The Planetary Society

THE PLANETARY REPORT

JUNE SOLSTICE 2022

VOLUME 42, NUMBER 2

planetary.org

THE PATH TO SAMPLE RETURN

CELEBRATING 25 YEARS SINCE NASA'S PATHFINDER LAUNCHED THE MODERN ERA OF MARS EXPLORATION

THE PATH TO MARS

Finding our place in the journey of exploration

by Bill Nye

THIS YEAR marks the 25th anniversary of NASA's Pathfinder mission. Many of us were there. I mean, we were here — on Earth — as the lander, barely bigger than a grocery cart, touched down on Mars on July 4, 1997. A few days later, the adorable Sojourner rover, barely bigger than a skateboard, gave us a taste of what it would be like to live among Martian rocks. Nowadays, we expect regular missions to Mars that unveil astonishing vistas of mountains, valleys and plains. But before Pathfinder, it had been 21 years since Viking 1 and 2 sent the first images from the Martian surface in 1976. I was there for those two too. Today, 25 years after Sojourner rolled off the Pathfinder lander on Mars, we're all here — on Earth.

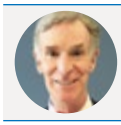
That 21-year success gap in U.S. Mars exploration is part of the story of The Planetary Society. Our founders, Bruce Murray, Carl Sagan and Lou Friedman, felt that the U.S. government had lost its momentum in planetary exploration, but public support for exploration remained high in the U.S. and around the world. They founded The Planetary Society in 1980 in part to show lawmakers just how much the public values space exploration. The Society has been advocating for missions to Mars and other worlds ever since.

When Pathfinder landed, it initiated a new era of Mars exploration. Since then, there hasn't been a single year or even month without an active mission at Mars. This sustained exploration of another world is a triumph, not only because the robots themselves have outlived and outperformed their operational life but also because there has been sustained funding. That's no easy feat! Presidents have come and gone, and congressional seats have been filled by new people, and yet NASA's Mars Exploration Program has continued to get the support it needs to keep its missions going. Take pride in this because Planetary Society members have helped make this happen. Who knows what we'll learn about our world by studying other ones.

As you'll read later in this issue, Planetary Society members have had connections to the Pathfinder mission from the beginning, even before it touched down on Mars. And through the advocacy and crowdfunding work that we're doing today, you all have a meaningful role in so many other missions that are underway or on the horizon.

Whether you've been a charter member since the very beginning or you're new to the Society, thank you for doing your part. Every mission becomes part of our journey as we find a path to other worlds.

Onward,



BILL NYE *is chief executive officer of The Planetary Society.*

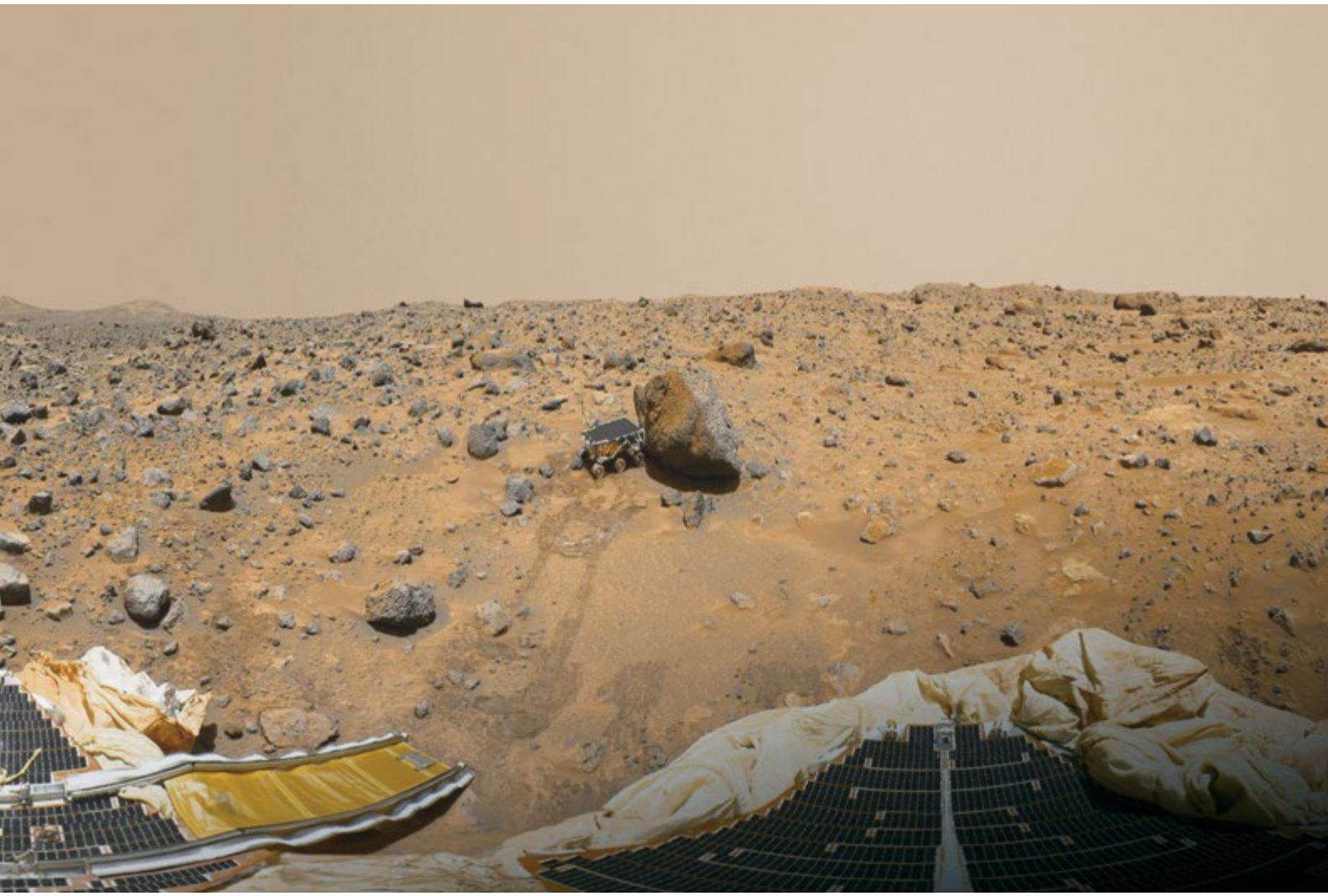
ON THE COVER: A color-enhanced mosaic of Ares Vallis landing site taken by the Imager for Mars Pathfinder, looking to the southwest toward the Rock Garden, a cluster of large, angular rocks. The Pathfinder rover, Sojourner, is shown snuggled against a rock nicknamed Moe. *Image: NASA/JPL* ⚘ The Planetary 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 the USA. Third-class postage at Pasadena, California and at an additional mailing office. Canada Post Agreement Number 87424. ⚘ Viewpoints expressed in articles and editorials are those of the authors and do not necessarily represent positions of The Planetary Society, its officers or its advisers.

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** *and* **RAE PAOLETTA**; *Contributing Editor* **KATE HOWELLS**; *Science Editor* **BRUCE BETTS**; *Technical Editor* **JAMES D. BURKE**; *Copy Editor* **NICOLE YUGOVICH**; *Art Director* **LOREN A. ROBERTS for HEARKEN CREATIVE**; *Creative Services* **ANDREW PAULY**

Contents

JUNE SOLSTICE 2022

NASA's Curiosity Mars rover takes a "selfie" with Mont Mercou.
NASA/JPL-CALTECH/KEVIN M. GILL



HOW THE PLANETARY SOCIETY GOT TO MARS

Behind the scenes of our milestone moment

by Rae Paoletta

IN DECEMBER 1996, NASA's Pathfinder spacecraft left Earth, carrying the names of thousands of Planetary Society members along with it. They became the very first names collected from the public to make it to the surface of Mars.

In a funny twist of fate, though, almost no one — not even Planetary Society members or staffers — knew the names had made it aboard. It was a historic moment that was both meticulously prepared and completely unexpected.

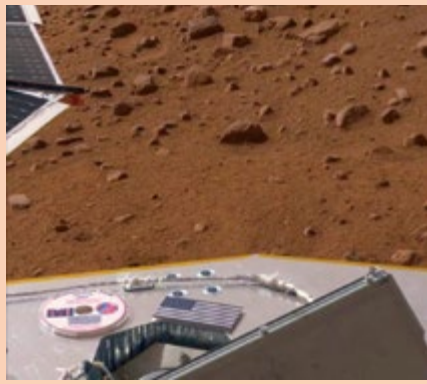
It all started with an idea Louis Friedman shared with his Planetary Society co-founders, Carl Sagan and Bruce Murray, sometime in the mid-'90s. They all agreed that sending members' names to Mars was a crucial, tangible way for members to participate in scientific research.

"We didn't just want to be cheerleaders," Friedman said in a recent interview with us. "We wanted to give people a sense of

MESSAGES FROM EARTH

The Planetary Society has helped send names, messages, images and good wishes aboard more than a dozen spacecraft. To date, we've sent our members and supporters to the Moon, Venus, Mars, Saturn, asteroids, comets, Pluto and out of the solar system entirely.

