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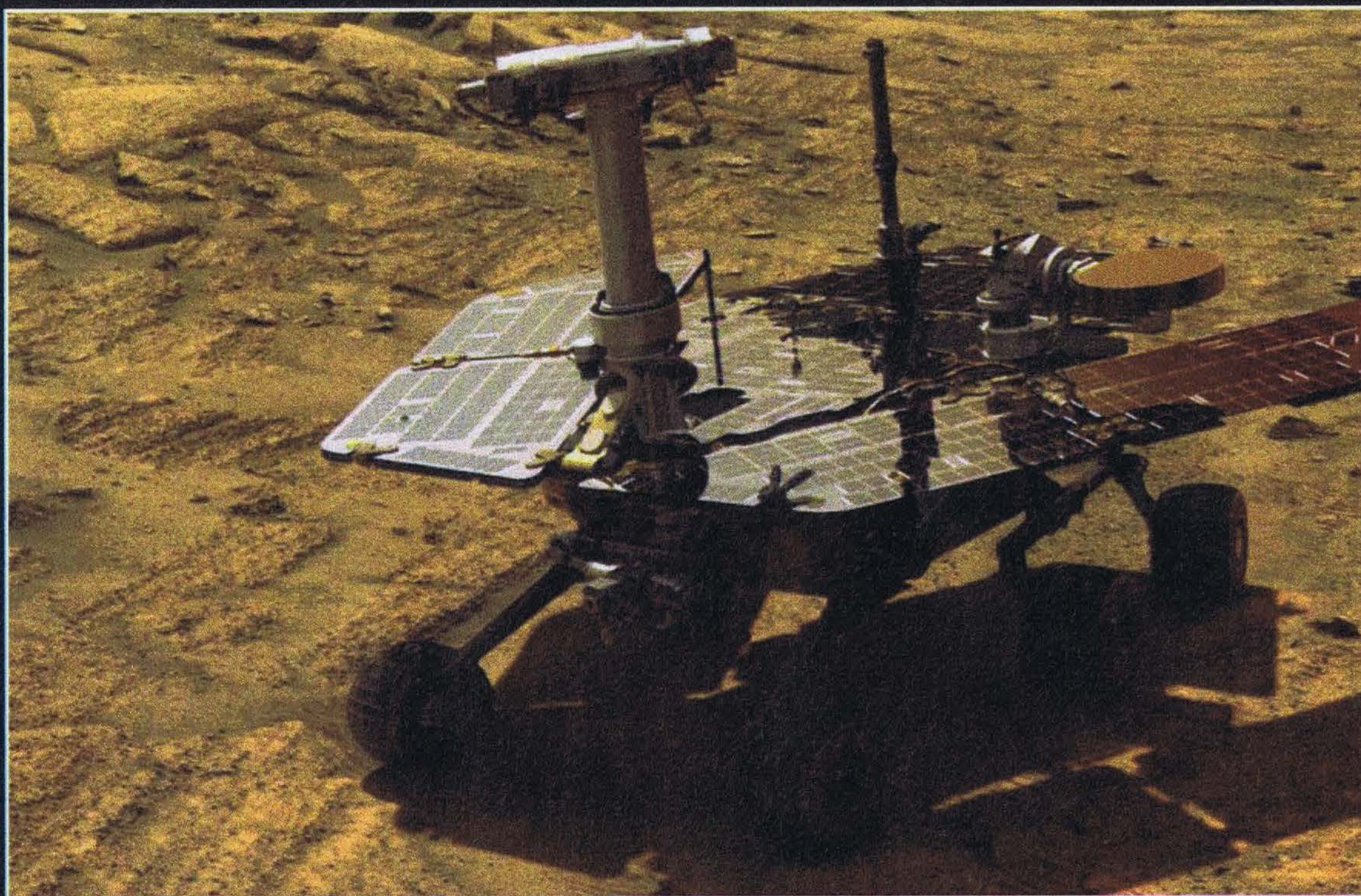
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**JANUARY 25, 2004**, marked the start of a 90-day planned mission for NASA's six-wheeled, golf cart-sized Opportunity rover — one of two vehicles comprising the Mars Exploration Rover mission. Fifteen years later — eight years after its twin, Spirit, went silent — Opportunity's mission finally drew to a close Wednesday, February 13, 2019.

