CELEBRATING 40 YEARS

THE PLANETARY REPORT

JUNE SOLSTICE 2020

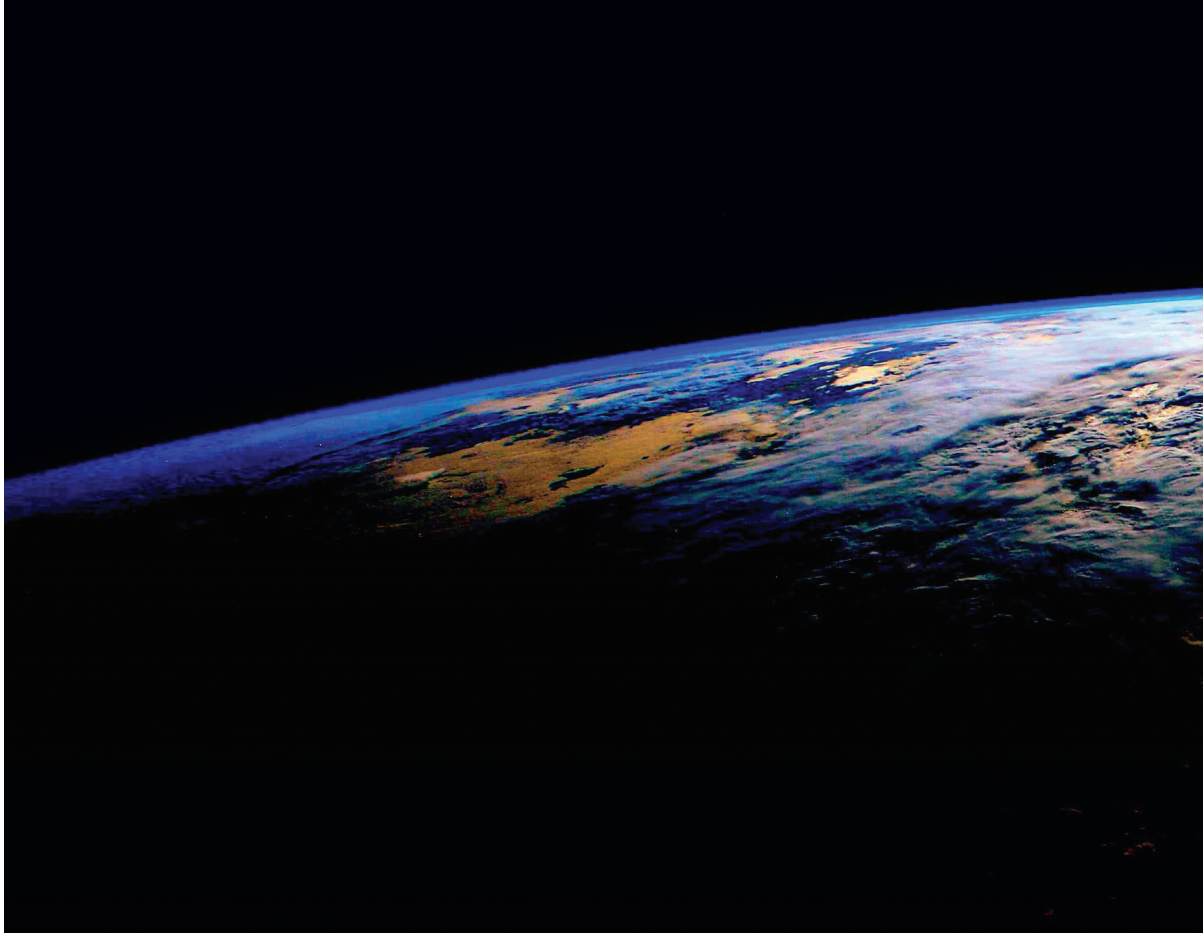
VOLUME 40, NUMBER 2

planetary.org

IN SPACE TOGETHER

FINDING COMFORT IN THE COSMIC PERSPECTIVE

EARTH FROM SPACE ✻ SAMPLE RETURN ROUNDUP ✻ SAGAN'S CASE FOR MARS



Perseverance Through It All

PLANETARY UNITY IN A TIME OF CRISIS

Fellow planetary explorers,

IN EARLY MARCH, I was working on my column for the June edition. It was going to be about the 4 new missions to Mars to be launched this summer (or southern hemisphere winter). Naturally, we all were expecting fabrication, shipment, assembly, and testing to progress steadily along their respective Gantt charts. Well, my friends, within a few weeks, this world—our world—had been turned on its head.

The spread of the novel COVID-19 coronavirus has changed life as we know it. The pandemic has kept many of us at home, away from loved ones and unable to work. It has pushed others who work in health care, food production, and delivery along with utility workers and other essential-service providers into extraordinarily stressful and hazardous working conditions. No one on Earth has been unaffected by this crisis.

While we work together by staying apart, space exploration inherently gives us perspective. Exploring our solar system and beyond drives home the uniqueness and loneliness of our place in space. As Carl Sagan pointed out, everyone you've ever known or known of is from here; Earth is our cosmic home. From this point of view, we humans are much more alike than we are different. Our planetary kinship drives us to work together. We will move past this stronger than ever.

I am inspired by the technicians, engineers, and scientists who are sticking with it despite the upheaval. As I write, the Perseverance Mars rover is still scheduled to make its mid-July launch period. Perseverance—an apt name indeed.

Compared to the health and safety of ourselves and our loved ones, space ranks lower on one's immediate priority chart. Still, even in the midst of a crisis, space explorers like you and I share a deep optimism for the future. We know that as a global society, we achieve extraordinary things when we work together with cooperation and science—everything from successfully addressing this pandemic to seeing the first humans land on Mars. We will persevere and keep that big picture in mind. We will look up and out into space with the confidence that scientific understanding can bring. We will endeavor to empower the world's citizens to create a limitless and hopeful future for humankind. Together, we will change the world.

Thank you for being with us,

Bill Nye

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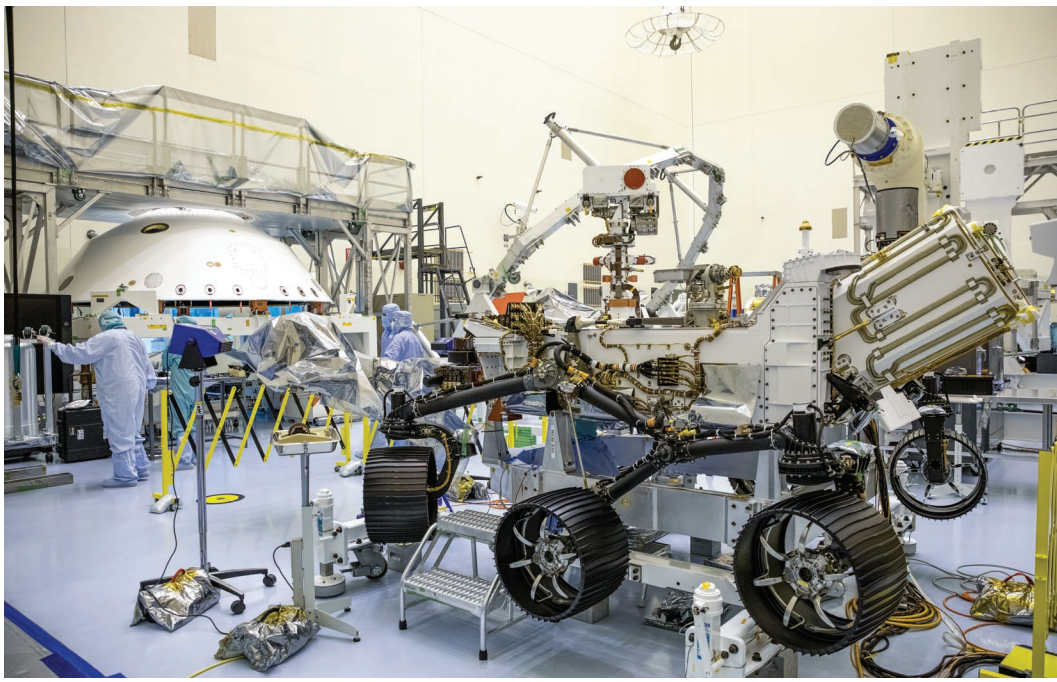


NASA

Racing to Space

Mars Launches Are Time Dependent

AS *THE PLANETARY REPORT* goes to press, China, the United Arab Emirates, and the United States all plan to launch missions to Mars during a brief window from late July through early August when Earth and Mars are optimally aligned. Because the next opportunity isn't until 2022, all 3 countries made these missions a top priority even as most in-person space industry work ground to a halt due to the COVID-19 pandemic.

This image shows NASA's Perseverance rover at the Kennedy Space Center Payload Hazardous Servicing Facility in Florida on 10 March 2020. On Mars, Perseverance will search for signs of past and present life while collecting soil and rock samples for future return to Earth. The missions that will return those samples to Earth, however, have not been formally approved.

In order to respond to any late-breaking changes to this summer's Mars launches, we moved our coverage online. To learn how these missions work, why they matter, and how you can help support future Mars exploration, including bringing Perseverance's samples back to Earth, visit **planetary.org/mars2020**.