In some cases, we built the hardware used to carry the names into space. In others, we partnered with other groups to collect names. See all missions that have carried or are carrying Planetary Society member names at **planetary.org/messages-from-earth**.



ABOVE *This image shows the DVD provided by The Planetary Society to the Phoenix mission, which contains 250,000 names of people who signed up to send their names to Mars. The DVD is mounted on the deck of the lander, which sits about one meter above the Martian surface, visible in the background.*

NASA/JPL/UNIVERSITY OF ARIZONA

involvement in planetary exploration."

And so the Society collaborated with NASA's Jet Propulsion Laboratory (JPL) to develop the project, which would send members' names to Mars. They ultimately created a chip called MAPEX (microelectronics and photonics experiment) that contained the names.

Before Pathfinder launched, The Planetary Society was also working with NASA on a separate project: a contest to name the rover that would fly on the mission. The winner — a student from Bridgeport, Connecticut named Valerie Ambroise — chose the name Sojourner, after the abolitionist Sojourner Truth.

The Society had a hand in several ambitious projects around this time, but not all of them panned out. MAPEX flew on Russia's Mars '96 mission, but regrettably, the mission failed shortly after launch. NASA had made extra copies of MAPEX in case it could be used on future missions, but no one knew where The Planetary Society members' names would end up, if anywhere.

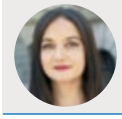
NASA finally found a suitable mission for them: Pathfinder. When the spacecraft landed on July 4, 1997, it was carrying copies of the documentation chip included in MAPEX. The Planetary Society had finally touched down on Mars.

Friedman said he heard the news just before the landing, which came as a "wonderful surprise."

"I remember getting a call from JPL that was essentially, 'Oh, by the way, Lou, we have MAPEX on the spacecraft,'" he said. "But it felt terrific. Getting to Mars was huge." The Planetary Society announced the surprise news to its members during Planetfest 1997, a joyous event celebrating the touchdown of Pathfinder on Mars.

Since Pathfinder, many missions have sent names into space, including MAVEN, New Horizons and OSIRIS-REx. Planetary Society staff even helped collect and sort the names that flew on NASA's Cassini mission to Saturn.

But gathering names from the public and sending them to Mars for the first time? It all started with us — and you. That legacy lives on in the cosmos forever.



RAE PAOLETTA *is the editorial director for The Planetary Society.*

ABOVE *A poster for Planetfest '97, the event where the Society announced that members' names were on Mars, included in MAPEX.*

LOREN A. ROBERTS FOR THE PLANETARY SOCIETY

OPPOSITE *This is the view from the site where NASA's Pathfinder mission and its Sojourner rover landed. In 1997, the lander was named the Carl Sagan Memorial Station in honor of The Planetary Society's late co-founder.*

NASA

REMEMBERING OUR JOURNEY

WE ASKED the Planetary Society members whose names became the first ever on the surface of Mars to share their memories about the Pathfinder mission and what they're looking forward to in the future of Mars exploration. Here are some of their responses. The full set of replies can be found at **planetary.org/pathfinderstories**.

Back in 1952 as a 12-year-old, I read up on astronomy and articles in Collier's on space travel by Willy Lay, von Braun and others. I said one day we will travel in space and got "ya right!" and was laughed at. Now every time we land on Mars, probe an asteroid or find new knowledge, I smile and know I get both pleasure and the last laugh. Learning and expanding your horizons is a real pleasure. Thanks to The Planetary Society, my name has been all over the solar system even if I haven't, and I am smiling as I travel. John Dunnewind

It is nice to be a part of a group that is finding things that I, as a child, was told did not exist or could not be done. I have believed in other planetary systems and visiting other worlds since elementary school. To know that I am a member of a diverse international group of fellow believers makes the long wait that much more exciting. To think that at some time in the near future, human explorers will see my name along with all the others already on the surface of Mars is rather humbling. John Reynolds

I am proud my name is on Pathfinder as part of The Planetary Society. Pathfinder is an example of human endeavor at its finest — exploration to benefit us all, science that will benefit us all as humanity and as stewards of our planet of origin. Alan De Salvio

When I joined the Society in 1980, I was a young woman with visions for the future of space exploration. Now, I am an elderly woman, knowing that only my name can go to space. I hope to live at least another 10 years, during which time I hope to see a colony on Mars and much more knowledge of all the planets calling Sol home. I wish for Earth to be restored, but I know that our species must move to the stars. I will always continue to watch, listen and imagine what our future holds. We are meant to explore. My heart lies somewhere out there. Gail Held

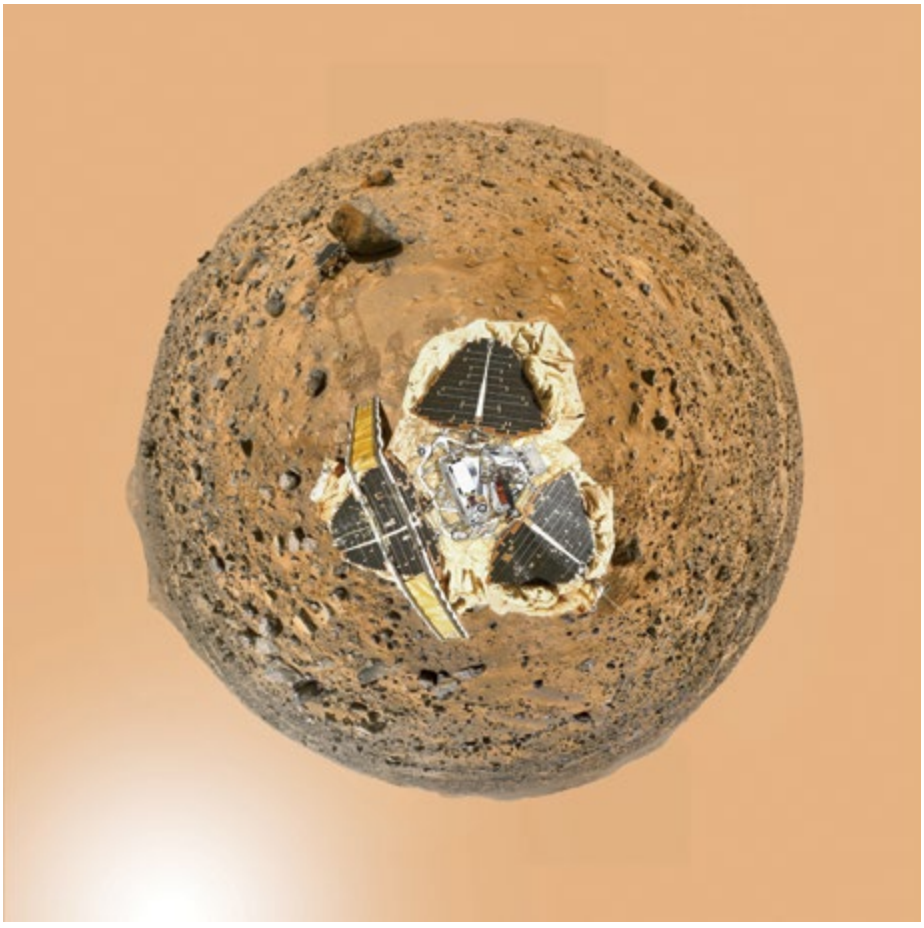
It's been a fascinating journey watching Pathfinder as it traveled across Mars and all the discoveries it has made. I'm proud of the part The Planetary Society has played and hope that future generations on Mars will see all the people that contributed to their reality. John Clark

On July 4, 1997, I, along with my brother and my 4-year-old niece, went to see the Pathfinder's landing live. I think it was at JPL in Pasadena. We, along with many others, were waiting for a long time, all the while looking at the big screen in front of us. My niece was getting impatient and wanted to go home. But first came the black and white images, and they were great. My niece became interested as I started explaining to her the pictures she was seeing. Then came the color images, and the crowd went wild. We all started to clap and scream from excitement. I have never seen color images of Mars except the ones in the books from the Viking landers. These color images were only 20 minutes old, and that's why they were special. Even my niece started jumping up and down. It was a great experience for all of us, and I will never forget that day. The Pathfinder was truly a trailblazer, and I hope there is more exploration of Mars that will lead to an international team of astronauts landing there, hopefully in my lifetime. Space exploration not only will help to secure the future for our species but it will help to foster international cooperation and peace here on Earth. Babak Eskandari

When I was young, I could only use my imagination or some artist's imagination to "see" the other planets of our solar system. Now, Mars is oddly familiar terrain, and the other planets feel closer to home. Our smallness in the cosmos makes the beauty of our home on Earth all the more amazing and all the more fragile. My hope is that the more we understand our place in the universe, the more we'll care for our home, not to mention feeling a little more humble and appreciative. Dennis Moritz

Space science and astronomy are my lifelong passion and hobby. I enjoyed Carl Sagan and jumped at the chance to join The Planetary Society in 1981 and support NASA. In some small way, we — the like-minded — advance this most noble of human endeavors. As far as we know, only humanity can appreciate Mars and the expanse beyond. As far as we know, that ability is the reason for our existence. Perhaps there is more. But if only to stand in awe of and reverence to the infinite beauty of being and to say that we have done so, then that is enough. Pathfinder is that statement. Harry R. Reinhart

ABOVE *Planetary Society charter member Olivier de Goursac (right) with the Mars Outreach team in the media trailer at NASA's Jet Propulsion Laboratory on the day of Pathfinder's landing on Mars. He helped set up the worldwide media event that broke world records for the greatest number of internet hits on a single day (60 million).*
OLIVIER DE GOURSAC



BELOW *The Mars Pathfinder "Presidential Pan," which de Goursac helped process.*
NASA/JPL/OLIVIER DE GOURSAC

Renaissance In Red

SETTING THE STAGE FOR MARS SAMPLE RETURN

by Jim Bell

LEFT *This image shows the remains of an ancient delta in Mars' Jezero Crater, which NASA's Perseverance Mars rover will explore for chemical or textural evidence of microbial life. The image was taken by the High Resolution Stereo Camera aboard the ESA (European Space Agency) Mars Express orbiter.*
ESA/DLR/FU-BERLIN

Mars is becoming a busy place.