The rover ultimately sent back more than 200,000 raw images and traveled a total of

**RED ROVER.**  
A simulated image shows Opportunity traversing Burns Cliff in Endurance Crater, which the rover studied in 2004. NASA/JPL-CALTECH

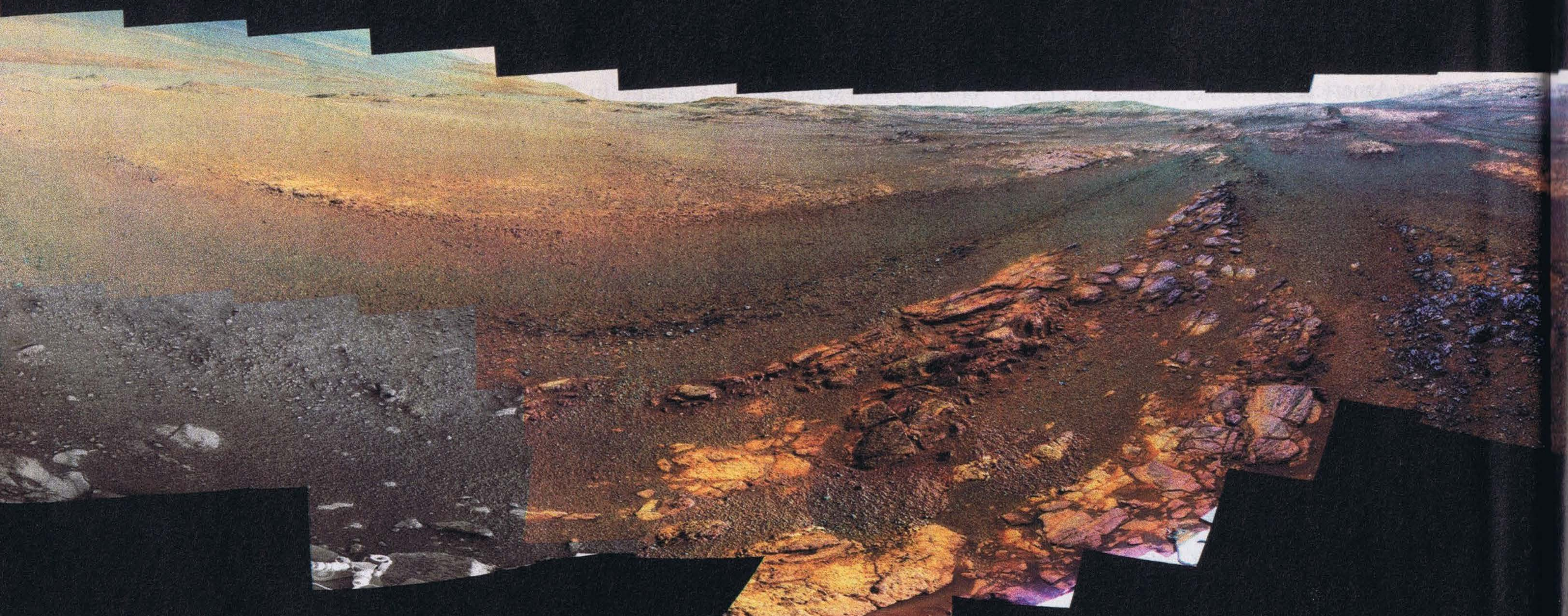
28 miles (45 kilometers), farther than a standard marathon and an accomplishment mission planners never expected. Over the years, Opportunity's findings have helped researchers reconstruct Mars' wet past, raising the possibility that microbial life could have survived on its ancient surface.

