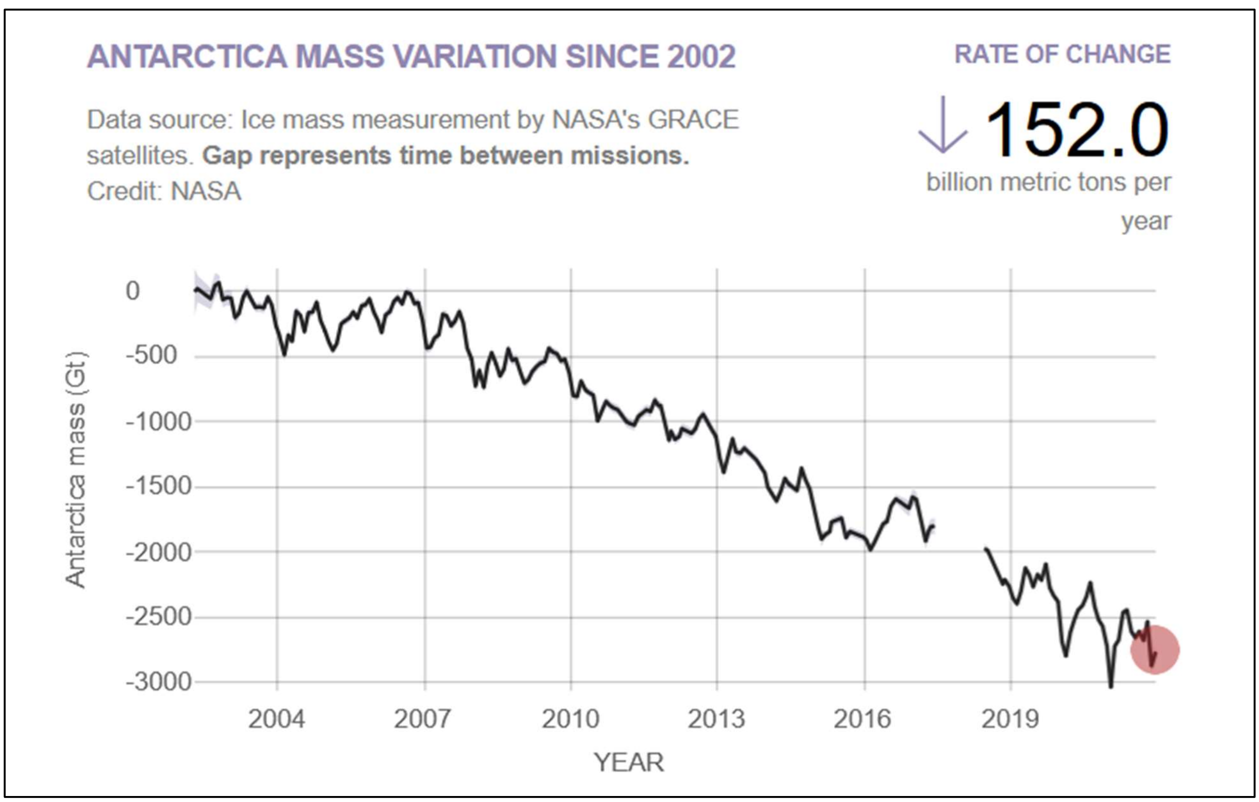

DIRECT MEASUREMENTS: 2005-PRESENT
Data source: Monthly measurements (average seasonal cycle removed). Credit: NOAA
Carbon Dioxide
CO2 (parts per million)
410
400
390
380
2007
2010
2013
2016
2019
2022
YEAR