Over the planet's past 13 orbits of the Sun (25 Earth years), a veritable fleet of robotic science emissaries has dramatically reshaped our understanding of the geology, meteorology and climate history of Mars. Nine orbiters, three landers, six rovers and even a helicopter have successfully operated on or around Mars since the start of the Mars Pathfinder mission in 1997. That's more than twice the number of Mars missions that had succeeded previously, dating back to 1960. Thirteen of these spacecraft are still working today.

More important than the sheer number of these missions, however, is how much they have accomplished. Success at Mars has been enabled by NASA and other space agencies, beginning the process of building infrastructure for the red planet.

Orbiters serve as communications relays and are now able to send multiple gigabits of data back to Earth every day. Sensors on landers and rovers have amassed a nearly continuous record of the planet's weather patterns over more than a Mars decade, enabling detailed forecasting of local dust storms and the comings and goings of the polar caps. Numerous technologies that will be critical for future robotic — and eventually, human — exploration of Mars have been tested and demonstrated.

Many of the missions sent to Mars have been built on scientific discoveries and lessons learned from their immediate predecessors. Maps have been created of the planet's major geologic and topographic features, mineral deposits and near-surface ground ice. Seismic surveys have been conducted to probe the level of activity of the planet's interior. The interaction between the Martian atmosphere and the solar wind — the stream of high-energy particles coming from the Sun — is now known to have had a profound impact on the planet's climate over time.

Through our robotic avatars, we have climbed tall mountains, descended into deep craters, dug trenches in the ruddy sands, zapped rocks with lasers to measure their chemistry, drilled holes in hard volcanic rocks and soft sedimentary layers and even flown across otherwise untraversable dunes.

All of the spacecraft sent to the surface have been designed to survive — and even thrive — in the extremely cold, low-pressure, dusty, three-eighths gravity environment of Mars. However, none of them have been capable of making the return trip back to Earth. A critical next step for Mars exploration is therefore a series of spacecraft and ultimately, a sample return.

RIGHT *About 1,000 Viking Orbiter red- and violet-filter images have been processed to provide global color coverage of Mars at a scale of 1 km/pixel. The color balance selected for these images was designed to be close to natural color for the bright reddish regions, such as Tharsis and Arabia, but the data have been "stretched" so that the relatively dark regions appear darker and less reddish than their natural appearance. This stretching allows us to better see the color and brightness variations on Mars, which are related to the composition or physical structure of the surface materials, including volcanic lava flows, wind- and water-deposited sedimentary rocks and (at the poles) ice caps. The north polar cap is visible in this projection at the top of the image, the great equatorial canyon system (Valles Marineris) is below center, and four huge Tharsis volcanoes (and several smaller ones) are at left. Also note heavy impact cratering of the highlands (bottom and right portions of this mosaic) and the younger, less heavily cratered terrains elsewhere.*
NASA/JPL/USGS

MAKING IT BACK FROM MARS

When Mars spacecraft die — for example, bogged down in deep and soft sand, starved of solar power by monster dust storms or unceremoniously crashing on arrival — they become part of the growing collection of historical alien artifacts slowly accumulating on the planet's surface. I believe that some of the relics and wreckage will become museum exhibits one day, maybe part of a branch of the Smithsonian Institution on Mars where youngsters can learn about the remotely controlled machines and their remote controllers who first began to chart the contours of their home planet.

Back in the summer of 2020, for the first time, a few parts of one of those Martian machines were launched off Earth with every intention of having them come back. Those parts were empty cigar-sized sample tubes carried by NASA's Perseverance rover and destined for a landing in a crater called Jezero that once hosted a lake in Mars' early history.

Why is bringing those samples back to Earth such a key part of the future of Mars exploration? Part of the answer comes from the study of Earth's earliest history, especially the hunt for the earliest evidence of life on our own planet.

The evidence is subtle because terrestrial organisms have only been leaving fossils behind for about 540 million years or so. Before then, in what geologists call the Precambrian geologic period, microscopic and macroscopic organisms were soft-bodied and much more susceptible to complete erosion and decay.

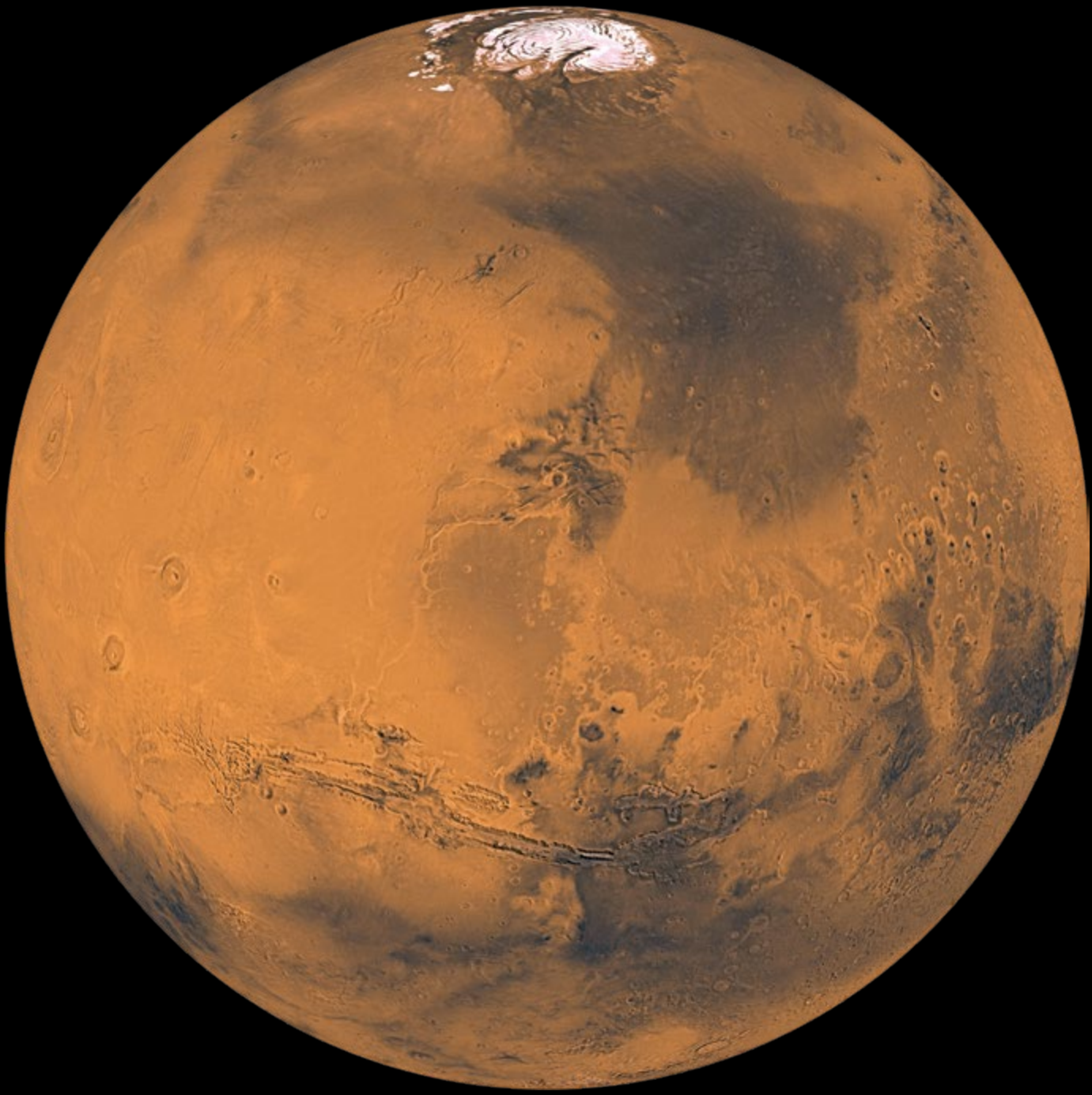
As a result, comparatively little evidence of them has been preserved in the geologic record. Precambrian geologists searching for the earliest examples of life on Earth are thus forced to rely on secondary clues, like chemical or textural signatures left behind by these organisms, rather than fossils. These clues are referred to as potential biosignatures, and there are fierce academic debates about them among geologists trying to pin down the origin of life on Earth.