# MISSION COMPLETE

## *for OPPORTUNITY ROVER*

*After 15 years exploring the Red Planet, the Mars Exploration Rover mission has ended.*

**by Alison Klesman and John Wenz**



## MISSION'S END

On June 10, 2018, Opportunity fell silent under the shroud of a planet-encircling dust storm. By February 6, 2019, NASA reported that more than 835 recovery commands had been sent to the rover over a span of frequencies, including those outside its normal communications range. None had been answered. According to the mission site, this was the team's "strategy of last resort."

In a February 13 press conference, NASA announced the completion of the Mars Exploration Rover mission. "Our beloved Opportunity remains silent," said Thomas Zurbuchen, associate administrator of the Science Mission Directorate, NASA Headquarters, during the broadcast. Zurbuchen had been present the previous evening during a final planned attempt to reach the rover, asking it to respond. But no response came, prompting NASA to conclude that it remains asleep, and the mission can now be honored as a resounding success.

"Today we get to celebrate the end of this mission," said NASA administrator Jim Bridenstine. He added that scientists will benefit for years from the data taken during Opportunity's 14 years spent roving the Red Planet.

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**"Spirit and Opportunity may be gone, but they leave us a legacy."**

MIKE WATKINS

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## WHAT KILLED OPPORTUNITY?

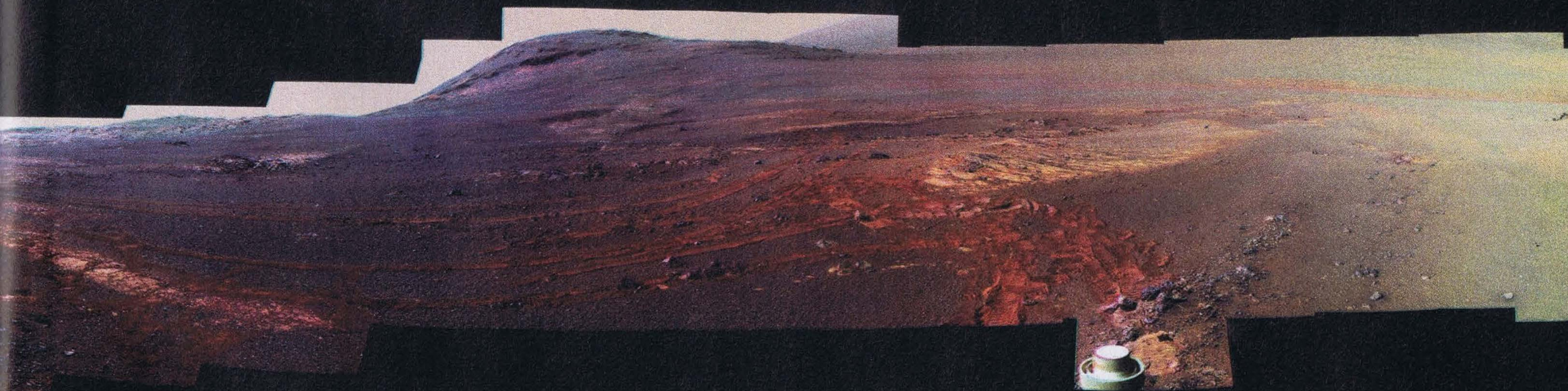
Early last June, Opportunity's location in Perseverance Valley, on the western rim of the crater Endeavour, had been engulfed by a growing dust storm. That storm clouded the Red Planet's skies with dust and blotted out the Sun. Opportunity, which relied on sunlight to charge its batteries and keep its electronics warm, went to sleep as a protective measure against



**DARKNESS FALLING.** In 2014, Opportunity snapped this wide-angle image of its own late-afternoon shadow against the backdrop of Endeavour Crater. NASA/JPL-CALTECH

the prolonged period of darkness. But even after the skies began to clear in early August, the rover slept on.