CONTACT US: The Planetary Society, 60 South Los Robles Avenue, Pasadena, CA 91101-2016; General calls: 626-793-5100; Email: *tps@planetary.org*; Internet: *planetary.org*; *Editors* **DANIELLE GUNN, JASON DAVIS, KATE HOWELLS**; *Creative Director* **ANDREW PAULY**; *Art Director* **LOREN A. ROBERTS for HEARKEN CREATIVE**; *Copy Editor* **NICOLE YUGOVICH**; *Technical Editor* **JAMES D. BURKE**; *Science Editor* **BRUCE BETTS**

ON THE COVER: Apollo 13 astronauts captured this photo of Earth in April 1970. Fifty-six hours into the mission, an explosion forced the crew to abort their landing and take shelter in the Lunar Module. The crew ultimately returned to Earth safely, and the mission became known as NASA's "successful failure." *Credit: NASA/processed by Emily Lakdawalla;* **ON P. 2/3:** NASA astronaut Scott Kelly snapped this image of Earth during his 1-year mission aboard the International Space Station. *Credit: NASA/Scott Kelly*

The Planetary Report (ISSN 0736-3680) is published quarterly at the editorial offices of The Planetary Society, 60 South Los Robles Avenue, Pasadena, CA 91101-2016, 626-793-5100. It is available to members of The Planetary Society. Annual dues are $50 (U.S. dollars) for members in the United States as well as in Canada and other countries. Printed in USA. Third-class postage at Pasadena, California and at an additional mailing office. Canada Post Agreement Number 87424.

Planetary Society member Antonio Peronace for The Planetary Society

The 2020 Day of Action

IN EARLY FEBRUARY, 115 Planetary Society members from 28 different states came together in Washington, D.C. for our annual Day of Action. Backed by tens of thousands of members worldwide, these advocates met with their representatives in Congress to speak in support of space science and exploration.

Over the course of one busy day, Planetary Society members had 161 meetings with congressional offices. They asked their elected leaders to embrace the search for life as a core motivation for exploration, to extend human presence into deep space, and to defend Earth from asteroid impacts. They knew these key messages well, having trained hard in the lead-up to their meetings.

Educating our members is an important part of our effort to empower the world's citizens as space advocates. Day of Action participants took full advantage of The Planetary Society's free, online educational resources, learning how NASA's budget is decided, familiarizing themselves with the rationales for our advocacy priorities, and learning how to be effective when advocating for space. When they arrived in Washington, they dove deeper into their preparation in a day-long training session where they got comfortable with their messaging and practiced their arguments.

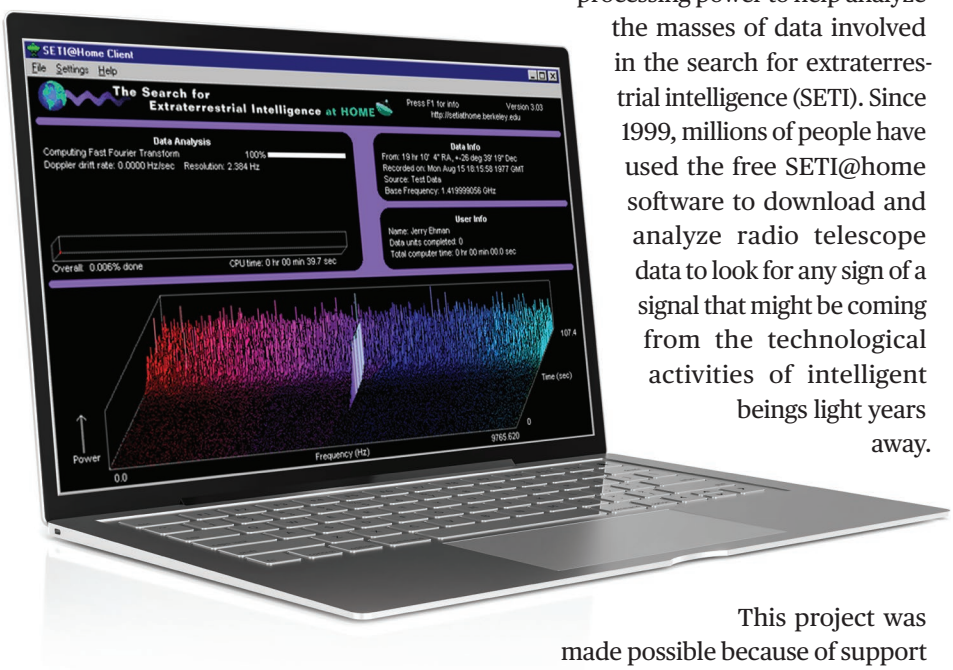
For the first time, this year's Day of Action also included a remote component. Informed by the same educational resources, hundreds of Planetary Society members took action from home by emailing and phoning their representatives in government and by sharing key advocacy messages on social media.

The Planetary Society is able to train and equip our members to take action like this because of the support of members like you. This was our biggest Day of Action ever, and we'll only keep growing it from here.

ABOVE *On 10 February 2020, Planetary Society members from 28 states came to Washington, D.C. for our 2020 Day of Action.*

SETI@home

THE UNIVERSITY OF California at Berkeley has announced the end of SETI@home, one of the largest citizen science projects ever undertaken. This project engaged ordinary people to contribute their personal computers' processing power to help analyze the masses of data involved in the search for extraterrestrial intelligence (SETI). Since 1999, millions of people have used the free SETI@home software to download and analyze radio telescope data to look for any sign of a signal that might be coming from the technological activities of intelligent beings light years away.



ABOVE *The famous "WOW!" signal as it would have appeared on the original SETI@home software.*

This project was made possible because of support from The Planetary Society's members. In 1998, 2 researchers from U.C. Berkeley (computer scientist David Anderson and SETI scientist Dan Werthimer) approached The Planetary Society with the novel idea of harnessing the enormous computing power of personal computers, which numbered in the millions and spent much of their time idle. For more than a year, they tried to raise money for their idea, approaching numerous companies in nearby Silicon Valley but coming up empty. The idea of involving the public in scientific research was a novel one, and the Silicon Valley visionaries found it difficult to believe that many people would lend their personal computers to a SETI search.

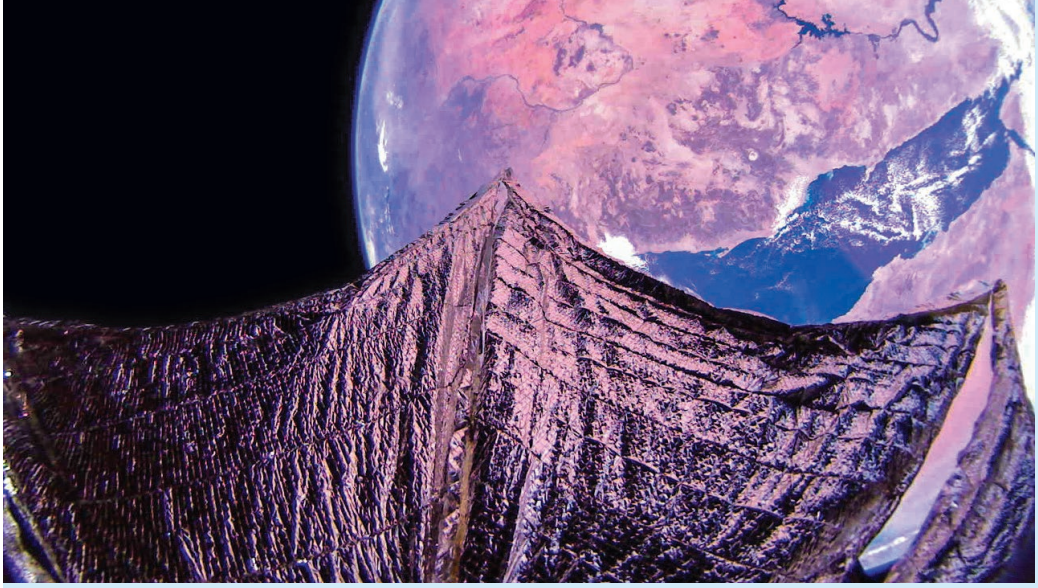
The Planetary Society reacted differently. SETI was in the Society's DNA from the very beginning, and public involvement in science was at the core of our mission. SETI@home, which combines the two, seemed perfect. With the support of our members, we raised $50,000 to help launch the project and secured a matching donation from Paramount Pictures, which was promoting its *Star Trek* movie franchise. SETI@home was off and running.

SETI@home went online on 17 May 1999 and was an immediate and unprecedented hit. Within a few months, more than a million people across the globe were processing work units on their personal computers, and within a year, the number was approaching 2 million. No one had expected this explosive growth, least of all Anderson and Werthimer, who had dreamed of recruiting perhaps 100,000 people. With SETI@home, the search for extraterrestrial intelligence had captured the public's imagination.

SETI@home did something else as well, something that no one expected: it launched a radically new way of doing science. The project's explosive success opened scientists' eyes to the fact that the public is eager to take part in cutting-edge scientific research and is happy to donate their computers and other resources for the cause. So, where SETI@home first tread, a long line of scientific projects has followed, each engaging the public in different and creative ways. Today, the public is invited to take part in studies of climate change, cancer cells, protein folding, gravity waves, interstellar dust particles, and many, many others. Thanks to SETI@home, researchers have begun to tap into the almost-unlimited resource of public enthusiasm for science.

Although SETI@home is ending, its legacy lives on. The Planetary Society is proud to have been a part of this project, and we thank our members for helping to launch a new era of public engagement in science.

SETI@home



LightSail 2 Enters Extended Mission Phase

On 25 June 2020, after 1 year in orbit, The Planetary Society's LightSail 2 spacecraft will complete its primary mission phase and will enter an extended mission phase. During its primary mission, LightSail 2 achieved its goals of demonstrating for the first time controlled solar sailing in a small spacecraft, raising the profile of solar sailing in the technical community and with the public as well as building excitement and engaging the public in space exploration.