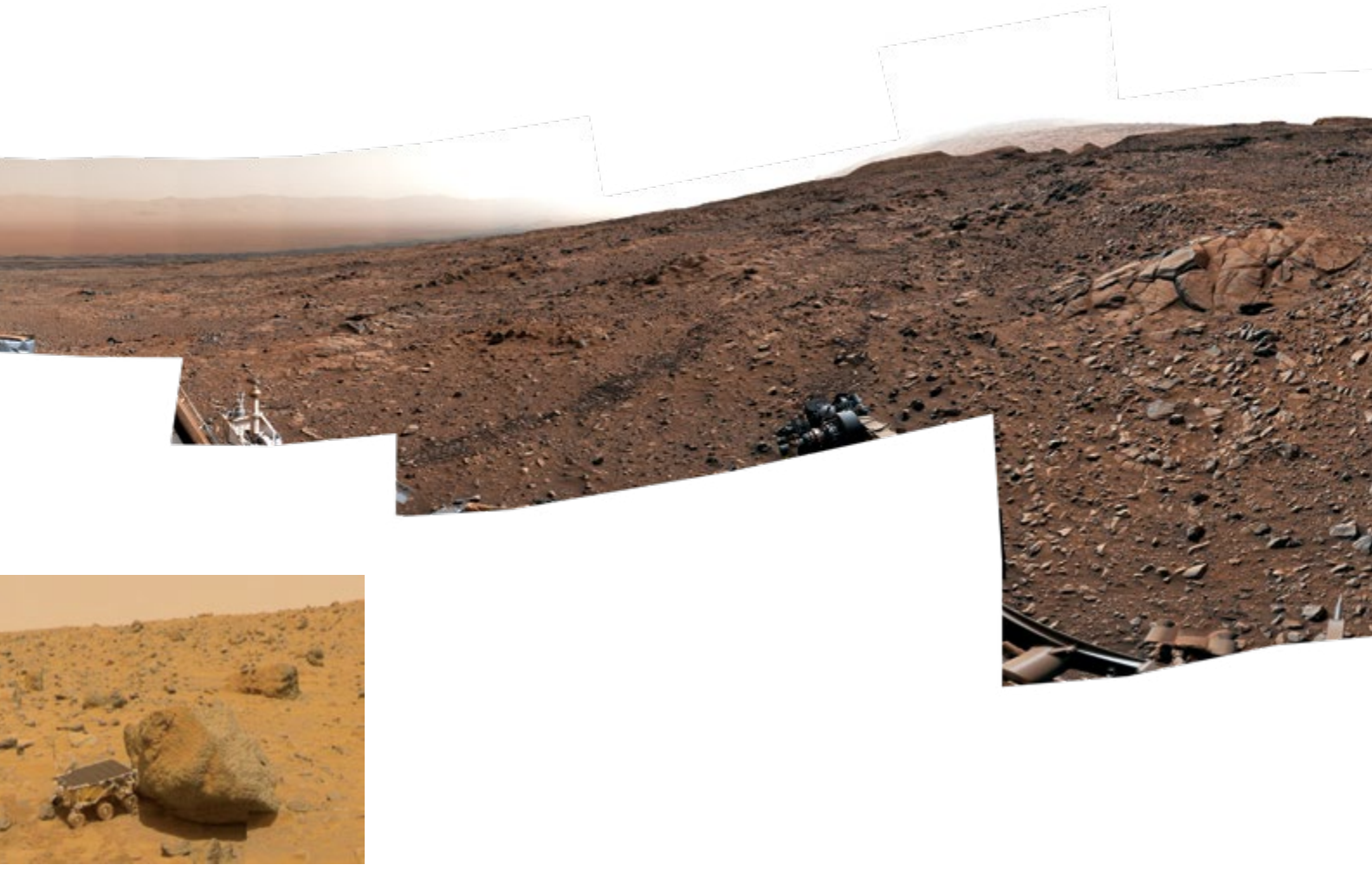
So, imagine if a potential chemical or textural biosignature was identified on Mars from rover instrument data — not a true fossil, as most space scientists aren't expecting to find such gob-smacking evidence for life on Mars given the ancient nature of the surface and the experience from terrestrial Precambrian geology. Instead, what if it was some subtle evidence of ancient life from early in the planet's more Earthlike history?

Even with the most promising discovery, scientists are skeptics by nature and training. It could be an insurmountable hurdle to convince the global scientific community that what had been found is truly evidence of life on Mars.

We actually have experience with just such a situation. In 1996, a group of scientists published a research paper claiming that they'd discovered evidence for ancient life on Mars, preserved in an ancient Martian meteorite that had been found in Antarctica back in 1984. The paper spurred an intense amount of public and scientific excitement and debate and helped to accelerate a new NASA focus on Mars exploration that continues to drive much of the agency's science agenda to this day.

But most of the relevant scientific community was — and remains — unconvinced by





ABOVE *A close-up of Sojourner as it placed its Alpha Proton X-Ray Spectrometer (APXS) upon the surface of the rock Yogi was taken by the Imager for Mars Pathfinder (IMP) over sols eight, nine and ten. Distortion in the background is due to parallax. Early results of Yogi show it to be low in quartz content, more primitive than the rock Barnacle Bill and more like the common basalts found on Earth.*
NASA/JPL-CALTECH

the evidence presented, citing nonbiological explanations as being more likely for each of the chemical, mineral and textural potential biosignatures presented. Despite some continuing support from the original research team and others, the discovery remains unconfirmed. As Carl Sagan, one of The Planetary Society's founders, used to note, "Extraordinary claims require extraordinary evidence."

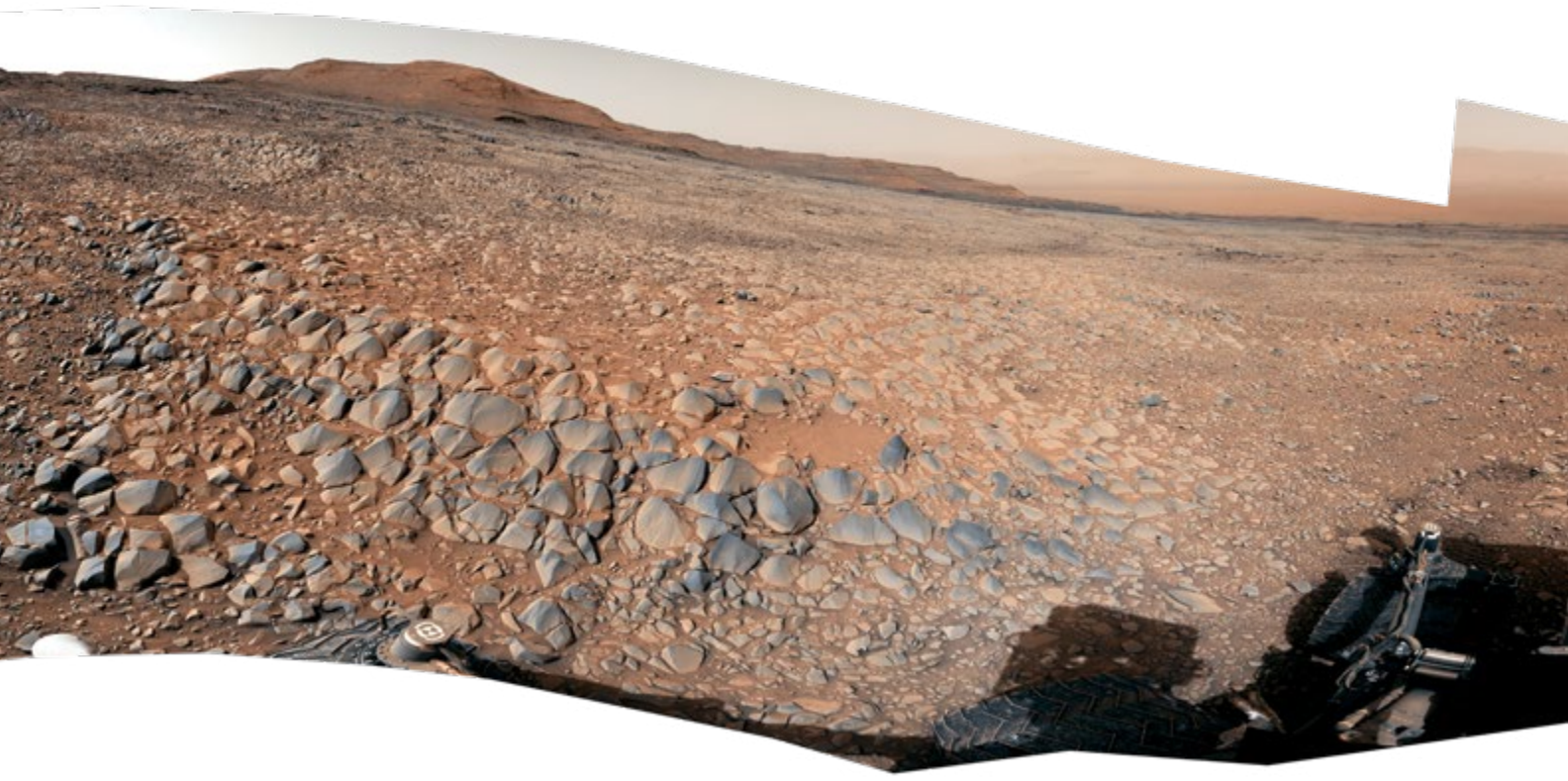
NASA and the planetary science community surmised the best way to show that biosignatures could be indicators of evidence of past (or present) life would be to collect samples on Mars. These samples would be carefully chosen to harbor potential biosignatures and would then be brought back to Earth for more detailed scrutiny.