By September 11, the atmosphere above the rover's location had cleared enough for adequate sunlight to reach its panels, provided they were relatively free of dust. It also started the clock on a 45-day period that NASA believed would be the best window for getting a response from the rover. Throughout that period, NASA's Deep Space Network continued broadcasting commands to the rover, which likely suffered a number of faults due to the prolonged lack of sunlight, affecting its internal clock and thus its ability

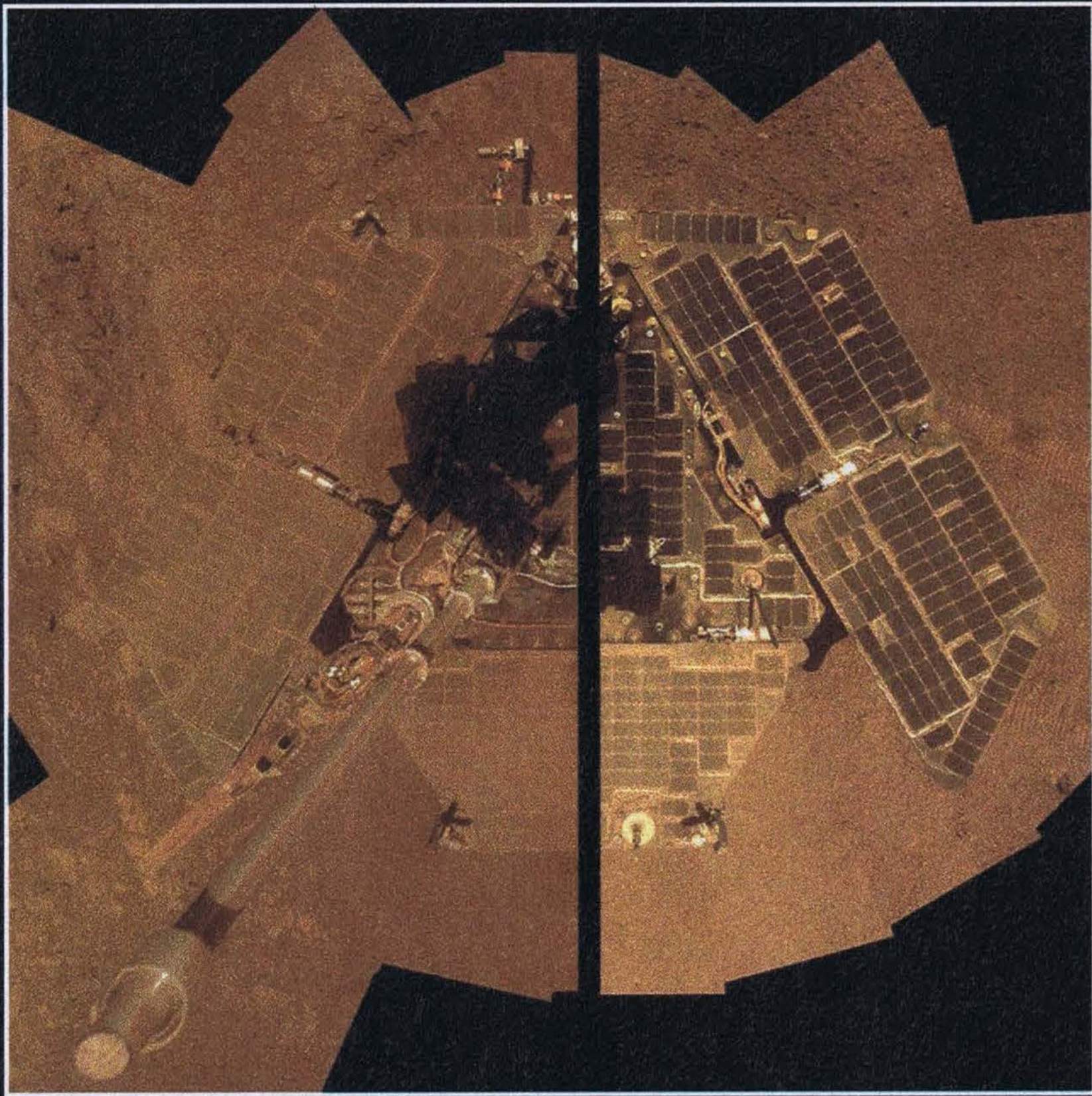


**ONE LAST LOOK.** This sprawling, 360-degree panorama — composed of 354 individual shots captured by Opportunity's Panoramic Camera between May 13 and June 10, 2018 — shows a host of intriguing features near a site fittingly named Perseverance Valley. This area on the western rim