As expected, the spacecraft will gradually lower due to atmospheric drag, with an expected reentry into Earth's atmosphere after many months of extended operations.

You can continue to follow the LightSail 2 mission at **sail.planetary.org**.

LIGHTSAIL 2 EXTENDED MISSION OBJECTIVES

- Continue to tune solar sailing performance
- Learn more about solar sailing operation through the study of various operational refinements and the study of spacecraft orbital evolution
- Continue taking pictures for public outreach and engineering analyses
- Implement deorbit studies of sail dynamics with the sail acting as a drag sail
- Test software that can automatically analyze engineering data and highlight potential errors
- Continue to share information about the mission and what we are learning from it with the technical community and the public through peer-reviewed journal articles, conference presentations, direct contact with future solar sailing missions, web articles, and social media

ABOVE LEFT *LightSail 2 flies over the Red Sea and Nile River on 9 February 2020.*

Naming a World

When an object is discovered in space, it is first assigned a rather uninspiring and technical name. Such was the case for 2007 OR10, a Kuiper Belt object discovered in 2007. A reddish, cold object slightly larger than Pluto's moon Charon, 2007 OR10 is considered a minor planet. It even has its own moon.

Its discoverers—astronomers Meg Schwamb, Mike Brown, and David Rabinowitz—wanted to give it a real name, something unique and meaningful. In 2019, they reached out to The Planetary Society to help. They had chosen 3 potential names associated with mythological creatures and figures that reflect aspects of 2007 OR10's physical properties, and we asked the public to vote on their favorite.

More than 280,000 votes were cast, and the winner emerged: Gonggong, named after a Chinese water god with red hair and a serpent-like tail, known for creating chaos, causing flooding, and tilting Earth.

In February 2020, the International Astronomical Union made it official: Gonggong is now a part of our solar system's family.

Whether you participated in the naming contest or are just hearing about Gonggong for the first time, there is much to anticipate as we continue to study this fascinating world.

BELOW *An artist's concept of Gonggong.*

Planetary Society members like you make this work possible. *Thank you!*

The Planetary Society; Alex H. Parker

THE PLANETARY SOCIETY

CELEBRATING 40 YEARS

An essay from the September 1996 issue of *The Planetary Report*, in which our cofounder, Carl Sagan, discussed the value of Mars exploration.

Why Mars?

by Carl Sagan

Mars has been a human destination for so long—in both scientific exploration and science fiction—that we might assume that everyone shares the same reasons for wanting to reach the Red Planet. In advancing the cause of Mars exploration, it can be valuable to step back and reassess the reasons for exploring Mars. That is what NASA Administrator Daniel Goldin asked Planetary Society President Carl Sagan to do. Here are his conclusions. —Charlene M. Anderson

- Mars is the nearest planet that astronauts can explore.
- About 4 billion years ago, Mars seems to have had an Earth-like climate, with rivers, lakes and perhaps even oceans. (This was at a time when the Sun was 25 percent dimmer than it is today.) Something unknown converted an Earth-like world to a deep ice-age planet. Perhaps we, who are perturbing our planetary environment, should understand what happened to the climate of Mars.
- Mars has a planet-wide ozone hole. Ultraviolet light from the Sun strikes its surface unimpeded. This is thought to be the reason that not even organic molecules were found by the *Viking 1* and *2* landers. The study of Mars, therefore, helps us understand what the extreme consequences of ozone layer depletion on Earth might be.
- In exactly the same epoch that Mars was warm and wet, life arose on Earth. Is it plausible that on two nearby planets with very similar environments, life arose on one and not the other? The search for morphological or chemical fossils of past life on Mars is one of the most exciting goals of planetary exploration. If found, it might indicate that life arises quickly on all planets in the universe where the conditions are right.
- As the martian climate degraded, life if any would have retreated to the last habitable regions, surface or subsurface. If there are martian "oases" today, could life on Mars—despite the negative results from *Viking*—be waiting to be found? If found, it might show what kinds of life—fundamentally different from life on Earth—are possible.
- Mars is an ideal arena for international cooperation in space exploration. Despite fiscal and infrastructure problems, the Russian space agency appears on track for the *Mars '96* launch and recently approved a *Mars 2001* mission plan. Mars Together remains a high-level government initiative. A Japanese Mars orbiter is scheduled to be launched in 1998. European national agencies (notably the French and German) have significant roles in current Mars missions and plan for future ones as well. The United States has an opportunity to play a key role in a new kind of coordinated scientific exploration of another planet through international combined operations.
- Mars exploration is a potential testing ground for a range of new technologies—including aerobraking and the use of martian resources to generate oxidizer and fuel for the return journey (and water and oxygen for eventual human missions). It is also an ideal testing ground for remote rover and returned-sample missions, as well as long time-delay telepresence and virtual reality.
- Because of the historic romance of the general public with Mars (consider even today the associations of the word "martian"), the exploration of Mars has a public resonance and support that probably no other goal of the space program can claim.

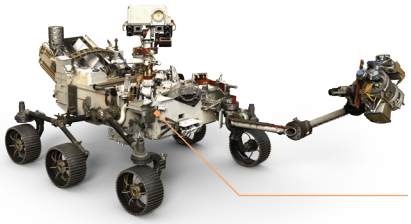
#InSpaceTogether

You don't need to leave the house to explore the cosmos. To help you get through social distancing, we've put together a one-stop shop to bring the universe to you. At **planetary.org/inspacetogether**, you'll find space images to peruse, videos for all ages, activities to try at home, free online courses, and much more.

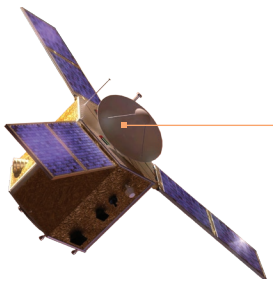
Do you have ideas for at-home space activities? We'd love to hear them! Send them to *connect@planetary.org*.

MARS MANIA

We're going to Mars in July! It's a great time to celebrate the excitement of a major mission launch. Reach out to your friends, family, coworkers, neighbors, or anyone you know who loves space and celebrate the next big steps in Mars exploration!



PERSEVERANCE
NASA's Perseverance rover will land near an ancient river delta, where it will search for signs of past life and collect samples for future return to Earth.



HOPE
The United Arab Emirates' Mars orbiter will build a complete picture of Mars' seasonal atmospheric cycles.

TIANWEN-1
China's first mission to Mars consists of an orbiter and rover that will search for water ice, study Mars' climate, and investigate the planet's habitability.

Head to **planetary.org/mars** to learn all about the Red Planet, how we study it, and how you can help advance Mars exploration. Wherever you live, you can take part in the adventure of exploration as the next generation of Mars missions takes off.

NASA/Ames/JPL-Caltech

Planetary Society Member Adventures

As we went to print, travel restrictions during the COVID-19 pandemic were evolving. For the latest travel options, contact Betchart Expeditions Inc. at 800-252-4910 or go to **betchartexpeditions.com**.

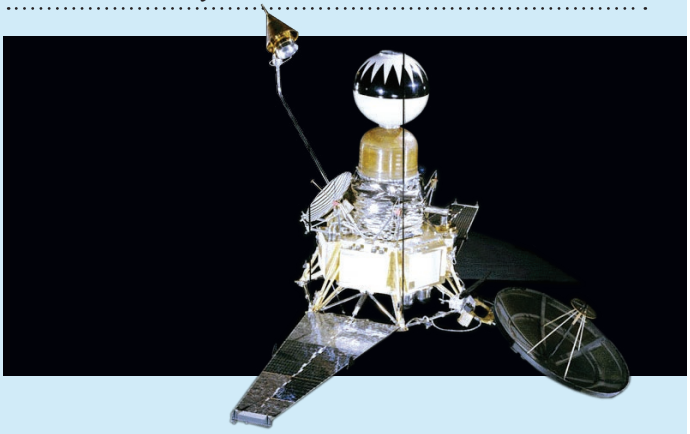
PERU & MACHU PICCHU OF THE INCAS
27 SEPTEMBER – 4 OCTOBER 2020
20-27 NOVEMBER 2020
Discover archaeological sites and Incan astronomy

ARGENTINA TOTAL SOLAR ECLIPSE 2020
8-19 DECEMBER 2020
With optional Peru or Easter Island pretrips, 2-8 December 2020

ALASKA AURORA BOREALIS
11-17 MARCH 2021
Come see the aurora dance across the night sky in this perennially favorite expedition!

ANTARCTICA TOTAL SOLAR ECLIPSE 2021
23 NOVEMBER – 15 DECEMBER 2021
A once-in-a-lifetime opportunity!

WHAT'S UP? *by Bruce Betts*



ABOVE LEFT *The Ranger 4 spacecraft was the first spacecraft to impact on the far side of the Moon.*

ABOVE RIGHT *The European Space Agency's BepiColombo spacecraft snapped this image of Earth during its flyby in April 2020. The spacecraft's magnetometer (lower right) and medium-gain antenna (left) can be seen in the foreground.*

IN THE SKY

Very bright Jupiter is paired with yellowish Saturn in the evening East, getting higher and farther apart as the weeks pass. Reddish Mars rises in the middle of the night in June and in the early evening by September. Watch Mars grow brighter as the weeks pass and Earth and Mars grow closer in their orbits. By September, Mars will be brighter than the brightest star, and by its 13 October opposition (opposite side of Earth from the Sun), it will be brighter than Jupiter. Super-bright Venus dominates the predawn East throughout this period. The Perseid meteor shower peaks 11-12 August with increased activity several days before and after. The most meteors will occur after midnight, but that is also when a quarter Moon will be up, interfering some with meteor visibility.