The precision and capabilities of terrestrial laboratories far outpace those that can be launched into deep space. If multiple labs around the world could agree that the evidence indicates that Mars had or has life as we know it, it would confirm one of the most profound and historic discoveries in the history of science.

Of course, maybe the results would be equivocal, and perhaps the same debates would ensue as those in the terrestrial Precambrian life community. Still, it would be our best shot. And that is exactly why the Mars 2020 mission — and its sample-caching rover that would ultimately be named Perseverance — was created and established as the first step in a multimission campaign called Mars Sample Return.

A QUARTER-CENTURY OF DISCOVERIES

This July marks the 25th anniversary of the Mars Pathfinder and Sojourner rover landing. In addition to observing that historic moment, we should also acknowledge the many international missions of robotic exploration that have since led us toward a sample retrieval.



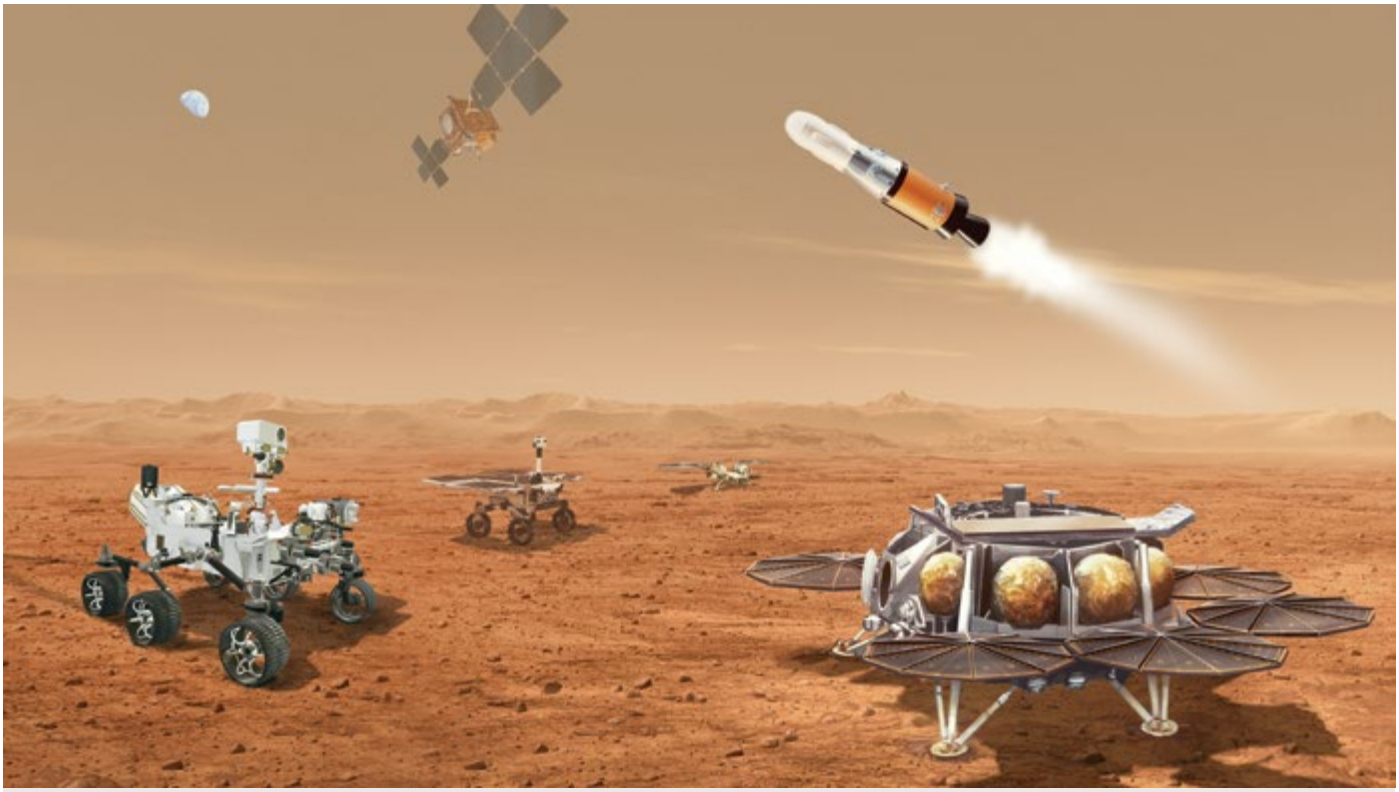
For example, teams of scientists and engineers designing, building and flying the Mars Global Surveyor (MGS), Mars Odyssey (ODY), Mars Express (MEx) and Mars Reconnaissance Orbiter (MRO) missions have built their geologic and geochemical science goals and instrument payloads on the results of each prior mission, dating back to the pioneering studies by the first orbital missions, like Mariner 9 and the Viking orbiters. Viking-era geologic maps helped choose the landing site for Pathfinder. In turn, Pathfinder helped to provide some of the "ground truth" that predicted many of the characteristics of future selected landing sites.

The story of how Jezero Crater was chosen as the landing site for Perseverance and the Mars Sample Return campaign is really a story about the ambitious set of robotic missions to Mars over the past 25 years. These missions have enabled us to identify a small number of places to explore in detail in the search for past or present extraterrestrial life.

MGS was the first (1997) to return to Mars orbit in this time period. That team was also the first to exploit the opportunities created by modern digital sensors observing the planet systematically from a 300-kilometer (about 187-mile) circular polar orbit. For more than nine Earth years, MGS mapped the planet's surface and monitored its weather, improving the resolution by a factor of 10 to 100 times better than Viking. It also added significant data sets that revealed new details about the global topography, mineralogy and magnetic field history of Mars.

Perhaps most intriguingly, MGS images revealed Mars to be a sedimentary planet with multitudes of layers of both volcanic and sedimentary rocks. Layers indicate changing conditions to geologists, and their presence — plus the discovery of river deltas and potentially relatively

ABOVE *NASA's Curiosity Mars rover used its Mast Camera, or Mastcam, to take this 360-degree panorama on March 23, 2022. The team has informally described the wind-sharpened rocks seen here as "gator-back" rocks because of their scaly appearance. These rocks form the surface of the Greenheugh Pediment, a broad, sloping plain in the foothills of Mount Sharp. The floor of Gale Crater is visible along the edges of the mosaic. As it climbs Mount Sharp, Curiosity is able to study different sedimentary layers shaped by water billions of years ago. These layers help scientists understand whether microscopic life could have survived in the ancient Martian environment.*
NASA/JPL-CALTECH/MSSS



How might Mars Sample Return work?

This illustration shows a concept for multiple robots that would team up to ferry to Earth samples collected from the Mars surface by NASA's Mars Perseverance rover.

NASA and ESA (European Space Agency) are developing concepts for the Mars Sample Return program designed to retrieve the samples of Martian rocks and soil being collected and stored in sealed tubes by Perseverance. In the future, the samples would be returned to Earth for detailed laboratory analysis.

One of the current concepts envisions delivering a Mars lander near Jezero Crater, where Perseverance (far left) is caching, or collecting, samples. A NASA-provided Sample Retrieval Lander (far right) would carry a NASA rocket (the Mars Ascent Vehicle), and a second lander, pictured in the background, would carry ESA's Sample Fetch Rover (center), which is a little smaller than a golf cart. The fetch rover would gather the cached samples left on the surface by Perseverance and transport them to the Sample Retrieval Lander, from which they would then be transferred onto the Mars Ascent Vehicle. Perseverance could also deliver additional samples directly to the lander. The Mars Ascent Vehicle would launch a container with the samples inside into orbit. Waiting in Mars orbit would be an ESA-provided Earth Return Orbiter, which would rendezvous with and capture the orbiting sample container using a NASA-provided Capture, Containment and Return System. This system would capture and orient the container and then prepare it for return to Earth inside the Earth Entry System.

NASA/ESA/JPL-CALTECH

young gullies — made it clear that the planet had a much more dynamic geologic and climate history than perhaps earlier believed. And some of those dynamic places (like gently deposited sandy, silty and muddy river delta sediments) could be much better than others at preserving potential biosignatures, based on analogs with similar kinds of landforms on Earth.