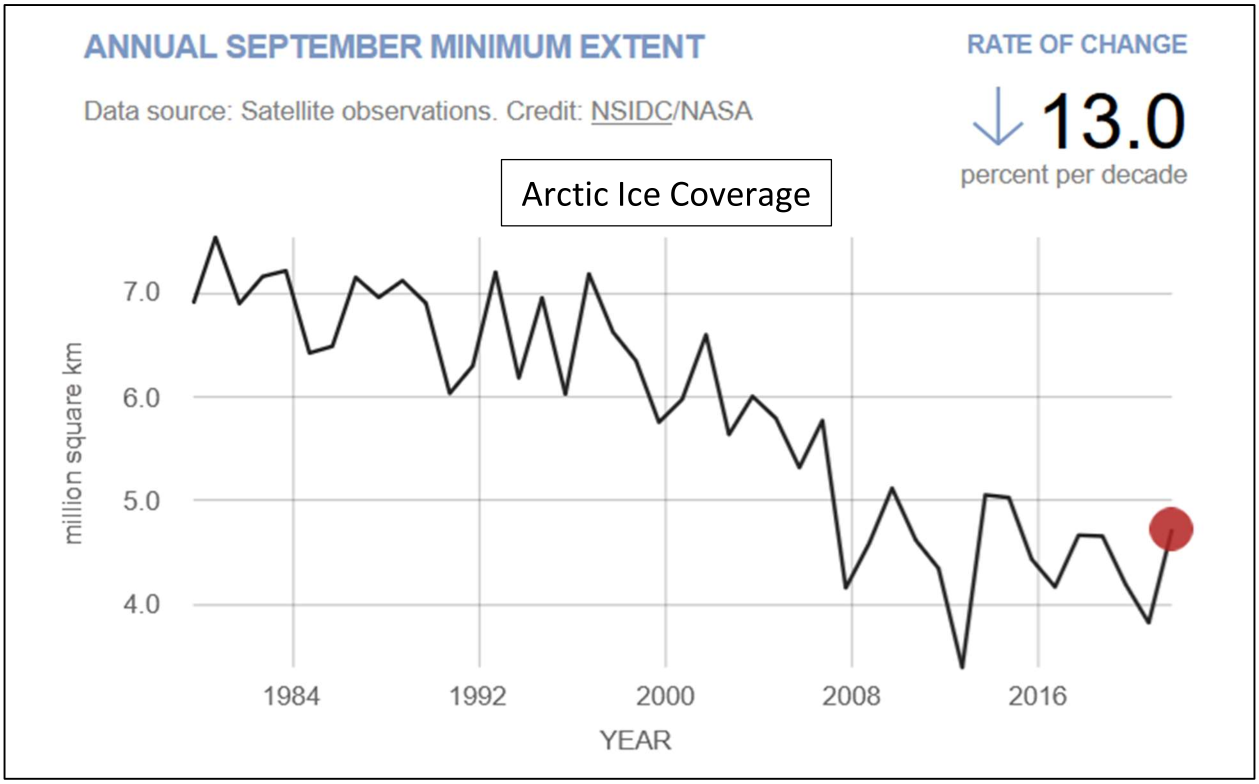

PROXY (INDIRECT) MEASUREMENTS
Data source: Reconstruction from ice cores.
Credit: NOAA
CO2 (parts per million)
420
380
340
300
260
220
180
CURRENT
HIGHEST HISTORICAL CO2 LEVEL
1950
800
700
600
500
400
300
200
100
0
Thousands of years before today (0 = 1950)


SATELLITE DATA: 1993-PRESENT
Data source: Satellite sea level observations.
Credit: NASA's Goddard Space Flight Center
RATE OF CHANGE
3.4
millimeters per year
Sea Level Change
Sea Height Variation (mm)
100
75
50
25
0
1995
2000
2005
2010
2015
2020
YEAR


SOURCE DATA: 1900-2018
Data source: Frederikse et al. (2020)
Credit: NASA's Goddard Space Flight Center/PO.DAAC
Sea Level Change (mm)
250
200
150
100
50
0
-50
SATELLITE DATA
TIDE GAUGE DATA
- Global dam projects
+ Mountain glaciers
+ Greenland Ice
+ Greenland & Antarctic Ice Sheets
+ Thermal expansion
+ Mountain glaciers
1900
1920
1940
1960
1980
2000
2020
YEAR


GREENLAND MASS VARIATION SINCE 2002
Data source: Ice mass measurement by NASA's GRACE satellites. Gap represents time between missions.
Credit: NASA
RATE OF CHANGE
275.0
billion metric tons per year
Greenland mass (Gt)
0
-1000
-2000
-3000
-4000
-5000
2004
2007
2010
2013
2016
2019
YEAR


ANTARCTICA MASS VARIATION SINCE 2002
Data source: Ice mass measurement by NASA's GRACE satellites. Gap represents time between missions.
Credit: NASA
RATE OF CHANGE
152.0
billion metric tons per year
Antarctica mass (Gt)
0
-500
-1000
-1500
-2000
-2500
-3000
2004
2007
2010
2013
2016
2019
YEAR



Earth's global average surface temperature in 2021 tied with 2018 as the sixth warmest on record, according to independent analyses done by NASA and the National Oceanic and Atmospheric Administration (NOAA). Global temperatures for 2021 were 1.5°F (or 0.85°C) above the average for NASA's baseline period (NASA uses the period from 1951-1980 as a baseline to see how global temperature changes over time), and collectively, the past eight years are the warmest since modern record keeping began in 1880. The warming is attributed to human activities, including the emission of greenhouse gases, such as carbon dioxide and methane.