RANDOM SPACE FACT

If you add the masses of Mercury, Venus, and Mars, the result is still a bit less than the mass of Earth.

TRIVIA CONTEST

Our December solstice contest winner is Nedya Gilman of Endicott, New York, USA. Congratulations! The question was: ***In January 2019, Chang'e-4 became the first spacecraft to soft land on the far side of the Moon, but what was the first spacecraft to impact on the far side of the Moon?*** The answer: ***Ranger 4 (pictured above) crashed into the far side of the Moon in 1962.***

Try to win a copy of *V.R. Space Explorers: Titan's Black Cat* by Bruce Betts and a *Planetary Radio* T-shirt by answering this question:

What was the first successful robotic mission to return samples from beyond Earth?

Email your answer to planetaryreport@planetary.org or mail your answer to *The Planetary Report*, 60 S. Los Robles Ave., Pasadena, CA 91101. Make sure you include the answer and your name, mailing address, and email address (if you have one). By entering this contest, you are authorizing *The Planetary Report* to publish your name and hometown. Submissions must be received by 1 September 2020. The winner will be chosen in a random drawing from among all the correct entries received.

For a weekly dose of "What's Up?" complete with humor, a weekly trivia contest, and a range of significant space and science-fiction guests, listen to *Planetary Radio* at planetary.org/radio.

Where We Are

An At-a-Glance Spacecraft Locator

ASSUMING THERE ARE no delays due to the COVID-19 pandemic, 3 new spacecraft from 3 different space agencies are scheduled to launch to the Red Planet in late July to early August. All should arrive in early 2021.

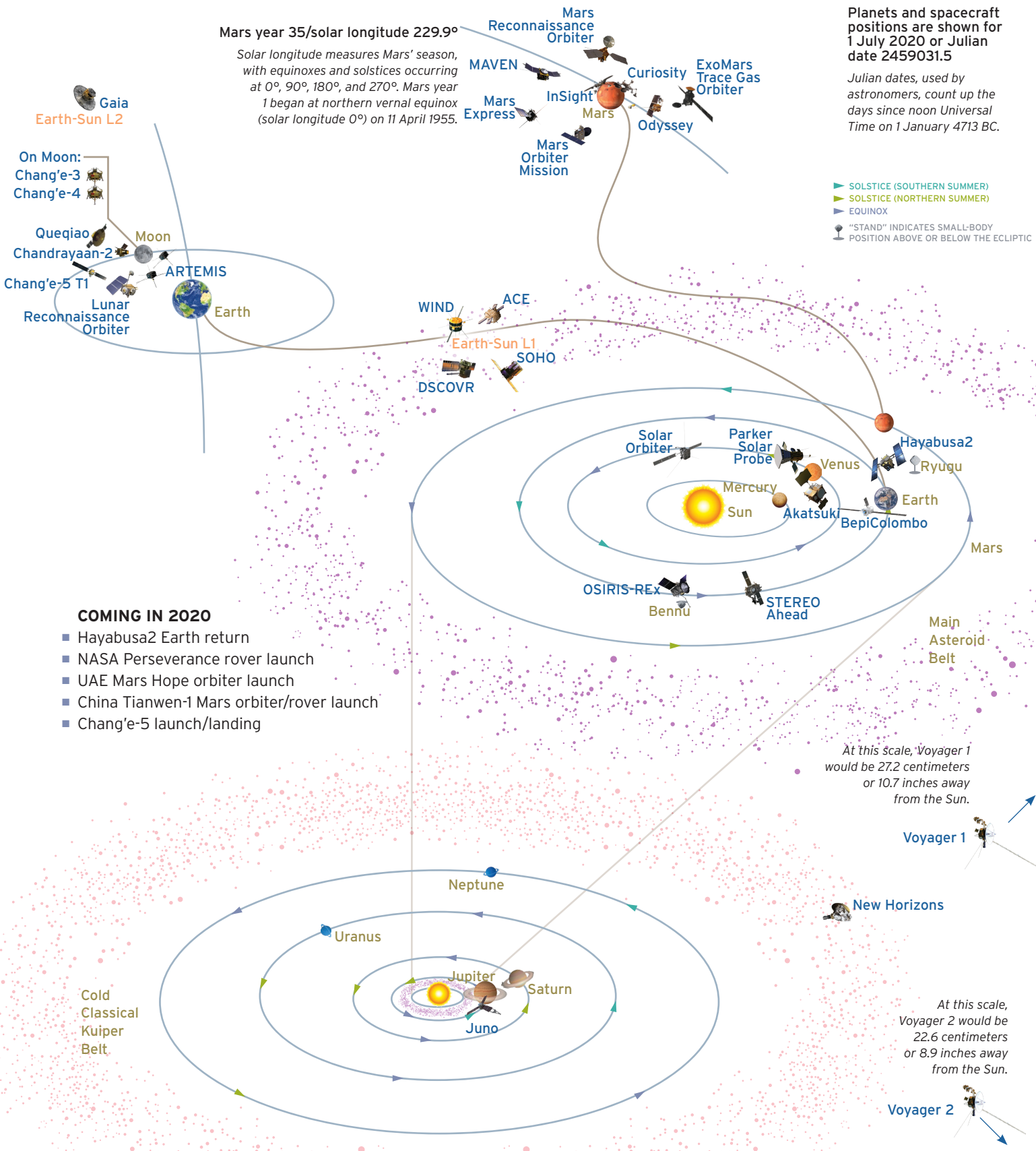
NASA's Perseverance rover will blast off on a mission to search for signs of past life and to collect samples for future return to Earth. China's Tianwen-1 orbiter and rover mission will search for water ice, study Mars' climate, and investigate the planet's habitability. Hope, a United Arab Emirates orbiter, is the Arab world's first mission to another planet. It will build a complete picture of Mars' seasonal atmospheric cycles.

Having completed its flyby of Earth on 13 April 2020, the European Space Agency's BepiColombo spacecraft is on its way to Mercury via Venus. Its first of 2 Venus flybys is scheduled for 16 October 2020.

Finally, the OSIRIS-REx mission is gearing up for the spacecraft's August 2020 sample collection attempt at asteroid Bennu. The spacecraft has been performing closer and closer approaches to the crater from which it will collect a sample, gathering data that will help it safely navigate to the surface.

For mission updates and more, check out *The Downlink*, our weekly email newsletter. Sign up at **planetary.org/connect**.

Ranger 4: NASA/JPL; BepiColombo: ESA/BepiColombo/MTM


Mars year 35/solar longitude 229.9°
Solar longitude measures Mars' season, with equinoxes and solstices occurring at 0°, 90°, 180°, and 270°. Mars year 1 began at northern vernal equinox (solar longitude 0°) on 11 April 1955.
Planets and spacecraft positions are shown for 1 July 2020 or Julian date 2459031.5
Julian dates, used by astronomers, count up the days since noon Universal Time on 1 January 4713 BC.
SOLSTICE (SOUTHERN SUMMER)
SOLSTICE (NORTHERN SUMMER)
EQUINOX
"STAND" INDICATES SMALL-BODY POSITION ABOVE OR BELOW THE ECLIPTIC
Mars Reconnaissance Orbiter
MAVEN
Curiosity
ExoMars Trace Gas Orbiter
InSight
Mars
Mars Express
Odyssey
Mars Orbiter Mission
Gaia
Earth-Sun L2
On Moon:
Chang'e-3
Chang'e-4
Queqiao
Moon
Chandrayaan-2
ARTEMIS
Chang'e-5 T1
Earth
Lunar Reconnaissance Orbiter
WIND
ACE
Earth-Sun L1
SOHO
DSCOVR
Solar Orbiter
Parker Solar Probe
Venus
Hayabusa2
Ryugu
Mercury
Earth
Sun
Akatsuki
BepiColombo
Mars
OSIRIS-REx
Bennu
STEREO Ahead
Main Asteroid Belt
COMING IN 2020
Hayabusa2 Earth return
NASA Perseverance rover launch
UAE Mars Hope orbiter launch
China Tianwen-1 Mars orbiter/rover launch
Chang'e-5 launch/landing
At this scale, Voyager 1 would be 27.2 centimeters or 10.7 inches away from the Sun.
Voyager 1
New Horizons
Neptune
Uranus
Jupiter
Saturn
Juno
Cold Classical Kuiper Belt
At this scale, Voyager 2 would be 22.6 centimeters or 8.9 inches away from the Sun.
Voyager 2