of Endeavour Crater spans roughly 600 feet (182 meters) and contains many shallow channels sloping down from the crater's rim to its floor. Visible are Opportunity's entrance point to the valley (near the top center) and portions of the rover, including its solar panel (just left of center at the bottom)

and low-gain antenna (on the right side at the bottom). The lower left portion of the panorama contains incomplete images taken in only one color filter before the rover shut down.

NASA/JPL-CALTECH/CORNELL/ASU



**DUST IN THE WIND.** In January 2014, Opportunity had accumulated a thick coat of red dust, as seen on the left-hand side of this self-portrait. Two months later, wind had blown off much of the dust, as seen on the right-hand side, improving the performance of the solar panels that gathered power for the rover. NASA/JPL-CALTECH/CORNELL UNIV./ARIZONA STATE UNIV.

to communicate at preplanned times. By consistently pinging the rover during both preplanned recovery times and other random intervals, engineers had hoped to catch Opportunity when it was awake.

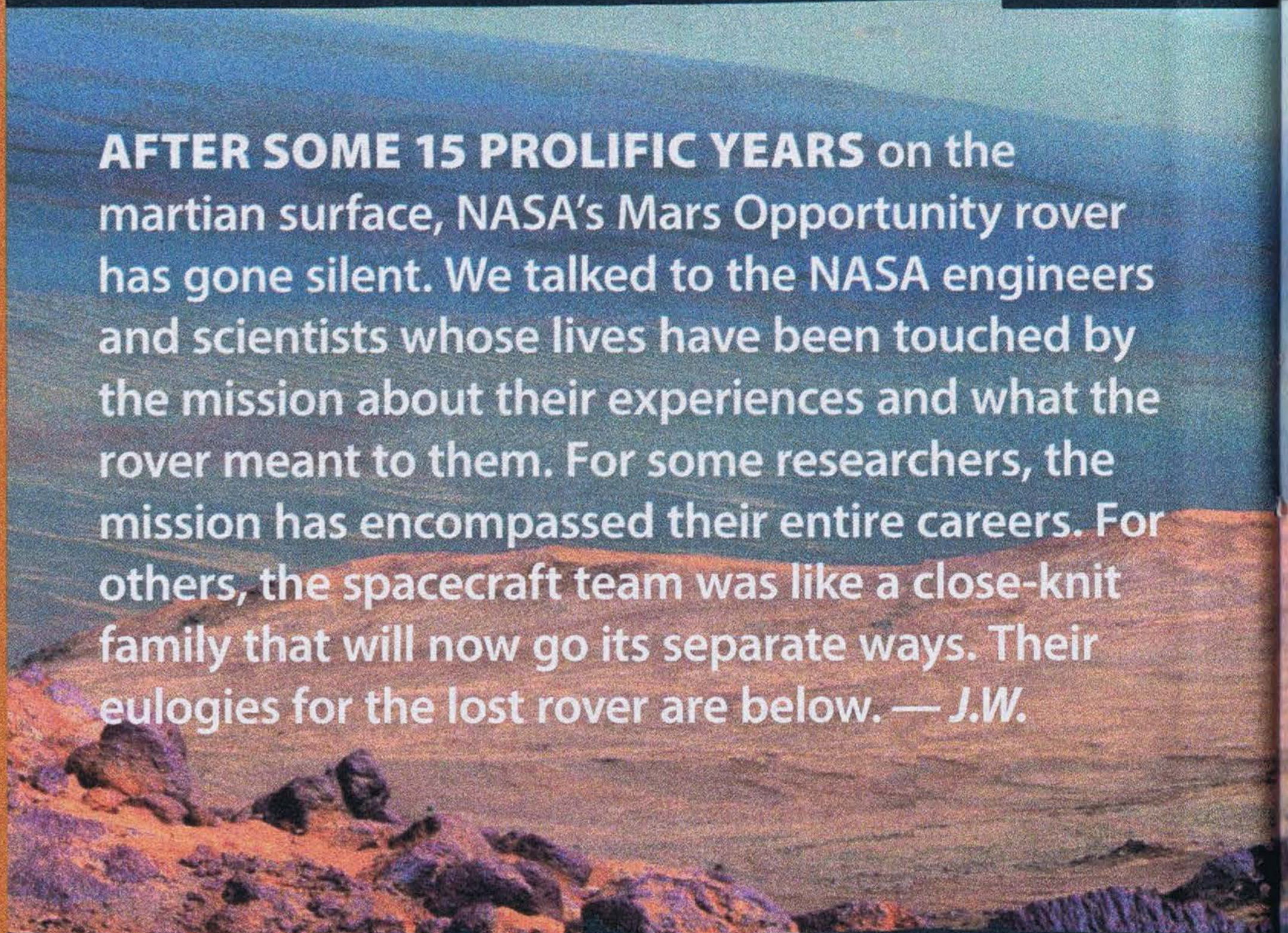
But after the final planned attempt, NASA concluded that Opportunity will remain silent and stationary at its final location.