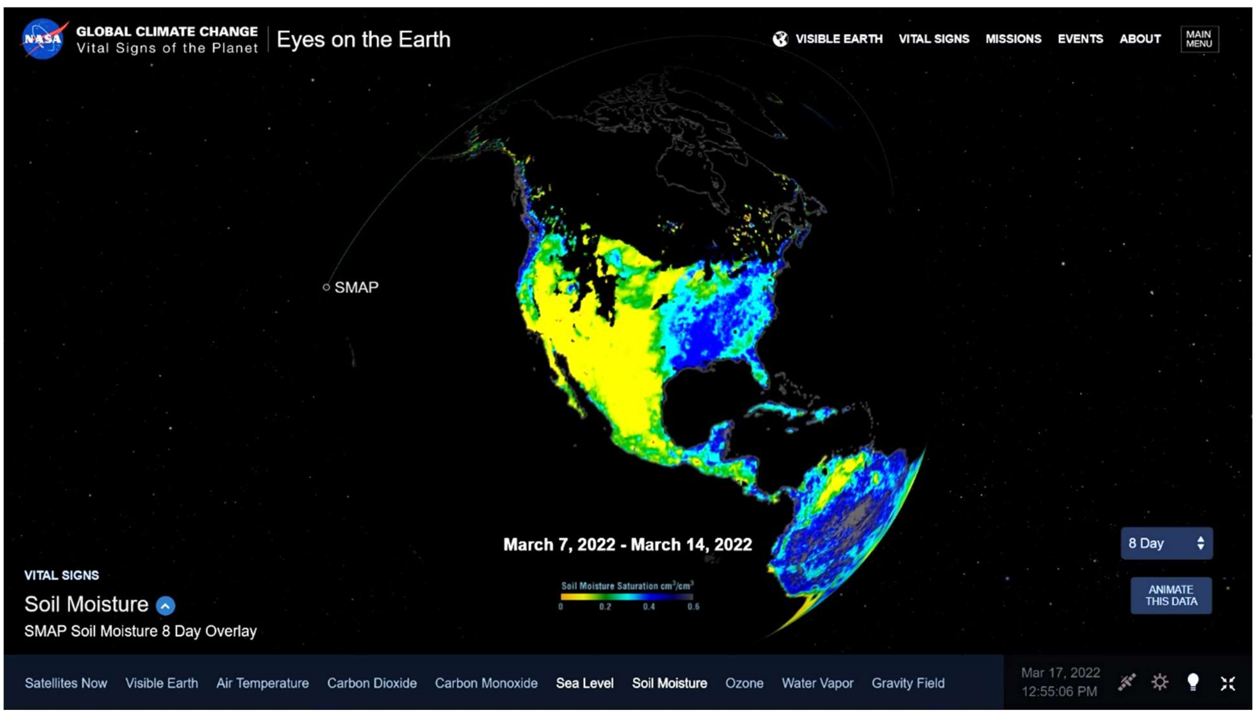
The Earth's oceans have absorbed much of the excess heat and carbon dioxide (warmer water also expands, contributing to rising sea levels). The top layer of the ocean (top 300 feet or 100 meters) has warmed more than 0.6°F (0.33°C) since 1969. Carbon dioxide and water also combine to form carbonic acid, which has increased the ocean's acidity by about 30% since the beginning of the Industrial Revolution. Between 7.2 and 10.8 billion metric tons of carbon dioxide are taken up by the oceans every year, impacting many ocean species (particularly those with shells and skeletons) and weakening coral reefs.

Cold water is more dense than warm water. This difference in density is responsible for ocean's currents (along with the global winds) and, to some degree, its level (the process is known as thermohaline circulation). Ocean currents regulate the Earth's temperature, transporting warm water and precipitation from the equator toward the poles and cold water from the poles back to the equator. Without currents, land temperatures would be more extreme and some areas, that currently benefit from the moderation, would not be habitable. The warming of the oceans reduces the temperature differential between the hot and cold regions and the energy available to drive circulation and upwelling (sinking cold water replaced by rising warm water). The Gulf Stream, which moves billion of tons of water up the east coast of North America every second, is becoming weaker and moving slower than it has in thousands of years.

The ice sheets covering Greenland and Antarctica have also decreased in mass. Satellite observations (by NASA's Gravity Recovery and Climate Experiment) have documented an average of 279 billion tons of ice lost each year between 1993 and 2019 for the Greenland ice sheet, while Antarctica lost ice at a rate of about 148 billion tons per year over the same period.

Global sea level rose about 8 inches (20 centimeters) in the last century - recorded by tidal gauges and, more recently, by satellites. The rate of increase has nearly doubled over the past two decades. A hotter planet is likely contributing to long-term climate changes (desertification and coastal flooding) and fueling extreme weather events that will impact our quality of life.