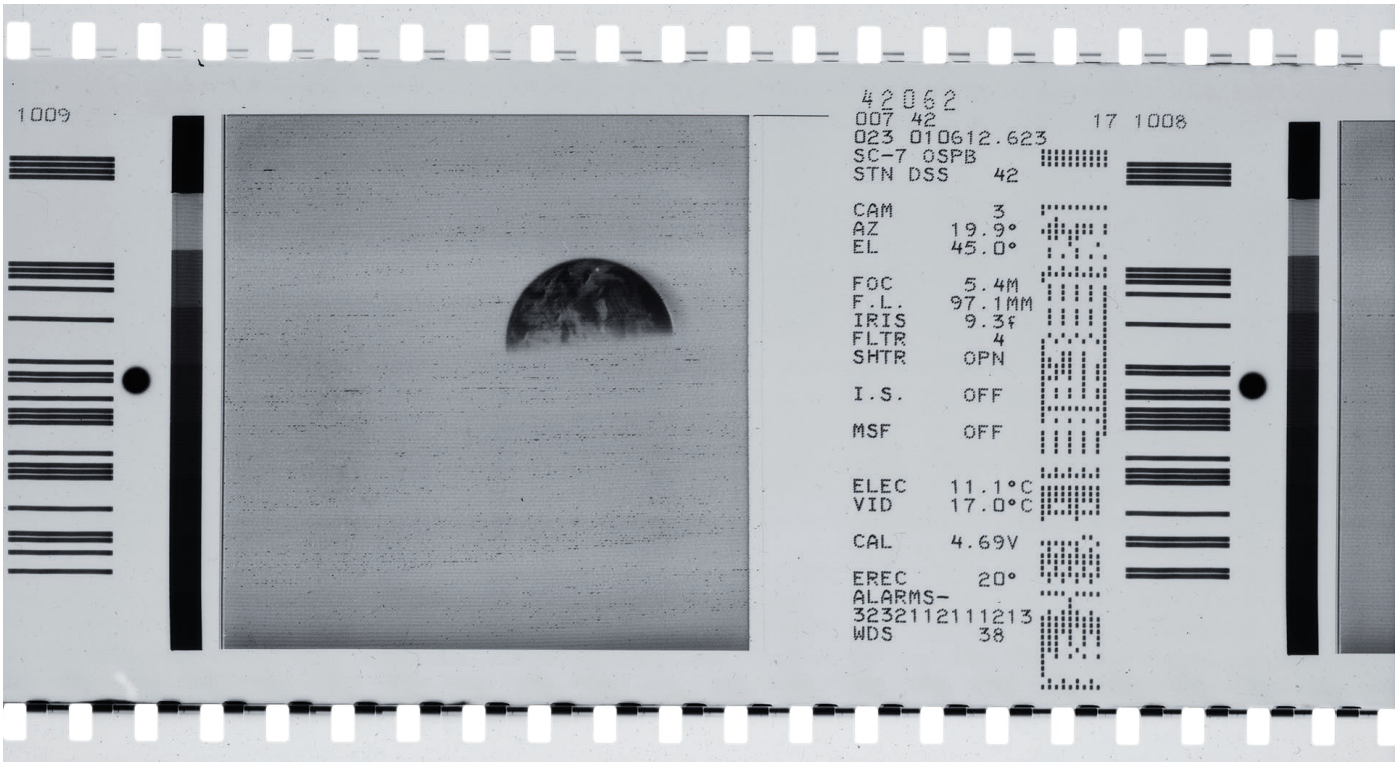
Pictures of Earth

Pointing a Celestial Mirror at a Pivotal Time in History

UNTIL THE ADVENT of spaceflight, we humans could only imagine what our planet looked like from space. Ever since we started sending robotic probes and humans into the cosmos, we've had a natural inclination to turn the camera back on ourselves to see our fragile world hanging in the blackness of space. As a result, some of the most memorable images in the history of spaceflight are of Earth.

During this singular moment in history as the entire world responds to the COVID-19 pandemic, we thought it would be appropriate to share some of our favorite pictures of Earth from space. Seeing our entire planet occupy just a few inches of page space gives us a sobering reminder of our commitment to take care of each other and Earth—the only home we've ever known.

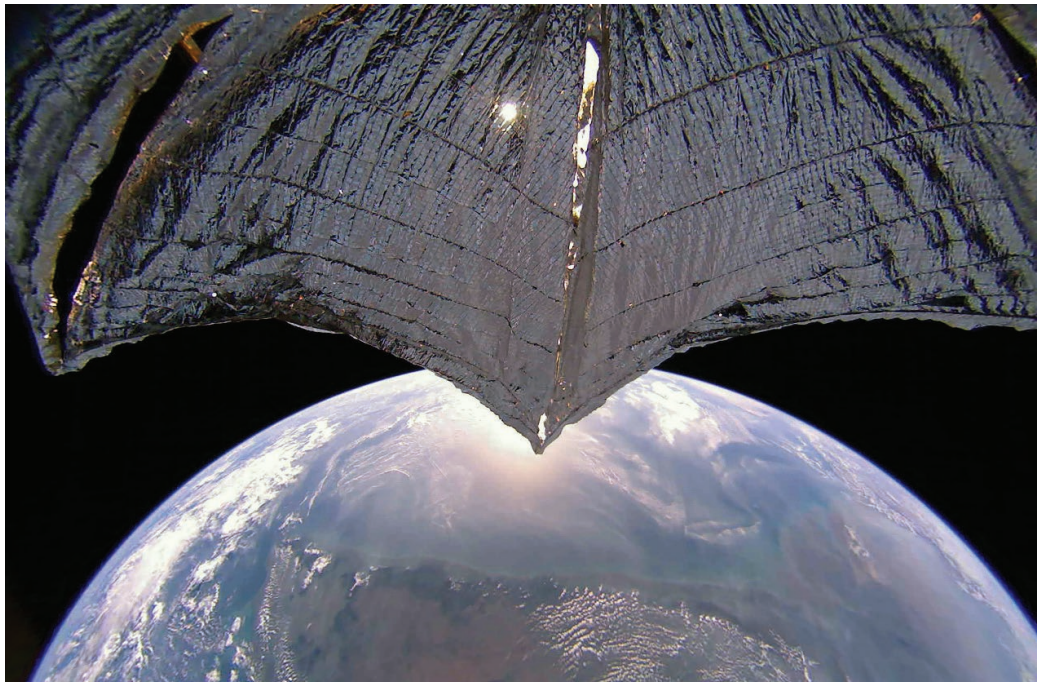
See more pictures of Earth from space at **planetary.org/picsofearth**.



ABOVE *NASA's Surveyor 7 spacecraft snapped this view of Earth from the lunar surface in 1968. Shown here is a scan of an original 70-millimeter film-reel negative on which the spacecraft's signal was received back on Earth.*

OPPOSITE PAGE *NASA astronaut Peggy Whitson floats in the International Space Station's Cupola—a 7-windowed portal that provides 360-degree views of Earth. Ever since its installation in 2010, the Cupola has been a favorite spot for astronauts aboard the station.*

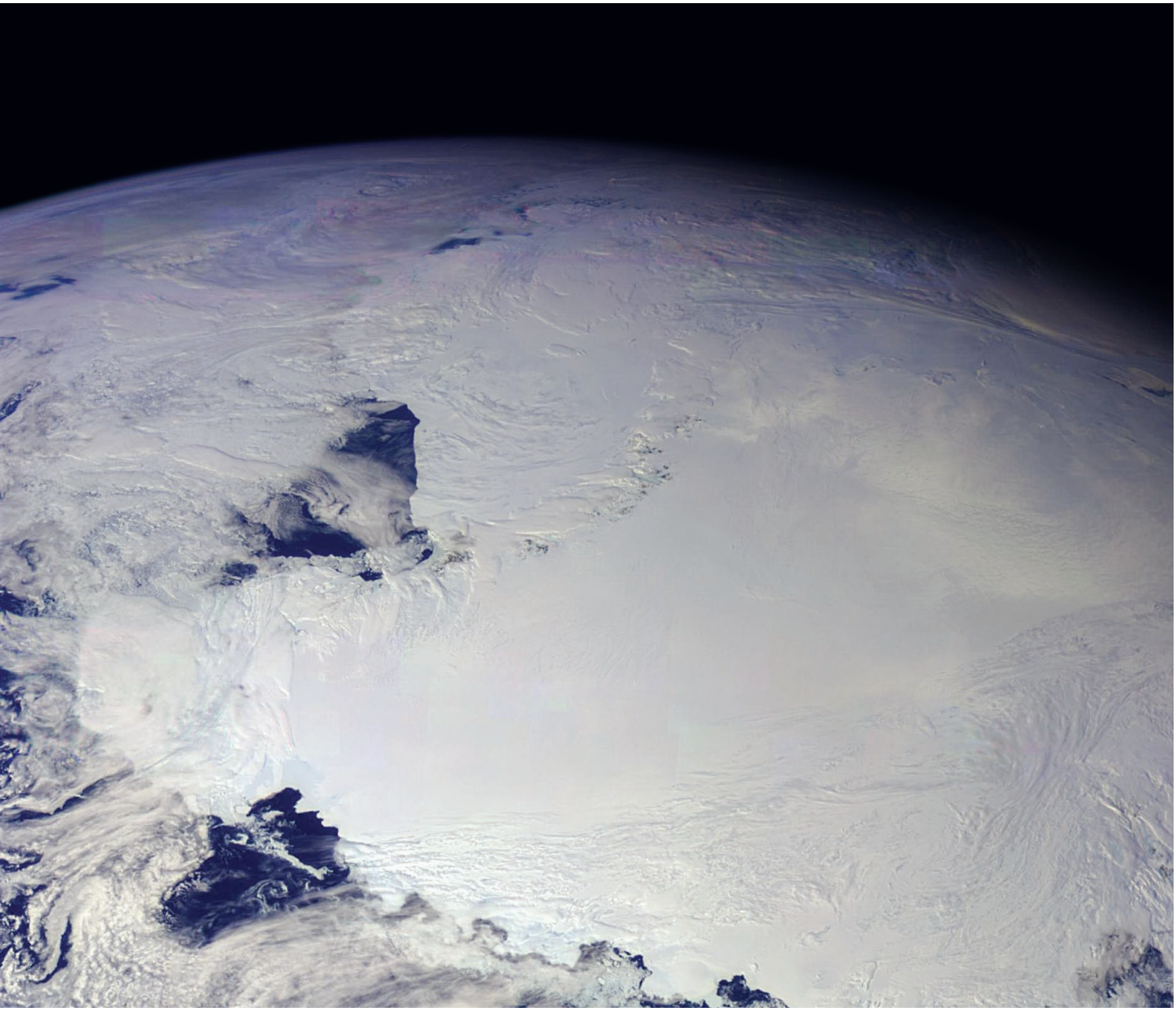
NASA/JPL-Caltech/University of Arizona Lunar and Planetary Laboratory; opposite: NASA



