

THE MANY PERSONALITIES OF MARTIAN ROVERS p.20

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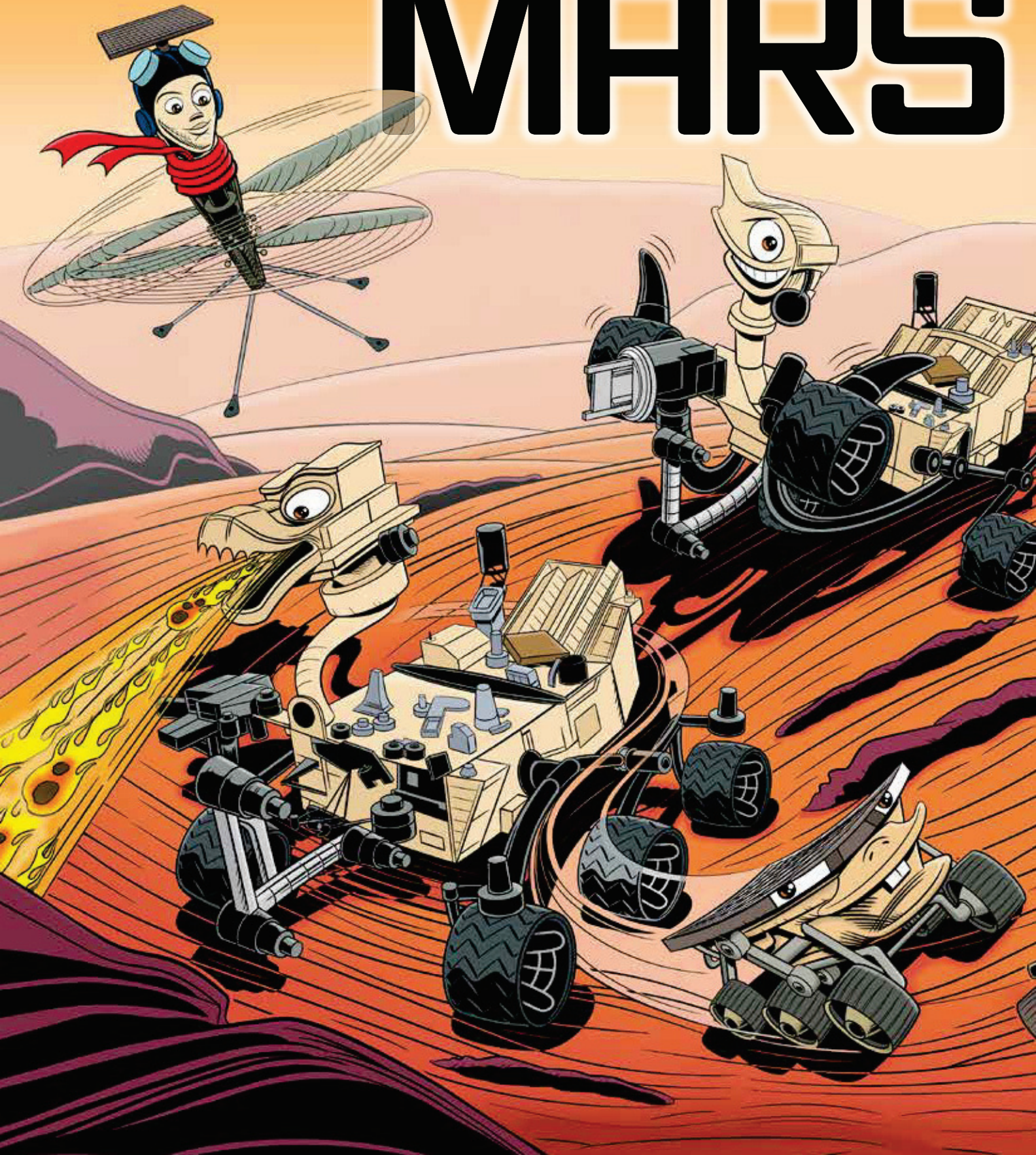