Building on the results from MGS and earlier missions, the ODY and MEx orbiters helped make the next big leaps in determining the most intriguing, revealing landing sites on Mars. Mineral mapping by these orbiter teams revealed a variety of volcanic rock compositions as well as evidence for clays, sulfates and other minerals formed from the watery alteration of those volcanic rocks. ODY data also revealed evidence for near-surface deposits of hydrogen, interpreted as water ice, at high northern and southern latitudes. The successful 2008 landing of NASA's Phoenix mission, for example, would provide the ground truth confirmation of that evidence by exposing and digging up ice just below the surface.

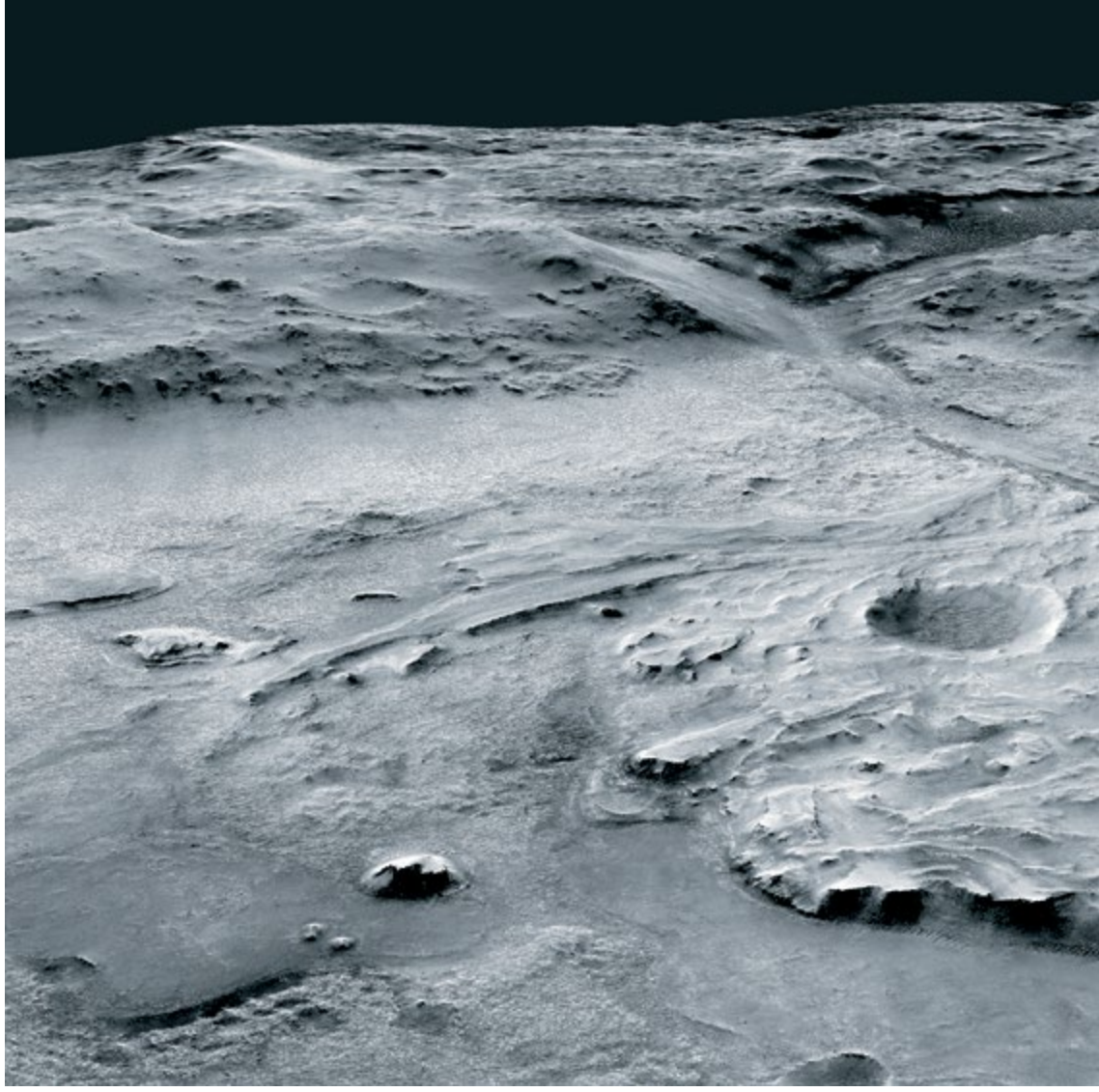
The next level of big advances in selecting potential future landing sites has come from MRO. That team has mapped the entire red planet at a scale of around 6 meters (about 20 feet) per pixel — good enough to count individual shipping containers if they were in orbital pictures of boats or trains here at home. They have also taken images of a carefully selected small percentage of the planet at five times better resolution than MGS did, resolving rocks and boulders and other small-scale geologic features as small as only about a meter (3 feet) across on the surface. Add to that new mineral maps of clays, sulfates, carbonates and iron-bearing minerals at a resolution higher than ever before plus radar mapping of the subsurface and the result has been the revelation yet again of a "new Mars" — one that has a more active surface than previously imagined.

This rich and incrementally growing collection of images and data has provided the feedstock for planetary scientists around the world to propose potential sites for many of the next-generation landers and rovers. For example, NASA and ESA have convened multiple community workshops open to all to solicit ideas and justifications for where to land the Spirit, Opportunity, Curiosity, Perseverance and Rosalind Franklin rovers. These exercises have started with dozens of potential sites being pitched, but then over time, the need to satisfy specific mission science goals and engineering constraints has winnowed down the choices to just a few.

ABOVE *This high-resolution still image is part of a video taken by several cameras as NASA's Perseverance rover touched down on Mars on February 18, 2021. A camera aboard the descent stage captured this shot.*
NASA/JPL-CALTECH

In the case of choosing the landing site for Perseverance, additional pressure came from the fact that NASA wants to bring samples back to Earth from that site — and not just any samples but a compelling set of samples that could enable new discoveries about not only the potential for life on Mars but for all kinds of other fundamental Mars science as well.

The four finalist sites were all interesting and scientifically important places to study up close on Mars — we need to visit them



RIGHT *This illustration depicts a possible area through which the Mars 2020 Perseverance rover could traverse across Jezero Crater as it investigates several ancient environments that may have once been habitable. The route begins at the cliffs defining the base of a delta produced by a river as it flowed into a lake that once filled the crater. The path then traverses up and across the delta toward possible ancient shoreline deposits and then climbs the 610-meter-high (2,000-foot-high) crater rim to explore the surrounding plains. About half of this traverse could be completed in Perseverance's prime mission (one Mars year, or two Earth years). For reference, the prominent crater near the center of the image is about 1 kilometer (0.6 miles) across.*
NASA/JPL-CALTECH/USGS

all eventually! Ultimately, however, Jezero was selected because the extensive orbital imaging of its spectacular river delta's sedimentary rocks showed it to be promising for preserving potential biosignatures. In addition, the presence of other volcanic and altered minerals could provide additional information on the history of the region.