TOP *The Planetary Society's LightSail 2 spacecraft regularly images itself to check the condition of the solar sails. This image, taken on 21 January 2020, includes the west coast of India. North is at right. The sail appears slightly curved due to the spacecraft's 185-degree fisheye camera lens. The image has been color adjusted, and some of the distortion has been removed.*

BOTTOM *China's Chang'e-5 test vehicle spacecraft captured this view of Earth from beyond the far side of the Moon on 28 October 2014.*

Top: The Planetary Society; bottom: CAST



ABOVE *This unique view of Earth's south pole shows Antarctica as seen by NASA's Galileo spacecraft during a flyby in 1990.*

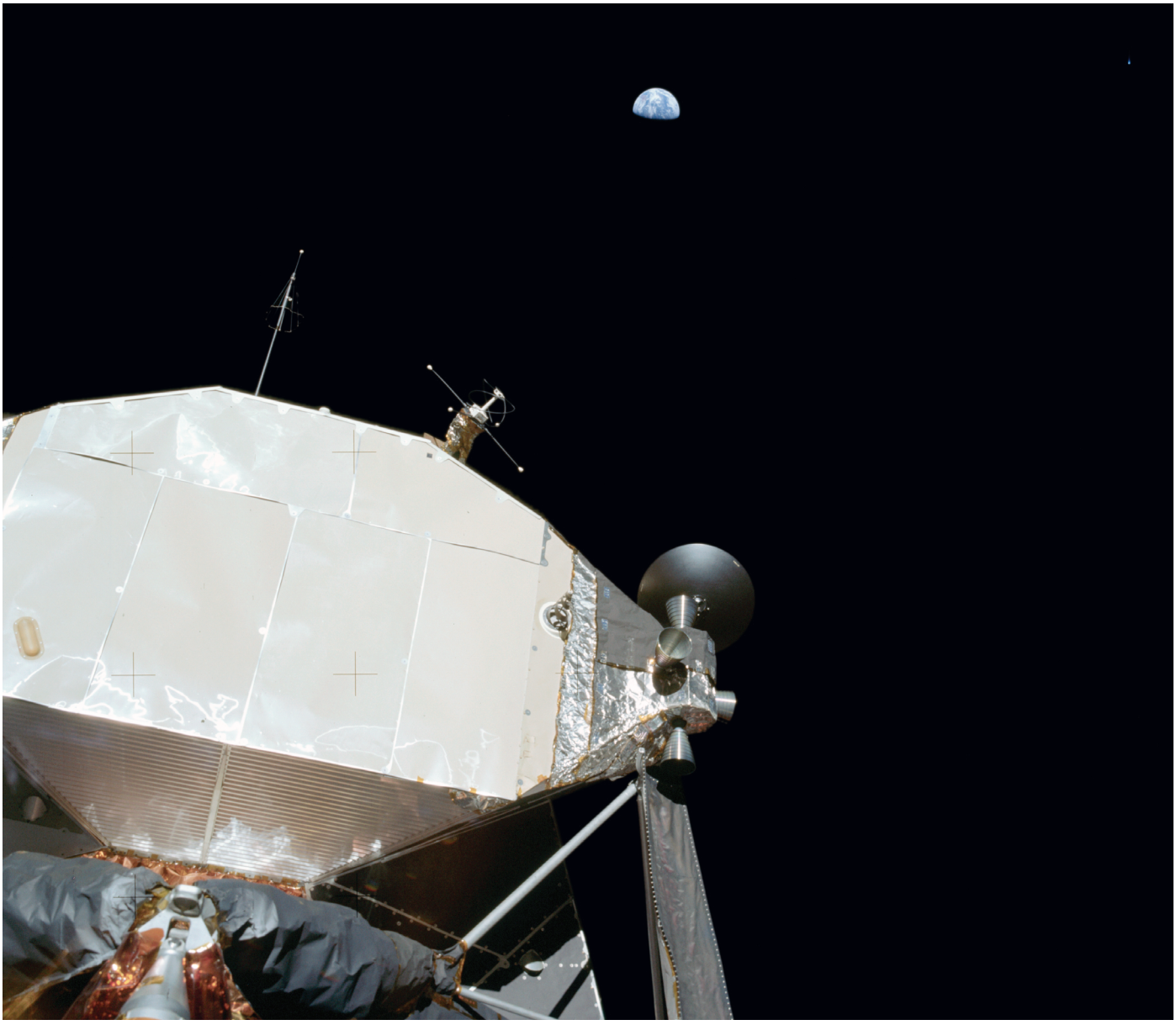
NASA/JPL

ABOVE *In 1990, Voyager 1 turned its camera back on Earth from a distance of 6 billion kilometers (3.7 billion miles) and captured the now-famous "pale blue dot" image of Earth suspended in a ray of sunlight scattered by the camera lens. For the 30th anniversary of the photo in February 2020, NASA's Kevin M. Gill reprocessed the image using modern image software and techniques.*

NASA/JPL-Caltech

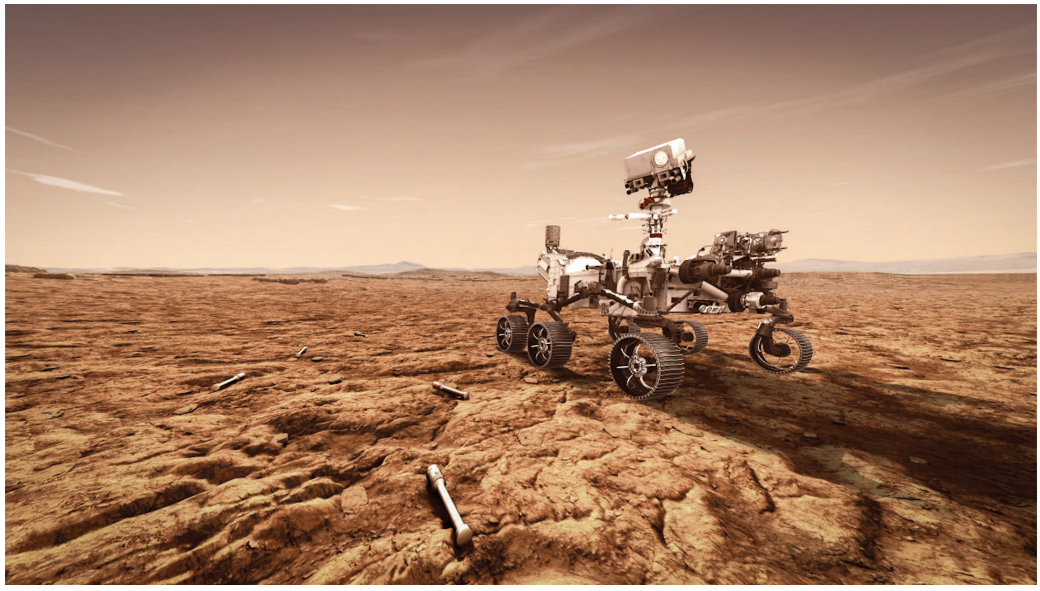
LEFT *The European Space Agency's Rosetta spacecraft snapped this image of Earth's nightside during a 2007 slingshot past our planet. Rosetta was over the Indian Ocean at the time; India is visible at the center.*

BELOW *This image, taken by the Apollo 11 crew during their historic July 1969 moonwalk, shows Earth suspended high above the lunar lander.*



Top: ESA ©2007 MPS for OSIRIS Team MPS/UPD/LAM/IAA/RSSD/INTA/UPM/DASP/IDA; bottom: NASA

EMILY STEWART LAKDAWALLA
is The Planetary Society's solar system specialist.



Sample Return Roundup

3 Countries and 4 Missions to Return Samples From Space

ABOVE *NASA's Perseverance rover will store rock and soil samples in sealed tubes on the planet's surface for future missions to retrieve, as seen in this illustration. Perseverance, scheduled to launch in July 2020, represents the first leg of humanity's first planned round trip to the surface of another planet. Future missions must retrieve and return the samples that Perseverance will collect and document.*

IT'S A BANNER YEAR for sample return missions. Not since the 1970s has there been so much invested in returning rocks to Earth from space. This year, China, Japan, and the United States will all have sample return missions in flight, seeking to retrieve material from near-Earth asteroids, the Moon, and eventually Mars.

WHY SAMPLE RETURN?

The capability of autonomous deep-space robots advances by leaps and bounds every decade, so why is it still necessary to study samples back here on Earth? There are 3 main reasons. First, many important types of laboratory analysis cannot yet be performed in space or can't be done very precisely. Scientists would like to analyze elemental and isotopic composition to determine the origin and ages of rocks. Neither of these types of analyses can be performed off Earth because the necessary instruments can't yet be built small enough, robust enough, and with low enough power requirements for spaceflight.