In 2018, NASA launched two missions that will provide decision makers (and the public) the latest information on the effects of climate change. The Gravity Recovery and Climate Experiment Follow-On mission (GRACE-FO), in partnership with the German Research Centre for Geosciences, continues the work of predecessor missions and is a significant improvement in the accuracy in tracking the movement of water (for example, from glaciers and ice sheets to the ocean). NASA also launched the Ice, Cloud, and Land Elevation Satellite-2, or ICESat-2, a mission that provides precise elevation measurements on the Earth's ice sheets, glaciers and sea ice. In November 2020, Sentinel-6 was launched, the latest in a series of satellites (starting with TOPEX-Poseidon and the Jason series) that have been monitoring global mean sea level since 1992. Future Earth Systematic Missions include the Surface Water & Ocean Topography (SWOT) satellite, currently scheduled for launch for the end of 2022.

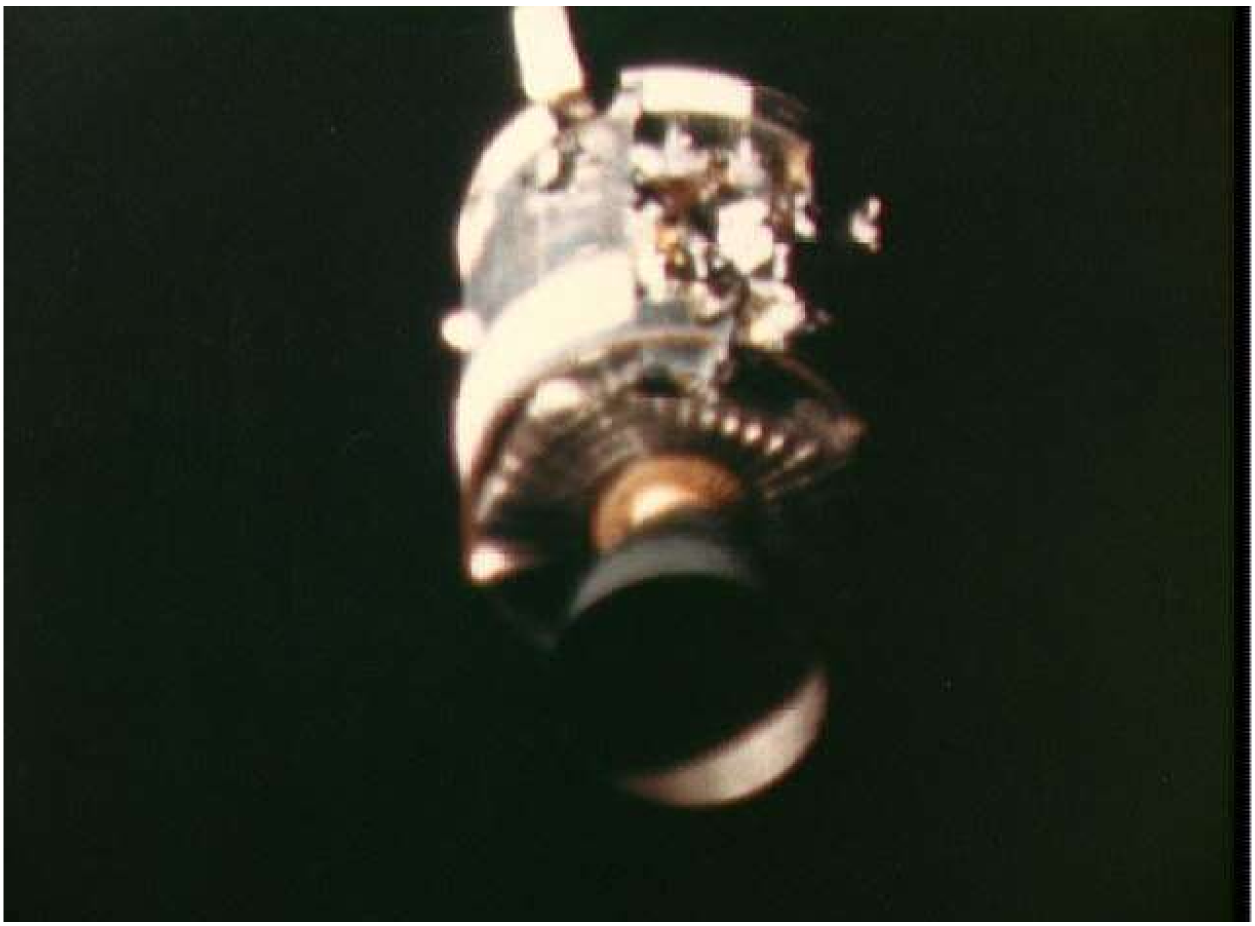


Data from the Soil Moisture Active Passive (SMAP) satellite for a week in March shows the western half of the US in drought condition. Currently 35 states are experiencing moderate or worse drought conditions with 112.8 million people affected. California and Texas have seen a large expansion of Extreme Drought and Exceptional Drought conditions, respectively. The outlook is for drought conditions to persist, with below normal precipitation for the central and western parts of the country.