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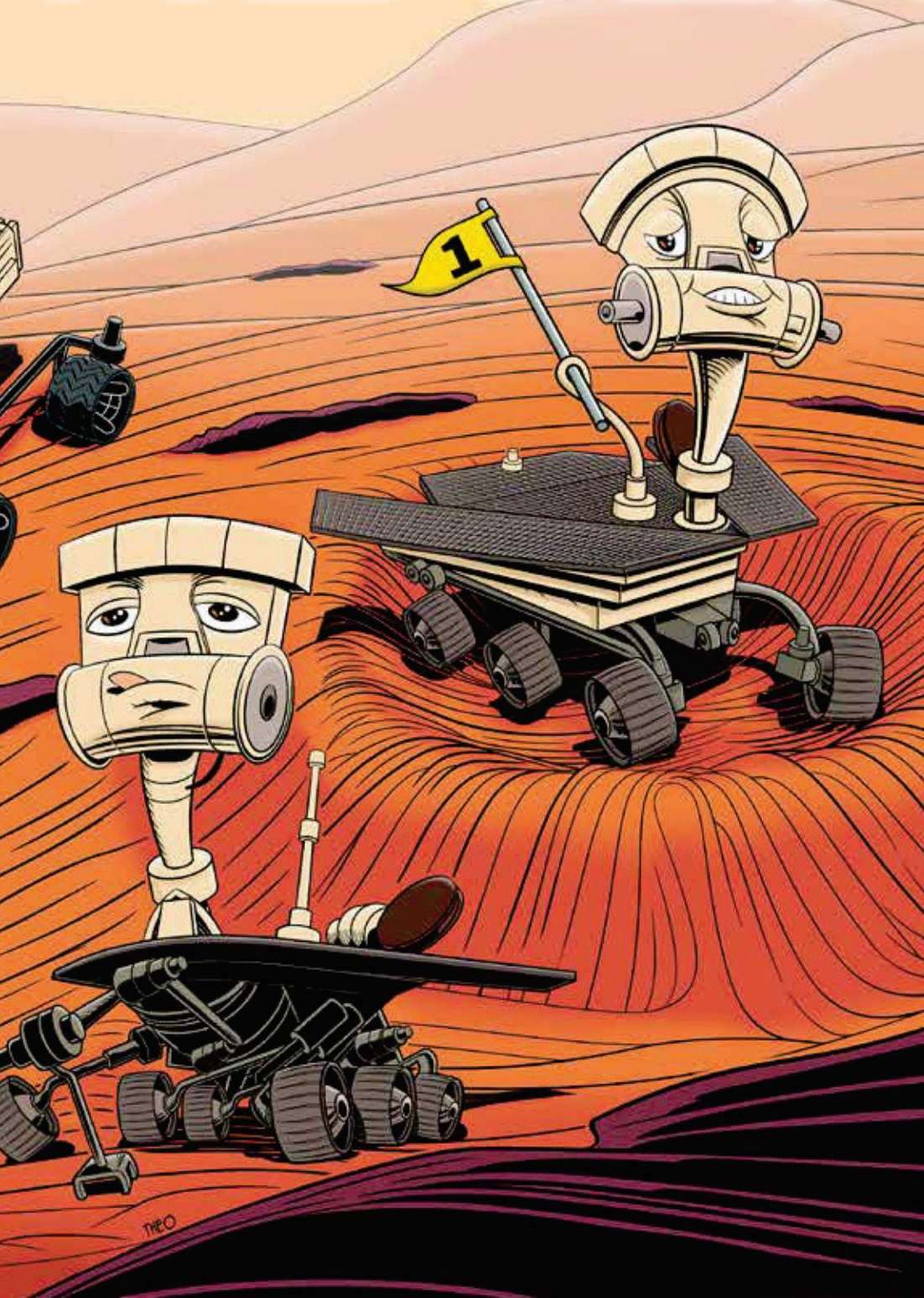
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The many personalities