Second, samples would permit scientists to attempt to reproduce others' results. Reproducibility is a core element of the scientific method; the more surprising a result, the more important it is to demonstrate its reproducibility. However, analyses performed in space by a single instrument on a single spacecraft are not reproducible. NASA's Perseverance rover, which launches to Mars in late July or early August, will be attempting to find biosignatures in Martian rocks, but it's not possible to prove beyond a reasonable doubt the existence of life on Mars without the experiment being reproduced by more than 1 instrument in more than 1 laboratory.

Third, having the materials on Earth means that in the decades to come–as scientists develop new questions to ask, new experiments to run, and new analysis techniques–sampled material will still be

NASA/JPL-Caltech

SAMPLE RETURN MISSIONS ACTIVE IN 2020

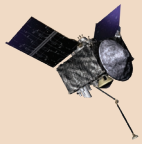
Hayabusa2 (Japan)

LAUNCH
2014

RETURN
2020

TARGET
Asteroid Ryugu

RETURNED SAMPLE QUANTITY
approx. 0.3 grams



OSIRIS-REx (NASA)

LAUNCH
2016

RETURN
2023

TARGET
Asteroid Bennu

RETURNED SAMPLE QUANTITY
60 to 2,000 grams

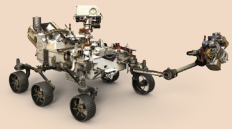
Chang'e-5 (China)

LAUNCH
2020

RETURN
2020 or 2021

TARGET
The Moon

RETURNED SAMPLE QUANTITY
2,000 to 4,000 grams



Perseverance (NASA)

LAUNCH
2020

RETURN
2031
(requires future missions)

TARGET
Mars

RETURNED SAMPLE QUANTITY
300 to 600 grams

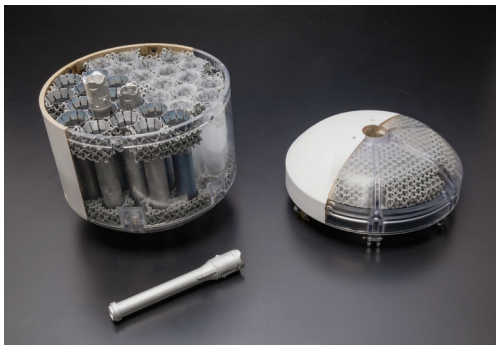
available for investigation. The U.S. Apollo and Soviet Luna samples from the 1960s and '70s are still producing valuable science more than 50 years after the last rock was collected from the Moon.

SAMPLING ASTEROIDS

Japan's Hayabusa2 mission collected samples from asteroid Ryugu on 22 February and 11 July 2019, storing each sample in separate chambers. The mission team believes it collected at least 300 milligrams of material and likely more. Hayabusa2 is now on its way back to Earth with its precious cargo, on course for a landing in the Australian desert in late 2020.

Based on images returned by Hayabusa2's German-built MASCOT lander, scientists believe that the sample canister will contain material and possibly gases preserved since the early days of the solar system, condensed from the dusty disk that eventually became the planets. Scientists will compare the chemical composition of the samples with Earth and Moon rocks, seeking to understand factors about Earth's origin, such as whether asteroids played a role in bringing water to Earth.

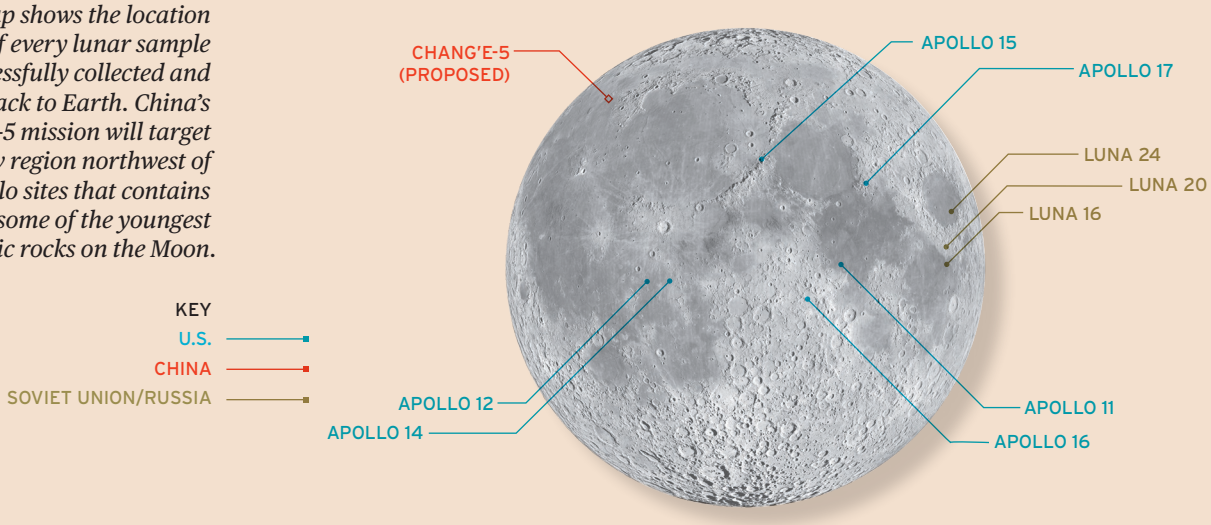
Meanwhile, at asteroid Bennu, OSIRIS-REx is performing low overflights of its selected touchdown site. The overflights will produce a detailed set of maps for the spacecraft to use as it autonomously collects a sample in late August. Superficially, Bennu looks similar to Ryugu; it will be fascinating to finally see Bennu up close to compare its surface with Ryugu's. The real payoff will come when the samples are returned to Earth and scientists can compare them with the ones returned from Hayabusa2. Both Ryugu and Bennu are carbon-rich asteroids, and carbon is a key ingredient for life as we know it. Will they tell the same story about the formation of the solar system, or will their tales be different and confusing, upending our predictions? Only time will tell. OSIRIS-REx's samples will land in Utah in 2023.



LEFT *This image shows a prototype container that could carry Perseverance's sample tubes from Mars back to Earth. Once launched into Mars orbit, the container would be picked up by an orbiting satellite, carried back to Earth, and sent hurtling through Earth's atmosphere to the ground for retrieval.*

NASA/JPL-Caltech

This map shows the location of every lunar sample successfully collected and sent back to Earth. China's Chang'e-5 mission will target a new region northwest of the Apollo sites that contains some of the youngest volcanic rocks on the Moon.



OPPOSITE PAGE *NASA's OSIRIS-REx spacecraft snapped this image of its sample collection arm, TAGSAM (Touch-And-Go Sample Acquisition Mechanism), hovering over asteroid Bennu during a touchdown rehearsal on 14 April 2020. The spacecraft was just 70 meters over the surface at the time. The circular TAGSAM sample head is 30 centimeters across; the rock with the longest shadow to TAGSAM's left is less than 2 meters across.*

WHY SAMPLE THE MOON AGAIN?

We already have 382 kilograms (842 pounds) of lunar material brought back by Apollo astronauts, so why do we need more? The main reason is that the samples we have aren't representative of the whole Moon and cannot provide clues to some very important mysteries.

The Apollo missions had severe restrictions on where they could land because safely returning the heavy, human-rated ships back to Earth required near-equatorial, nearside landing sites. To better understand lunar chronology, we need to return samples from a wider variety of locations.

China's Chang'e-5 sample return mission, planned for launch at the end of this year, will land in Oceanus Procellarum, far north and west of all the Apollo sites in a region where more recent lava flows covered up the material from the Imbrium impact. Procellarum is one of the lunar science community's highest-priority targets for future sampling because it contains some of the youngest volcanic rocks on the Moon.

The impact history of the inner solar system is best recorded on the Moon, which makes it the standard by which we try to measure time on other planets. Thus, obtaining a sample from Procellarum and pinning a number to the youngest of the Moon's large lava flows will help us establish the timing of similar events on Mercury, Earth, and Mars.

FINALLY, MARS SAMPLE RETURN

NASA's Perseverance rover, launching this summer, will drill for Martian samples and store them in hermetically sealed tubes for later retrieval. NASA and the European Space Agency (ESA) have scoped out a pair of future missions to go to Mars and bring back the samples.