April History

Apollo 16 wasn't the only lunar mission launched in the month of April. Two years earlier, on April 11, 1970, Apollo 13 lifted off from Cape Canaveral in what was intended to be the third manned mission to the Moon. The crew of James Lovell, Fred Haise and Jack Swigert never got their chance.

Two days later and almost 200,000 miles from Earth, the No. 2 oxygen tank exploded, cracking the feed pipe to the No. 1 oxygen tank and crippling the fuel cells providing the electrical power to the Command Module. The next four days would become the greatest human drama in space history.



Damaged Apollo 13 Service Module photographed after the Command Module separation

Photo: NASA

With failing power and a cloud of debris surrounding the space craft, the three astronauts shut down the Command Module and moved into the Lunar Module (LM). The LM was designed to support two astronauts for a maximum of 45 hours. The LM now needed to support the three astronauts for 75 to 100 hours for a safe return to Earth. To conserve supplies, almost all the spacecraft's systems were turned off. The temperature dropped to just above freezing, water condensed on all the internal surfaces and instruments, and the level of carbon monoxide increased to life-threatening levels. Fluids and gases being expelled from the crippled Command Module acted like small rockets, continually pushing the spacecraft off course. The debris cloud prevented anything more than rudimentary navigation. The astronauts became dehydrated (fuel cells also provide water) and the conditions inside the spacecraft became increasingly unsanitary when the crew, through a misunderstanding, began to accumulate human waste inside the spacecraft (instead of discharging it).

Only through the ingenuity of the engineers back in mission control, the backup crew and hundreds of contractors involved in the assembly and operation of the spacecraft, was the crew returned safely to Earth. The crew and the spacecraft reentered the Earth's atmosphere not knowing whether the heat shield had been damaged in the explosion or whether the parachutes would still deploy after four days of extreme cold. While Houston lost contact with the spacecraft for a minute longer than expected, Apollo 13 splashed down right on target.

The cause of the accident was eventually traced to damage the No. 2 oxygen tank had sustained during its removal from Apollo 10. With a damaged drain, internal heaters were used to empty the tank. Unfortunately, the pad power supply was not compatible with the spacecraft's power systems. The higher voltage melted the insulation leaving bare metal exposed to the pure oxygen environment inside the tank. When Jack Swigert turned on the tank fan, the contents exploded. The story of Apollo 13 is detailed in astronaut Jim Lovell's book "Lost Moon," former Flight Director Gene Kranz's book "Failure is Not an Option," and recreated in the Ron Howard/Tom Hanks film "Apollo 13."

Comet History

Comet Hale-Bopp graced the evening sky in the spring of 1997. It was brighter than the brightest stars in the sky, with a dust tail that stretched almost 45 degrees across the sky. The photo, taken

on April 2, 1997, one day after perihelion (closest approach to the Sun). shows the brighter, yellow dust tail and the dimmer, blue ion (gas) tail.

The orbital period of *Hale-Bopp* as it entered the inner solar system was 4,206 years. A close encounter with Jupiter in April of 1996 modified its orbit, shortening its orbital period to 2,380 years as it returned to the outer solar system.

April Showers

The Lyrid meteor shower is expected to peak just before dawn on April 22nd. The dust producing the shooting stars is from *Comet Thatcher*. Expect to see 10 to 20 meteors per hour if light from an early morning moon doesn't interfere. As with all meteor showers, the Lyrids are named for the constellation (Lyra) from which they appear to radiate.

Sunrise and Sunset (New Milford, CT)

Date	Sunrise	Sunset
April 1st (EDT)	06:36 am	7:19 pm
April 15th	06:13 am	7:34 pm
April 30th	05:51 am	7:50 pm