### MISSION COMPLETE

As of January 25, Opportunity — with an original mission plan lasting just 90 days and covering only about 1,100 yards (1 km) of distance — had clocked 15 years on Mars. The rover had long surpassed both its original three-month warranty period, as well as its twin rover, Spirit, which fell silent in 2010 at a location on the western side of the Home Plate plateau named Troy. Spirit, which had suffered wheel damage, became stuck and was unable to collect sufficient sunlight during the martian winter, succumbing to a lack of power and cold damage.

"Spirit and Opportunity may be gone, but they leave us a legacy," said Mike Watkins, director of NASA's Jet Propulsion Laboratory. The Mars Exploration Rovers, he added, "energized the public about the spirit of robotic Mars exploration." Their legacy, he said, will live on with the enthusiasm and support for not only Curiosity, currently exploring Mars, but the upcoming Mars 2020 mission as well. ☞

**Alison Klesman** is an associate editor of *Astronomy*.



**AFTER SOME 15 PROLIFIC YEARS** on the martian surface, NASA's Mars Opportunity rover has gone silent. We talked to the NASA engineers and scientists whose lives have been touched by the mission about their experiences and what the rover meant to them. For some researchers, the mission has encompassed their entire careers. For others, the spacecraft team was like a close-knit family that will now go its separate ways. Their eulogies for the lost rover are below. — *J.W.*

# REMEMBERING OPPORTUNITY

“Put simply, I loved Opportunity, as I did her twin sister, Spirit. I was privileged to be part of a team that was ecstatically devoted to them for years. We sacrificed dinners with family, vacations, whole marriages, to those rovers.

“And they were worth it: In exchange, they gave us a planet. They were our eyes and ears, our remote robot bodies, as we made a god into a place. [They were] our daughters, alongside whom we were lucky enough to walk for a while.

“The thought of saying goodbye to Opportunity fills me with mixed emotions. Pride, certainly, at her enormous accomplishments. But grief and despair at her loss. And truthfully, I think the pride will have to wait a while. There's no room for it now.”

— **Scott Maxwell**, former rover planning lead for Mars Exploration Rovers Spirit and Opportunity

“If I had the chance to say one last goodbye, I would thank her for her tireless service above and beyond all possible expectations. There's probably no more fitting way for her to have gone than in the strongest dust storm we've ever seen on Mars — for her, I would expect nothing less. Now she can rest, beneath a thin layer of dust, knowing she did humanity proud.”