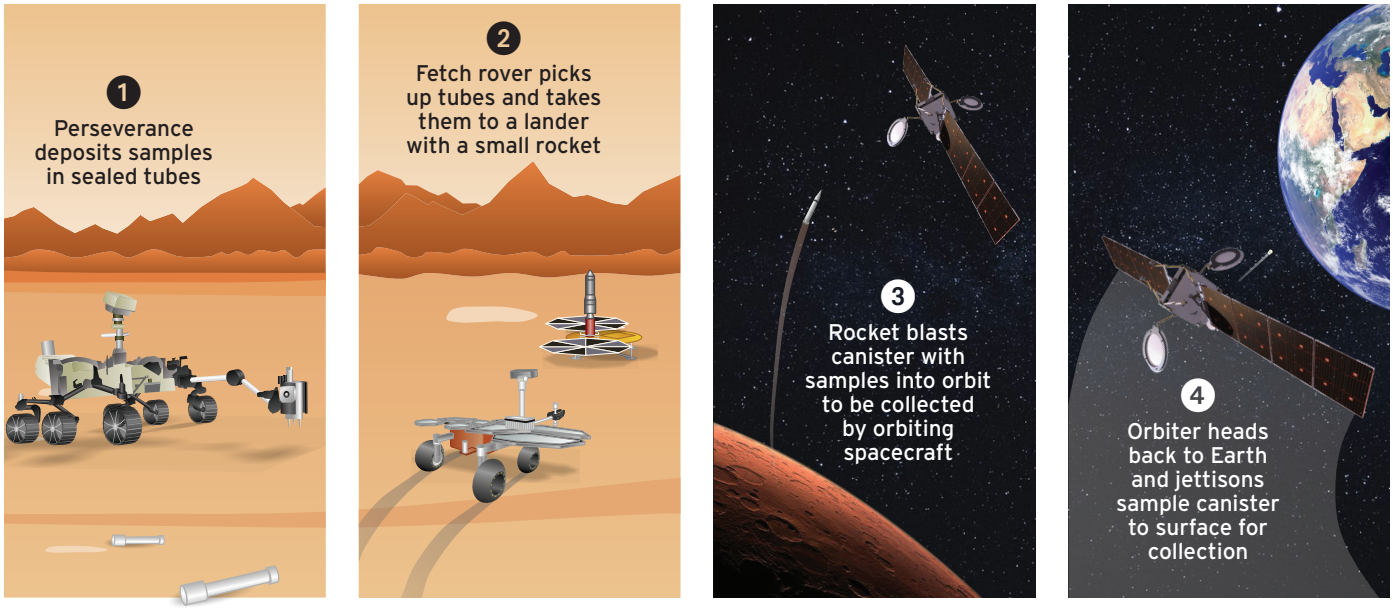
Perseverance will collect samples from inside Jezero crater. Billions of years ago, a lake pooled within Jezero. The lake was filled by a river that built a fan-shaped deposit of sediment, called a delta, on the lake floor. Once underwater, the delta now stands high above the crater floor. Long after the water was gone, molten rock flowed into the floor of the crater from nearby volcanoes, solidifying into a layer of volcanic rock that lapped onto the delta but didn't bury it entirely.

When sampling, the Perseverance team will focus on delta rocks that might preserve biosignatures (physical or chemical indicators of long-extinct life forms) and information about the atmospheric chemistry and climate that prevailed when they formed. They'll also sample the lava rock that formed after the watery activity ended. On Earth, scientists can

Moon base map from NASA/Goddard/Arizona State University; OSIRIS-REx: NASA/Goddard/University of Arizona

A Multistep Handoff

NASA AND THE EUROPEAN SPACE AGENCY'S PROPOSED PLAN FOR RETURNING SAMPLES FROM MARS



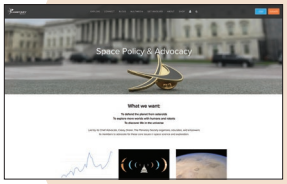
Charles Braden and Loren A. Roberts for The Planetary Society

use isotopic ratios to determine absolute ages of Jezero's rocks. That information, combined with the climate chemistry, will help us understand when Mars transitioned from a warm, watery world to a cold, dry desert. This in turn will tell us how long life might have had to arise on the planet.

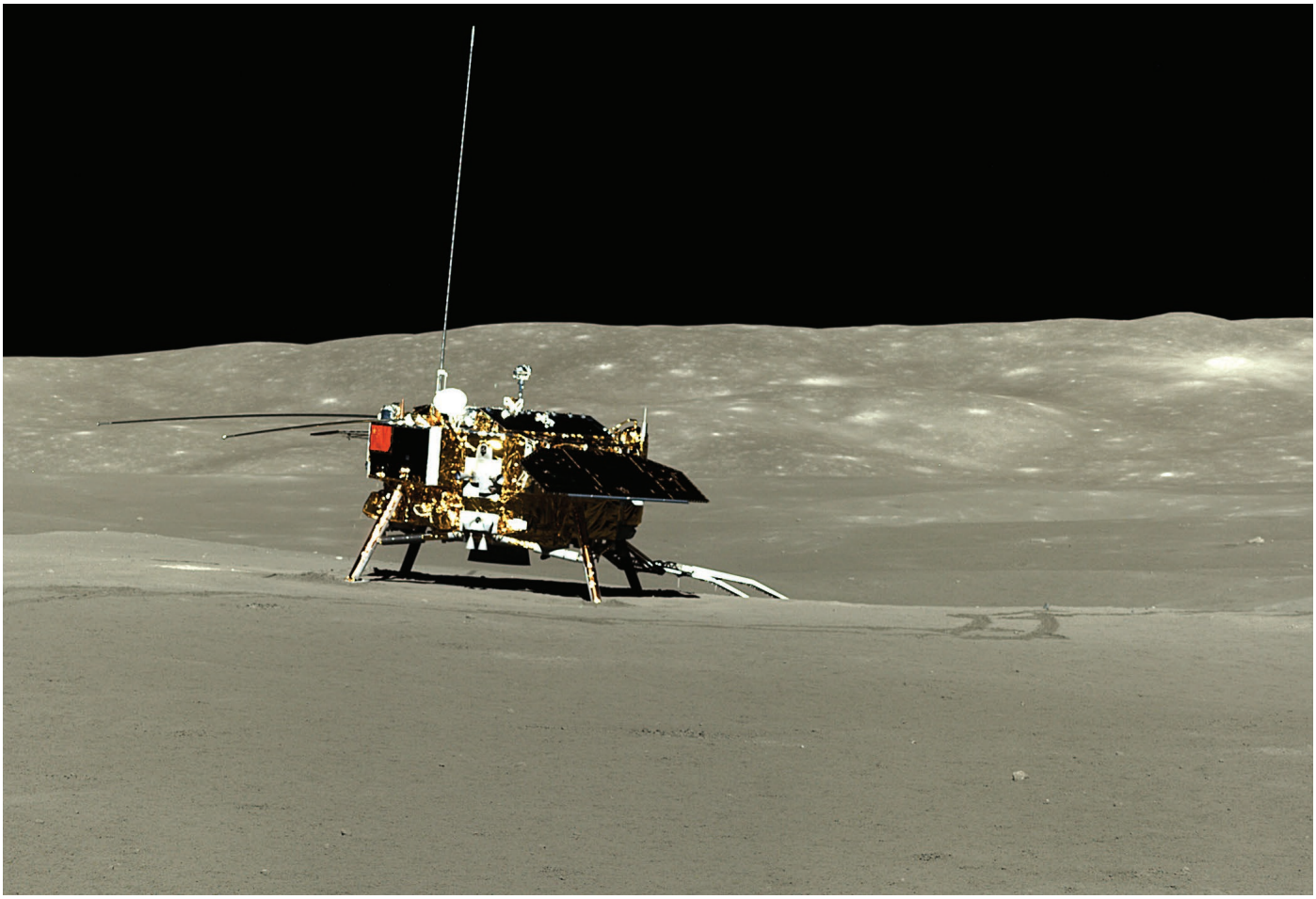
Assuming the missions to return Perseverance's samples to Earth get funded as planned, 2 launches would aim for Mars in 2026. The first would include a lander, fetch rover, and launch system that would land together near Perseverance in 2028. The fetch rover would collect the samples dropped by Perseverance, bring them to the lander, and place them in a sample capsule inside a rocket. (For redundancy, Perseverance can also bring samples directly to the lander.) The rocket would launch the samples into Mars orbit.

The second mission would be a Mars orbiter that would arrive in 2027. It would support telecommunications for Perseverance, the lander, and the fetch rover. Once the sample capsule was launched, the orbiter would locate and dock with it, place it into an Earth return capsule, carry it to Earth, drop it onto an Earth entry path, and fly onward. If all goes according to plan, the samples would arrive in 2031.

This year, we're celebrating The Planetary Society's 40th anniversary. Society cofounder Louis Friedman often quipped that no matter what year it was, NASA was always planning for a Mars sample return mission 20 years in the future. At long last, that horizon appears to be getting closer.



The missions that will return the Perseverance rover's samples to Earth still need to be formally approved and funded. The Planetary Society is advocating to make these missions a reality. Learn more and get involved at **planetary.org/marssamplereturn**.



CNSA/CLEP/Doug Ellison

THIS YEAR, CHINA plans to launch Chang'e-5, the first lunar sample return mission since the Soviet Union's Luna 24 spacecraft returned to Earth in 1976. Two successful previous landers have paved the way for China's next step in exploration. This photo of the Chang'e-4 lander on the lunar farside was taken by the Yutu-2 rover on 8 February 2019, early in the mission's second lunar day. The rover had already driven more than 50 meters northwest of the lander. Its tracks are visible near the lander, which sits on the sloping rim of a subdued crater. In the year since this photo was taken, the rover has journeyed a further 200 meters west. On the first anniversary of the landing, 3 January 2020, the mission released a trove of science-quality data to the world, including the images that compose this panoramic view.

–Emily Stewart Lakdawalla

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Dr. Mark A. Garlick,
Dust Storm on Mars

The Martian environment poses many challenges to those who explore it. Temperature, radiation, and a lack of water or atmosphere are problems that threaten future human explorers more than our robotic emissaries, but massive storms of dust are a danger to robots and humans alike. Martian dust storms can last for weeks on end, sometimes cloaking the entire planet in a haze. The dust can coat a robot's solar panels, starving it of energy and potentially ending its mission. This was the fate of NASA's Opportunity rover, which couldn't survive a planet-wide dust storm in 2018.

This image, created by author and astronomical artist Dr. Mark A. Garlick, gives us a chance to imagine the awe and terror that such a storm would inspire in a human explorer. It captures the dual nature of Mars: beautiful and intriguing yet hostile and incredibly challenging. It's a world that calls out to be explored and is one that demands the very best of us.

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