Astronomical and Historical Events

1st	New Moon
1st	Apollo Asteroid 2007 FF1 near-Earth flyby (0.050 AU)
1st	History: Comet *Hale-Bopp* reaches perihelion – closest approach to Sun (0.914 AU) (1997)
1st	History: launch of the first weather satellite, Tiros 1 (1960)
2nd	Aten Asteroid 2016 GW221 near-Earth flyby (0.025 AU)
2nd	Aten Asteroid 2021 GN1 near-Earth flyby (0.034 AU)
2nd	Amor Asteroid *18106 Blume* closest approach to Earth (2.475 AU)
2nd	History: U.S. release of the movie "2001 A Space Odyssey" (1968)
2nd	History: launch of Zond 1, Soviet Venus flyby mission (1964)
2nd	History: selection of the Mercury 7 astronauts (1959)
2nd	History: French physicists Louis Fizeau and Leon Foucault take first photo of the Sun (1845)
3rd	Apollo Asteroid *469219 Kamo`oalewa* closest approach to Earth (0.165 AU)
3rd	Apollo Asteroid *4257 Ubasti* closest approach to Earth (1.339 AU)
3rd	History: Soviet spacecraft Luna 10 becomes the first artificial satellite to orbit the Moon (1966)
4th	History: launch of Apollo 6, last test flight of the Saturn V rocket (1968)
5th	Apollo Asteroid *2012 TV* near-Earth flyby (0.049 AU)
5th	Amor Asteroid *8034 Akka* closest approach to Earth (1.557 AU)
5th	Apollo Asteroid *4179 Toutatis* closest approach to Earth (2.748 AU)
5th	History: launch of the Compton Gamma Ray Observatory (1991)
5th	History: launch of the first Pegasus rocket (1990)
5th	History: launch of Pioneer 11, Jupiter and Saturn flyby mission (1973)

Astronomical and Historical Events (continued)

6th Scheduled flight of the Axiom 1 mission, a commercial mission to the International Space Station. The 10-day commercial mission, managed by Axiom Space, will be commanded by former NASA astronaut Michael López-Alegría, with 3 paying passengers aboard the SpaceX Crew Dragon.
6th History: launch of Intelsat 1, first commercial communications satellite (1965)
7th Moon at apogee (furthest distance from Earth)
7th History: launch of the Mars Odyssey orbiter (2001)
7th History: first spacewalk from the space shuttle (Story Musgrave, Don Peterson, STS-6) (1983)
7th History: launch of Luna 14, Soviet Moon orbiter mission designed to test radio transmission stability, measure the lunar gravity field, solar wind and cosmic rays (1968)
8th Centaur Object *37117 Narcissus* at Opposition (6.299 AU)
8th History: launch of the Bigelow Expandable Activity Module (2016) aboard a SpaceX Dragon cargo vehicle - module was installed on the International Space Station for a two-year long demonstration of the expandable habitat
8th History: discovery of Saturn moon's *Telesto* by the Voyager 1 spacecraft (1980)
8th History: meteorite hits house in Wethersfield, Connecticut (1971)
8th History: launch of the unmanned Gemini 1 (1964)
8th History: Project Ozma, the search for extraterrestrial intelligence, begins as Frank D. Drake, an astronomer at the National Radio Astronomy Observatory in Green Bank, West Virginia, turns the 85-foot Howard Tate telescope toward the star Tau Ceti (1960)
9th **Second Saturday Stars - Open House at McCarthy Observatory**
9th First Quarter Moon
9th Apollo Asteroid 2020 GH1 near-Earth flyby (0.043 AU)
10th Kuiper Belt Object 2013 FS28 at Opposition (81.914 AU)
10th History: Japanese lunar probe Hiten impacts Moon; first non-U.S./Soviet lunar probe, also first to visit the Lagrangian Points L4 and L5 during its three-year mission (1993)
10th History: discovery of asteroid *216 Kleopatra* by Johann Palisa (1880)
11th History: ESA spacecraft Venus Express enters orbit around the planet Venus (2006)
11th History: launch of Apollo 13 with astronauts James Lovell, Fred Haise and Jack Swigert; mission aborted when oxygen tank explodes and cripples the Command Module (1970)
12th Apollo Asteroid 363599 (2004 FG11) near-Earth flyby (0.049 AU)
12th Amor Asteroid *5653 Camarillo* closest approach to Earth (0.584 AU)
12th Kuiper Belt Object 523693 (2014 FT71) at Opposition (46.291 AU)
12th History: launch of the first space shuttle (Columbia) with astronauts John Young and Robert Crippen (1981)
12th History: launch of Vostok 1 with cosmonaut Yuri Gagarin, first person to orbit the Earth (1961)
12th History: Edward Maunder born; studied solar cycle and sunspots. Analyzed period between 1645 and 1715 when almost no sunspots where recorded - known as the "Maunder minimum" or "Little Ice Age" because of the severe winters (1851)
12th History: discovery of Asteroid 10 *Hygiea* by Annibale de Gasparis (1849)
13th History: launch of Transit 1B, first experimental navigation satellite (1960)
14th Apollo Asteroid *4581 Asciepius* closest approach to Earth (0.487 AU)
14th History: Christiaan Huygens born, Dutch scientist and discoverer of Saturn's rings and largest moon *Titan* (1629)