MARS



of NASA's ROVERS



The first explorers of Mars include the rich and entitled, the bratty kids, the barnstorming aviators, and the selfie-obsessed social media sensations. (Did you think we meant humans?)

**STORY BY
MELISSA RICE
AND ILLUSTRATIONS
BY THEO COBB**

Rovers may be lifeless robotic hunks of metal, but to the scientists and engineers who work on them, each mission has its own personality. Clockwise from upper left: Ingenuity, Perseverance, Opportunity, Spirit, Sojourner, and Curiosity.

In January 2004, two rovers opened their eyes for the first time on Mars. They were identical twin robots with the same goal: to search for signs of past water in the rocks and minerals. But like any set of twins, they developed distinct personalities, shaped by their different environments and circumstances.

Opportunity — or Oppy, as it was affectionately called by the mission team — immediately found evidence for ancient water while Spirit searched for years to discover the same. Oppy covered a marathon's distance with relative ease; Spirit busted a wheel and limped backward. Near the equator, Oppy was exploring year round; farther south, Spirit had to hunker down for each cold, dark martian winter. When Oppy got stuck in the sand, it struggled but got free. When Spirit got stuck in the sand, it struggled and struggled ... and then winter came, and it died.

As a graduate student, I was part of the mission science team for both rovers, helping with their day-to-day operations. We talked about them as if they were different people: Oppy was the golden child, and Spirit had to fight for everything. I loved them both, but I liked Spirit better — the kid had moxie.

Personifying Spirit and Oppy was easy to do because they were designed to be like us in some ways. Their science

cameras had a resolution equivalent to 20/20 human vision and were placed at the average height of a person's eyes. Their robotic arms were the length of a long human arm, with shoulder, elbow, and wrist joints. And they were so darn cute, with those big, round doe eyes.

Let's be clear: Spirit and Oppy did not have personalities. They were hunks of metal. The rovers' *missions*, however, each had a unique personality shaped by engineering quirks, scientific fortunes (and misfortunes), and the people on their teams. If you were to teleport me blindfolded into one of the rover's operation rooms circa 2008, I could tell you whether it was Spirit's or Oppy's plan being discussed just from the vibe.

Since the Spirit and Opportunity missions ended, I've continued operating Mars rovers as part of the Curiosity and Perseverance (Percy) mission science teams. These newer-generation robots are less humanlike than their predecessors: They're bigger, beefier, less symmetrical, and, for all those reasons,

decidedly less cute. But their missions still have distinct personalities. I can't help but project those onto the rovers themselves, and I enjoy speculating about the kinds of people these rovers would be. *Would Curiosity be into Steely Dan? Would Percy wear an ascot?*

I asked several of my scientific colleagues — fellow Mars rover veterans — what they think about the missions' different personalities. Even the most formidable, uncompromisingly logical minds in the business admit to personifying the different robotic explorers.

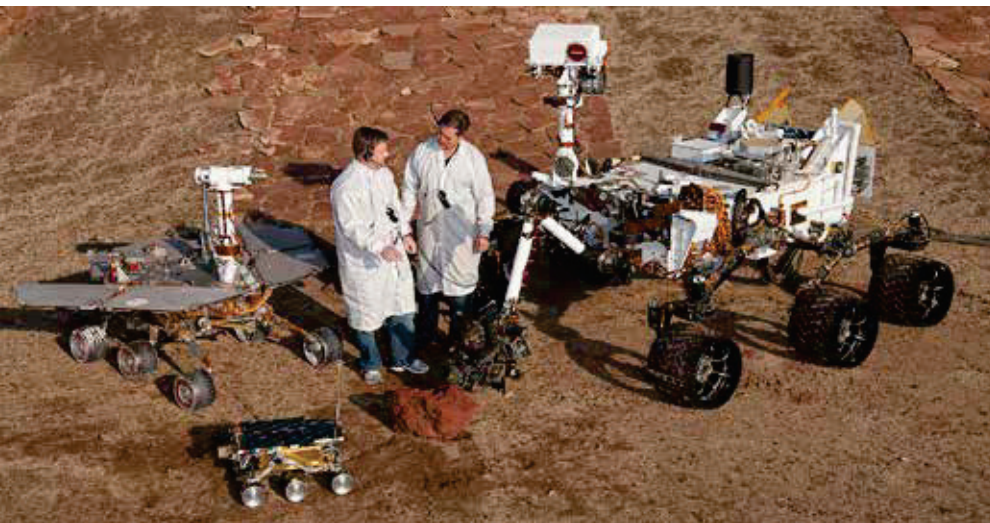
What follows is a character study of each NASA craft on Mars with wheels or rotors. While I draw upon the insights and stories from my colleagues, these depictions and taglines are highly subjective, often ridiculous, and ultimately my own.

SPiRiT • 2004-11

SPiRiT AND OPPORTUNITY WERE THE TWiNS of NASA's Mars Exploration Rover mission, but Spirit always had a harder go of it. Spirit was, as several colleagues put it, a "blue-collar" kind of rover. "It went to work each day with lunch pail in hand, ready to work on rocky terrain," says Jeff.

Early in its mission — only its 17th martian day, or sol — a problem with the rover's flash memory made its computer reboot over and over all through the night, draining its battery. Many team members thought this would be the end of Spirit, but the engineers sent commands to reformat its entire flash memory system, saving the mission. Spirit was up and running again by Sol 32.