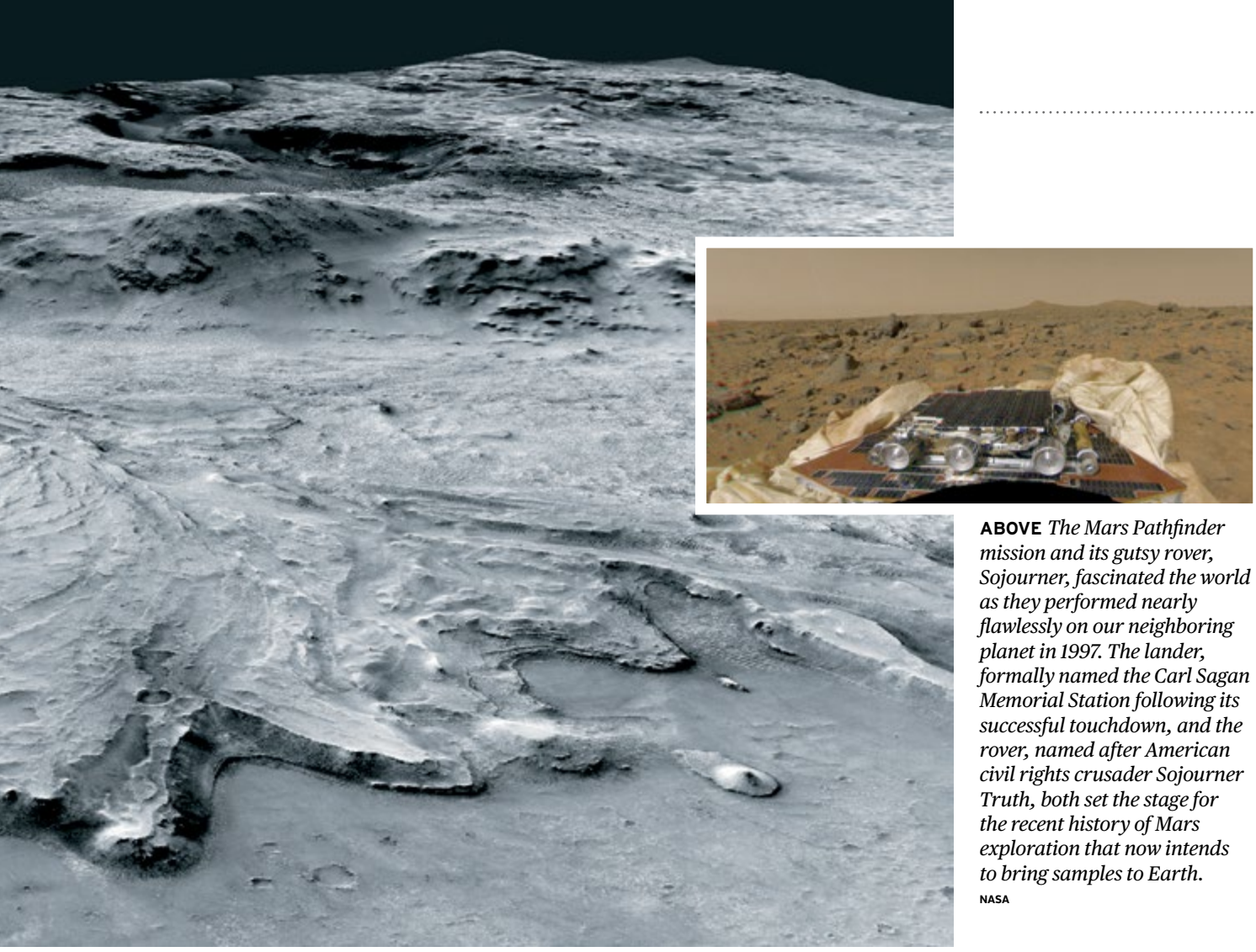
The Jezero site would enable the rover team to pose specific testable hypotheses. For example, Jezero hosted a long-lived crater lake early in Mars history; volcanic rocks from the crater floor can help establish the age of the delta and other features.

In my opinion, what set Jezero apart from the other finalist sites is the ability to pose specific hypotheses and to craft a relatively simple story around the exploration and sampling of an ancient river, a delta, lake sediments and nearby volcanic materials.

LOOKING AHEAD

Of course, Perseverance landed dramatically and successfully on Feb. 18, 2021. Despite many different rover instrument and systems teams having to work together mostly in isolation from each other during the COVID-19 pandemic, the first year of the mission has been a resounding success, with eight samples of Jezero Crater floor rocks safely stored in sample tubes inside the body of the rover. But how will those samples be returned to Earth?

While it's an evolving plan involving collaboration between at least NASA and ESA, one possibility is that Perseverance would drop a cache of samples onto the ground in a specific location and then a small "fetch rover" sent to land nearby in Jezero would collect them and bring them back to its lander, where they would be loaded onto a rocket on that lander and blasted into Mars orbit. Once there, a specially designed orbiter would



ABOVE *The Mars Pathfinder mission and its gutsy rover, Sojourner, fascinated the world as they performed nearly flawlessly on our neighboring planet in 1997. The lander, formally named the Carl Sagan Memorial Station following its successful touchdown, and the rover, named after American civil rights crusader Sojourner Truth, both set the stage for the recent history of Mars exploration that now intends to bring samples to Earth.*
NASA

capture the sample container and rocket out of Mars orbit to bring the sample capsule back for a parachute-assisted landing in the Utah desert. What could possibly go wrong?

Actually, many parts of that plan have been demonstrated to various degrees in previous missions, like the small Spirit/Opportunity-class fetch rover, the sample-caching spacecraft (OSIRIS-REx, Genesis and Stardust) and the Earth-return sample canister landing (Genesis, Stardust and Hayabusa).

Some parts are new, though. The Mars Ascent Vehicle (MAV) — the rocket that launches the sample container into Mars orbit — is a completely new and untested concept in Mars exploration. And the capture of that sample container by an orbiter around Mars would be another first-time activity in deep space exploration. Indeed, there are a lot of things to work out, and as the final plan is approved over the coming months to years, there will certainly be changes to the basic outline envisioned today.

In the meantime, the Perseverance team will continue its part of the job in earnest: exploring volcanic and sedimentary materials in Jezero Crater and collecting a set of samples to somehow, someday bring back to Earth.

Planetary scientist **JIM BELL** *is a professor in the School of Earth and Space Exploration at Arizona State University. He has been involved in all of NASA's Mars rover missions and leads the Perseverance rover's Mastcam-Z camera team. Jim was president of The Planetary Society from 2008 to 2020 and currently serves as secretary of the Society's board of directors.*

HELP DEFEND EARTH

Together, with the support of members like you, we're advancing the global effort to protect Earth from an asteroid impact. It's one large-scale natural disaster we can actually prevent — but only if we try.

Want to be a planetary defender and power our crucial work?

You can double your impact on planetary defense when you make a gift today. When you do, a generous fellow member **will match your gift up to a total of $15,000!** It's a great opportunity to make a difference.

Visit planetary.org/defendearth today!

SCAN ME

THE PLANETARY SOCIETY

THREE YEARS OF SAILING ON LIGHT

June 25 will mark the third anniversary of the launch of our crowdfunded LightSail 2 spacecraft. This groundbreaking project was funded by contributions from tens of thousands of members and donors to design, build, launch and operate the first CubeSat ever to use sunlight alone to adjust its orbit around Earth. The spacecraft continues to operate under an extended mission to further advance solar sailing technology, and new solar sailing missions are already building off what LightSail 2 has taught us. We don't know just how long LightSail 2 will remain in orbit, but we hope that you share our pride in all that it has already accomplished.

ADVANCING SPACE ADVOCACY

Shortly after our 2022 Day of Action wrapped up in early March, we launched a fundraising campaign to support our overall space policy and advocacy program. Thanks to all of your support, we will be able to do even more this coming year to craft impactful space policy recommendations, empower our members as advocates and make a difference for the future of exploration.

CELEBRATING TOGETHER AT LAST

Every year on April 12, space enthusiasts around the world celebrate Yuri's Night — the anniversary of cosmonaut Yuri Gagarin's flight as the first human in space. This year's Yuri's Night festivities were particularly special because we were able to safely celebrate together in person for the first time since 2019.

Planetary Society volunteers helped run the Yuri's Night event at the California Science Center in downtown Los Angeles, which featured speeches, dancing, costumes, food and drink and other festivities. Yuri's Night celebrations happen all around the world each year, maybe in your own area. If you didn't catch one this year, keep an eye out in 2023 or organize your own event!

Learn more at **yurisnight.net**.

WORKING TOGETHER TOWARD MARS

The Planetary Society was proud to contribute to the 2022 Humans to Mars Summit, another event that attendees and organizers were relieved to have in person this year. Planetary Radio host Mat Kaplan moderated two panels at the summit: Will Humans Be on the Surface of the Moon by the Mid-2020's and Travel to Mars by the Mid-2030's? and How Can Humans on Mars Unite the World? The Humans to Mars summit is the annual conference of Explore Mars and the largest annual conference in the world dedicated to the goal of a sustainable human presence on Mars. This year, it took place on May 17-19 at the George Washington University in Washington, D.C. Recordings of the panels can be watched at **exploremars.org**.

LEFT *This image taken by The Planetary Society's LightSail 2 spacecraft on Feb. 27, 2021 shows the Red Sea, Nile River, eastern Mediterranean Sea and surrounding areas. North is approximately at top right.*
THE PLANETARY SOCIETY

CENTER, RIGHT *Loretta Hidalgo Whitesides opens the show at the 2022 Yuri's Night Los Angeles party on April 9, 2022.*
PETER RUPRECHT, MAT KAPLAN

INAUGURAL STEP

We're proud to announce the two winning proposals for the first-ever round of STEP Grants, funded by a generous donation from the Halıcıoğlu Family Foundation.

STEP (Science and Technology Empowered by the Public) is a new grant program we announced in 2021 to support projects that help advance The Planetary Society's core interests of exploring other worlds, finding life and defending Earth from dangerous asteroids. The winners are chosen through an open, international, competitive proposal process. In the future, winning projects will be presented to the Society's members for crowdfunding support.

WINNER

Are we alone? A citizen-science-enabled search for technosignatures

WE AWARDED $49,980 to a team from the University of California at Los Angeles (UCLA) led by Professor Jean-Luc Margot for a citizen science project focusing on the search for extraterrestrial intelligence (SETI).

SETI research looks for signals sent from other worlds — in this case, radio frequency signals. This is the most direct sign of the use of technology (aka technosignatures) on other worlds. This field has often been overlooked and underfunded by federal granting agencies, including NASA, despite being a valid and important component of the search for life beyond Earth. The Planetary Society has a long history of filling this gap by funding SETI projects, including engaging our members in citizen science SETI research.

One of the big challenges in radio SETI research is that radio signals generated by humans can interfere with the detection of signals coming from elsewhere in the cosmos. This project addresses that challenge by engaging citizen scientists to efficiently and accurately separate Earth radio signals that are picked up when searching for extraterrestrial radio signals.