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

15th Atira Asteroid 2021 PH27 closest approach to Earth (0.587 AU)
15th Amor Asteroid *7480 Norwan* closest approach to Earth (2.064 AU)
15th Centaur Object *31824 Elatus* at Opposition (14.928 AU)
16th Full Moon (Full Pink Moon)
16th History: launch of Apollo 16 with astronauts John Young, Ken Mattingly and Charles Duke, the only mission to the lunar highlands (1972)
16th History: Leonardo Da Vinci born, first to correctly explain Earthshine (1452)
17th Easter Sunday
17th History: closest flyby of the Sun by a spacecraft, Helios 2 (1976)
17th History: launch of Surveyor 3, Moon lander, first to experience a lunar eclipse from the Moon's surface during which the temperature fell 250° F; Apollo 12 would later land near Surveyor 3 in 1969, retrieving pieces of the lander for return to Earth and analysis of the effects of the harsh lunar environment (1967)
18th Apollo Asteroid 2020 TQ6 near-Earth flyby (0.034 AU)
18th Aten Asteroid *326290 Akhenaten* closest approach to Earth (0.614 AU)
18th History: launch of the Transiting Exoplanet Survey Satellite (TESS) by a SpaceX Falcon 9 rocket from the Cape Canaveral Air Force Station, Florida (2018)
19th Moon at perigee (closest distance from Earth)
19th Scheduled launch of SpaceX's Crew Dragon with a crew of four from the Kennedy Space Center to the International Space Station
19th Amor Asteroid *1980 Tezcatlipoca* closest approach to Earth (1.920 AU)
19th Dwarf Planet *136108 Haumea* at Opposition (49.282 AU)
19th History: launch of the last Soviet Salyut space station, Salyut 7 (1982)
19th History: launch of the first space station, Soviet Salyut space station, Salyut 1 (1971)
20th Apollo Asteroid 2011 MD closest approach to Earth (0.866 AU)
22nd Lyrids Meteor Shower peak
22nd Earth Day
22nd Apollo Asteroid 2017 UR2 near-Earth flyby (0.049 AU)
22nd Apollo Asteroid *11885 Summanus* closest approach to Earth (0.799 AU)
22nd History: Cassini's final close flyby of Saturn's moon Titan, initiating the 22 Grand Finale orbits between the planet and its rings and the end of mission in September (2017)
22nd History: launch of the Air Force's X-37B prototype space plane from Cape Canaveral, Florida; first orbital mission (2010)
23rd Last Quarter Moon
23rd Atira Asteroid 2013 JX28 closest approach to Earth (0.463 AU)
23rd Amor Asteroid 3271 Ul closest approach to Earth (2.111 AU)
24th History: launch of space shuttle Discovery (STS-31) and deployment of the Hubble Space Telescope (1990)
24th History: launch of Mao 1, first Chinese satellite (1970)
24th History: cosmonaut Vladimir Komarov dies during re-entry of a prototype Soviet lunar spacecraft (Soyuz 1) when parachute lines become entangled (1967)
25th Aten Asteroid 2020 VN1 near-Earth flyby (0.049 AU)
25th Kuiper Belt Object *38083 Rhadamanthus* at Opposition (40.654 AU)
25th Kuiper Belt Object 2020 FY30 at Opposition (97.836 AU)
26th Amor Asteroid *3908 Nyx* closest approach to Earth (1.799 AU)

Astronomical and Historical Events (continued)

26th History: first flight of the modified Boeing 747 with its 98.4-inch (2.5 meter) diameter infrared telescope – the Stratospheric Observatory for Infrared Astronomy (SOFIA) (2007)
26th History: Venus flyby (gravitation assist) by the Cassini spacecraft (1998)
26th History: Ranger 4 impacts Moon (1962) - while the mission didn't return any scientific data due to an onboard computer failure, Ranger 4 become the first U.S. spacecraft to reach another celestial body when it crashed on the far side of the Moon
26th History: launch of Sputnik 14 (Cosmos 4), first successful Soviet reconnaissance satellite – designed to study upper layers of atmosphere and monitor U.S. nuclear tests (1962)
26th History: discovery of Asteroid 9 *Metis* by Andrew Graham (1848)
27th Aten Asteroid *2340 Hathor* closest approach to Earth (0.511 AU)
27th Centaur Object *472235 Zhulong* at Opposition (32.136 AU)
28th Apollo Asteroid 418135 (2008 AG33) near-Earth flyby (0.022 AU)
28th Apollo Asteroid *1685 Toro* closest approach to Earth (1.773 AU)
28th History: launch of the Cloudsat/Calipso cloud imaging and profiling satellites (2006)
29th Mercury at its Greatest Eastern Elongation (21°) – greatest apparent separation from the Sun in the evening sky
29th Apollo Asteroid 2017 UK52 near-Earth flyby (0.007 AU)
30th New Moon
30th History: Surveyor 3 lander takes the first picture of Earth from the Moon's surface (1967)