— **Tanya Harrison**, director of research for the Space Technology and Science Initiative at Arizona State University and science team collaborator on the Mars Exploration Rover Opportunity

**“I wish she could have persevered a little longer, but Mars had other plans.”**

KERI BEAN



**LONG HAUL.** Opportunity took this false-color panorama while looking down onto Marathon Valley from an overlook near Endurance Crater in March 2015. Once the rover reached the valley, it had traveled the equivalent of an Olympic marathon. NASA/JPL-CALTECH/CORNELL UNIV./ARIZONA STATE UNIV.

“[Opportunity is] the longest lasting mission we’ve had on the surface. That rover was basically driving until the end. It deployed its IDD [the rover’s arm] shortly before the storms started. . . . They’ve got an instrument down ready to do science. The fact that you’ve had a functioning mission for this long set a bar awfully high for Mars exploration. Mars 2020 is going to really have to work to best Opportunity. It’s appropriate that Perseverance Valley is where the Opportunity rover rests.”

— **Mike Siebert**,  
former tactical activity planner, sequence integration engineer, flight director for the mission, and Opportunity rover planner

“Because [Opportunity has] such a small team, we have a lot more of a family feel. . . . We’re all really close, we hang out on the weekends, we go out to dinner, and I haven’t really gotten that vibe with any other project. . . . It’s sort of sad to see this family disbanded.

“I think Opportunity has made the solid case that at least in some point in the past, Mars was habitable. We don’t know when, we don’t know if it ever happened, but at least there were several spots on Mars where we could have potentially had life, and I think that’s really fascinating.

“For me personally, I think Opportunity has just always persevered. Mars has thrown a heck of a lot at her. This isn’t even her first global dust storm. She’s survived so much. Parts have broken along the way. There have been problems along the way. Yet every single time, we’ve overcome it, and this is finally the one we can’t overcome. It’s kind of bittersweet that she’s dying in Perseverance Valley. I wish she could have persevered a little longer, but Mars had other plans.”

— **Keri Bean**,  
science planner on Opportunity and Curiosity team member

“It’s sort of bittersweet. We lasted almost 15 years for a three-month mission. We made multiple scientific discoveries that fundamentally changed our understanding of Mars, in a way that has guided all of the future exploration that we’ve been doing since. And to have been a part of that, and to have had it be so much more successful than anybody’s wildest imagination, is a really wonderful thing. It’s going to be a sad day, but it’s also going to be a day to celebrate in a way, because what we’ve accomplished is incredible and honestly may never be matched again.

“Things that we had to do to survive with Spirit and Opportunity have now become fundamental, built-in parts of Curiosity and 2020. And again, I don’t know that we’ll ever have another surface asset that contributes as much for as long. I certainly think that the distance that we’ve driven may be the longest we drive off the planet for a long time to come. And just being able to look at that and say, ‘Look at what we can achieve.’ I think that will be the other [part] of its legacy.”

— **Ashley Stroupe**,  
Opportunity rover planner and Curiosity engineering team member

“Opportunity was the first rover to find evidence for liquid water on the surface of Mars. Before that, we didn’t have any definitive evidence. It was the first rover to look at sedimentary rocks on another planet. And we learned a lot about how to drive rovers on another planet using Opportunity.

“Another legacy that I think is important from my personal story is the legacy of inspiration. I know I’m not the only one who . . . thinks that Spirit and Opportunity flipped a switch in their heads and said, ‘Oh my gosh, I’d love to pursue a career in math or in science to be able to do something like this for a career,’ whether it be a rover or doing science. . . . I think that’s just as important as the science results that have come out.”

— **Abby Fraeman**,  
Opportunity deputy principal investigator

Some quotes have been edited for length and clarity.

**John Wenz** is a former associate editor of *Astronomy* who now freelances from Lincoln, Nebraska.