Researchers using the Green Bank Telescope, the largest steerable radio telescope in the world, have already amassed a huge set of radio data from 100 star systems that host exoplanets as well as tens of thousands of nearby stars, and they continue to collect more data all the time.

This new STEP-Grant-funded project will create and implement a citizen science project to sort and classify signals in the data from the Green Bank Telescope. Using the well-established citizen science platform Zooniverse, participants will search the data for Earth radio interference signals so they can be removed. Their classifications will help determine the most promising signals in the data and will also be used to train a machine learning system that can eventually take up the task.

The project is led by Professor Jean-Luc Margot of the UCLA Department of Earth, Planetary and Space Sciences and the Department of Physics and Astronomy along with UCLA Co-investigator Lisa Garibay. STEP Grant funding will also support a paid graduate student, four paid undergraduate students and 40 students and alumni who will be tasked with interacting with the participating citizen scientists.

GRANT WINNERS

WINNER
Demystifying near-earth asteroids

WE HAVE AWARDED $44,842 to a team from the University of Belgrade in Serbia led by Professor Bojan Novaković for a project that will develop a new way of characterizing the physical properties of asteroids.

Characterizing asteroids is an important part of the effort to defend Earth from impacts. A near-Earth asteroid (NEA) could have a number of different physical characteristics, from solid rock to a loose collection of gravitationally bound boulders, pebbles or even dust. Knowing the difference is essential for understanding the object, calculating its chances of impacting Earth and planning a deflection if needed. Missions that have visited asteroids, like OSIRIS-REx and Hayabusa2, have advanced our understanding of their characteristics, but it's impossible to send spacecraft to study every potentially hazardous asteroid up close. Of the tens of thousands of known NEAs, we only know the physical properties of a small percentage.

This STEP-Grant-funded project proposes a new way of determining an asteroid's physical properties including using data collected here on Earth. Advances in NEA research have revealed that asteroids experience tiny changes in their orbits (called Yarkovsky drift) caused by heat radiating off the asteroid's surface as it rotates. Asteroids with different surface properties have been found to have corresponding differences in their Yarkovsky drift. For example, a surface heats and cools at different rates depending on whether it is a solid object or a loose pile of dust. Yarkovsky drift measurements for a number of asteroids are becoming available, but these measurements have not yet been used to calculate surface physical properties. This project will develop complex computer modeling to use Yarkovsky drift data to determine the near-surface physical properties and, where possible, the density of around 150 NEAs. The project will also demonstrate this method as a viable characterization technique with potential application to future data.

This project is led by Professor Bojan Novaković of the University of Belgrade Department of Astronomy and his University of Belgrade Co-investigators: Professor Dušan Marčeta, Dr. Marco Fenucci and Vanja Petkovic. Funding will support faculty and student labor as well as the purchase of a powerful computer on which to run mathematical models.

TOP *University of California at Los Angeles (UCLA) Professor Jean-Luc Margot.*

BOTTOM *University of Belgrade in Serbia Professor Bojan Novaković.*

You can get more information at **planetary.org/step-grant-winners-2022**.

TOP *Romanian cosmonaut Dorin Prunariu with kids at Asteroid Day in Luxembourg.*
MAX ALEXANDER/ASTEROID FOUNDATION

BOTTOM *A group celebrates Asteroid Day in Brazil.*
ASTEROID FOUNDATION

ASTEROID DAY 2022

The Planetary Society is proud to partner once again with the Asteroid Foundation for Asteroid Day, an internationally recognized celebration of all things asteroid. This year's virtual and in-person events will highlight and celebrate asteroid research and planetary defense initiatives taking place in laboratories, university departments and space agencies around the world. You can watch the Asteroid Day event for free online on June 30, including special presentations, speeches, video premieres and much more. Learn more at **asteroidday.org**.

MARK YOUR CALENDARS!

Mission launches and milestones are always great opportunities to bring people together in celebration of space exploration. Here are two for which to prepare:

BepiColombo, a joint mission of the European Space Agency (ESA) and the Japan Aerospace Exploration Agency (JAXA), will perform a flyby of Mercury on June 23, 2022. This will be its second of six flybys it will perform to pick up enough speed to enter into orbit around Mercury in 2025. When it passes by its eventual destination, it will have a chance to send back photos and other data.

NASA's **Psyche** mission is set to launch in August 2022. This mission is heading to a unique, metal-rich asteroid (also named Psyche) that orbits the Sun between Mars and Jupiter. Psyche is thought to be of similar composition to planetary cores, so studying it can teach us about what lies at the center of Earth and other planets. Psyche will reach its destination in 2026.

Keep an eye on The Planetary Society's social media channels (Facebook, Twitter and Instagram) and our weekly email newsletter, The Downlink, for the latest news and information about these and other missions.

LEFT *This image taken by LightSail 2 on 16 Oct. 2020 shows Lake Victoria (center). To the left is Lake Tanganyika and at far right is the Horn of Africa. North is at upper right. Countries visible include Tanzania, Kenya, Uganda, as well as Burundi, Rwanda, the Democratic Republic of the Congo, and Somalia.*
THE PLANETARY SOCIETY

WAKE UP TO PLANETS!

IN THE SKY
All five planets that can be seen with just your eyes are visible in a line during late June and early July, and all but Mercury continue their visible line dance through September. From east to west, the line includes bright Mercury, super-bright Venus, reddish Mars, very bright Jupiter and yellowish Saturn. The complete line is visible in the pre-dawn east early in this period. Mercury disappears by mid-July, and the others spread out from one another as the weeks pass. By September, Saturn and Jupiter are rising in the east in the early evening, while Venus is very low in the pre-dawn east. The planets appear in a line because they all orbit in approximately the same plane. The Perseid meteor shower peaks August 12/13, with increased activity several days before and after. A full Moon will limit the number visible this year. For more night sky tips, you can always check out **planetary.org/night-sky**.

RANDOM SPACE FACT
As of June 25, 2022 (its three-year launch anniversary), The Planetary Society's LightSail 2 spacecraft has traveled in Earth orbit more than 7 million kilometers (4 million miles) during approximately 16,000 orbits.

TRIVIA CONTEST
Our December solstice contest winner is Mickey Fuson of Falls Church, Virginia, USA. Congratulations! The question was: ***Of the 88 modern constellations agreed upon by the International Astronomical Union (IAU), which is the smallest in area (solid angle subtended)?*** The answer: ***Crux, which contains the Southern Cross. Crux is 0.17% of the total sky.***

Try to win a copy of "Super Cool Space Facts" by Bruce Betts and a Planetary Radio T-shirt by answering this question: ***What single space mission returned the highest mass of samples from a body other than 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 Dec. 1, 2022. One entry per person. 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.


EXMOUTH QUAY,
WESTERN AUSTRALIA

***Please contact Terri or Taunya at Betchart Expeditions for brochures and updated information on COVID and travel. Call 1-800-252-4910 or go to* betchartexpeditions.com.**

We invite you to join other members of The Planetary Society to discover the world on Betchart Adventures!

HAWAII TOTAL LUNAR ECLIPSE
NOVEMBER 6-14, 2022
See the total lunar eclipse on the Big Island of Hawaii with astronomer Dr. Tyler Nordgren. Also visit Hawaii Volcano National Park and astronomical observatories that explore our solar system, galaxies, black holes and more!

ALASKA AURORA BOREALIS
MARCH 16-23, 2023
Discover magnificent Denali and the northern lights in the pristine splendor of Alaska in winter.

BALI AND EAST TIMOR
TOTAL SOLAR ECLIPSE
APRIL 10-23, 2023
Enjoy the enchantment of Bali, see the Komodo dragons on Flores and then fly to East Timor to see the total solar eclipse.

WESTERN AUSTRALIA
TOTAL SOLAR ECLIPSE
APRIL 13-24, 2023
Delight in the magnificent natural world of Western Australia. Stay on a quarter-million-acre cattle station near Exmouth in glamping tents for the time of your life! Swim with manta rays and whale sharks in the Indian Ocean.

The Planetary Society

60 SOUTH LOS ROBLES AVENUE
PASADENA CA 91101-2016 USA

Susan Gaby-Trotz, "The South Pole of Mars"

Planetary Society member Susan Gaby-Trotz created this hooked-rug portrait of the Martian south pole using images from the European Space Agency's Mars Express spacecraft. "The focus of the piece is on the lotuslike frozen water and carbon dioxide with dry river beds blending into the rusty brown Mars crust," says Gaby-Trotz. This rug is one of eight pieces from her 2017 South Poles project, each based on data from different space probes. "Using the traditional method of hooking rugs with linen burlap backing and a rich variety of wools, yarns and silks, I have blended art and science together with a fresh perspective for each. As a former teacher, I liked to encourage my students to analyze primary resources and to synthesize their understanding in innovative ways. In my own art practice, I try to do the same thing."

Do you want to see your artwork here? We love to feature our members throughout this magazine.
Send your original, space-related artwork to *connect@planetary.org*.