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

- 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

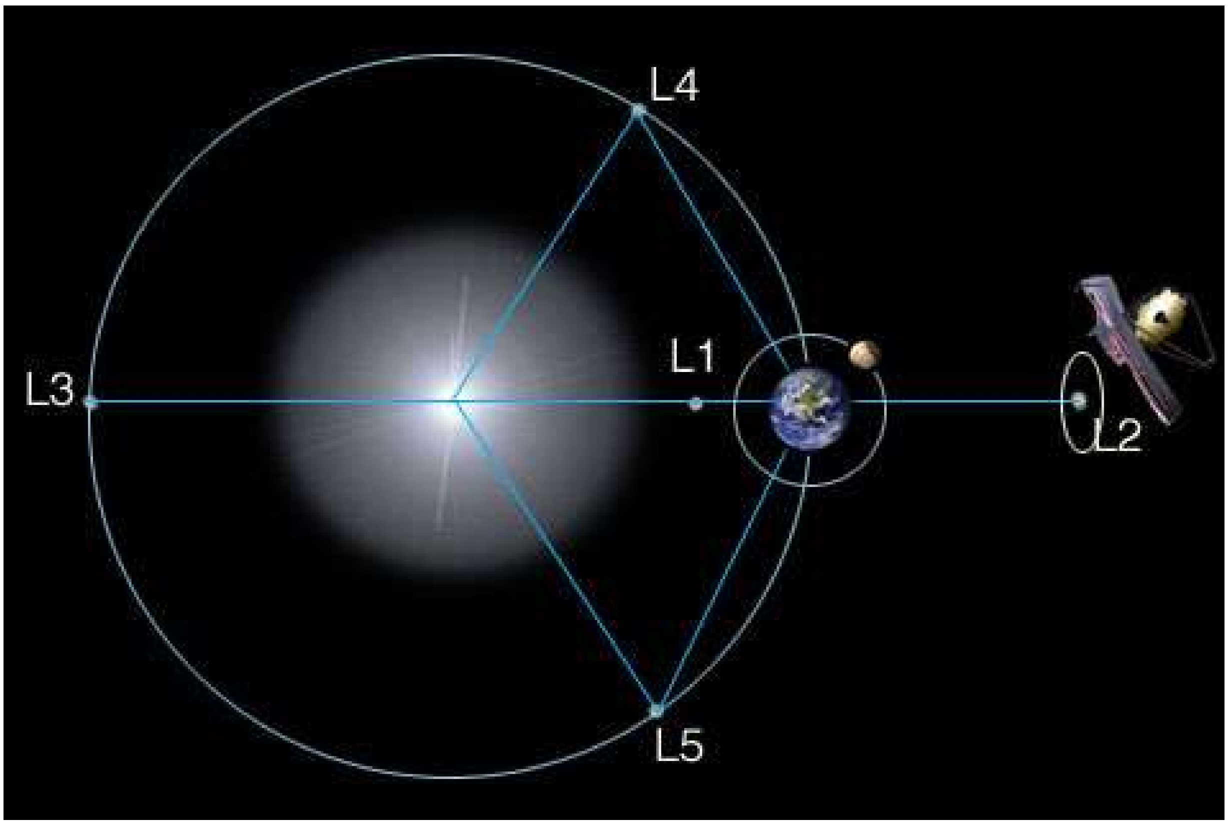
- Vital Signs of the Planet: https://climate.nasa.gov/

Mars – Mission Websites

- Mars 2020 (Perseverance rover): https://mars.nasa.gov/mars2020/
- Jezero Crater map: https://mars.nasa.gov/mars2020/mission/where-is-the-rover/
- 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/

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 location of the Webb telescope) is located 1 million miles (1.5 million km) beyond the Earth (as viewed from the Sun).



James Webb Space Telescope

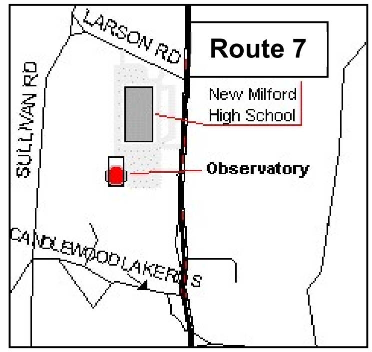
- https://webb.nasa.gov/index.html

Contact Information

The John J. McCarthy Observatory
P.O. Box 1144
New Milford, CT 06776

New Milford High School
388 Danbury Road
New Milford, CT 06776

Phone/Message: (860) 946-0312
www.mccarthyobservatory.org



	www.mccarthyobservatory.org
	@McCarthy Observatory
	@McCarthy Observatory
	mccarthy.observatory@gmail.com
	@JJMObservatory
	@mccarthy.observatory