And that's how it went: The rover would have a major setback, and the science team would find a way to overcome it. Even Spirit's landing site reflected this pattern. NASA sent Spirit to Gusev Crater, expecting to find rocks that formed in an ancient lake. Instead, Spirit saw only basaltic rocks made in lava flows. Jim Bell, the principal investigator for the rovers' Panoramic Cameras, describes the Gusev plains as "a basaltic prison." But in typical Spirit style,



Three generations of Mars rovers are represented in this portrait. In front on the left is Sojourner; behind it is a test rover that is a cousin of Spirit and Opportunity; at right is a test rover for Curiosity. NASA/JPL-CALTECH

SOJOURNER • 1997

THE FIRST WHEELS ON MARS were those of the Sojourner rover, which was a technology demonstration and part of NASA's Mars Pathfinder mission. Roughly the size of a microwave oven, Sojourner drove only short distances,

always staying within view of the Pathfinder lander, like a bear cub that couldn't stray too far from its momma.

Sojourner had "the personality of a toddler," according to Jeff Johnson, a geologist and planetary scientist who was part of the Pathfinder science team. Jeff is one of a handful of lucky scientists who have

been part of every NASA Mars rover mission to date.

"We hoped it went in the direction we said, but its final location wasn't always as intended," Jeff says. "We were not quite sure how it would respond to specific commands, so we learned its limitations and strengths by observing. Its



fisheye camera made everything look big and fuzzy, but we marveled at the views anyway."

Sojourner could be a pest sometimes, getting in the way of the serious work Pathfinder was doing. A few times in its short mission, the robot toddler photobombed the panoramic images that the lander's cameras were taking. From these stories, I always pictured Sojourner as a mischievous rug rat with its hand in the cookie jar.

Sojourner The Rugged Rug Rat

- First wheels on Mars
- Drove short distances
- Dependable; a pest
- Fisheye camera
- Mysterious and mischievous



NASA/JPL-CALTECH

the team made a jailbreak: They drove the rover east for two years toward a row of hills beckoning on the horizon.

Along the way, Spirit's solar panels got dusty, blocking their view of the Sun and limiting the rover's power. The team had seen dust devils swirling ominously nearby, and one scored a direct hit on Spirit. But it didn't topple the rover or cause any harm. Instead, it swept Spirit's solar panels clean, restoring the rover to full power. Several more times during its extended mission, Spirit would luck into these dust devil

cleaning events, the closest thing on Mars to a car wash.

When Spirit arrived at the Columbia Hills, it summited the highest peak, but another major setback struck: Its right front wheel stopped turning. For the rest of its mission, Spirit had to drive backward, dragging its dead wheel behind it and digging a trench in the dirt the whole way. This slowed things down, but ultimately led to one of the most exciting discoveries of the mission.

"I've never seen anything like this on Mars," Jim told me when I met with him for the first time as a green graduate student. "What

Spirit The Luckiest Unlucky Rover

- Twin of Opportunity
- "Blue-collar" worker
- Weathered setbacks
- Broken right front wheel
- Dug out minerals



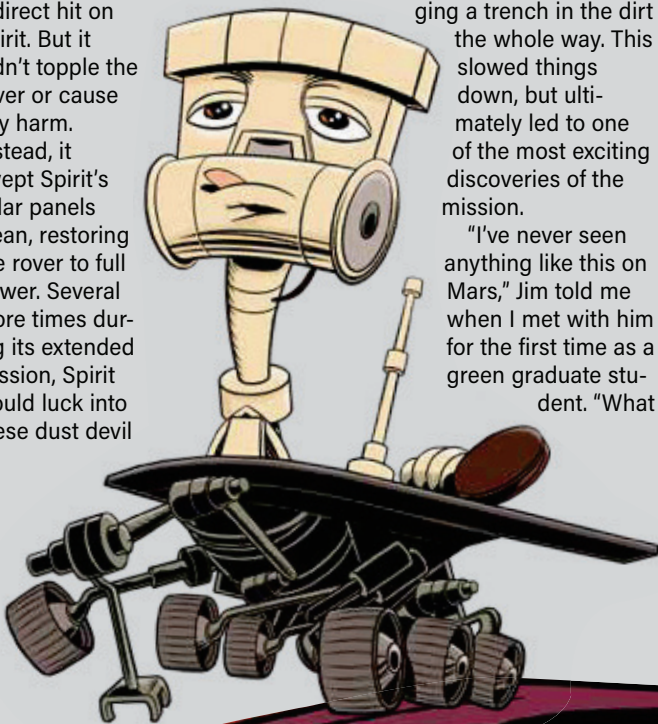
NASA/JPL-CORNELL UNIVERSITY

the heck is this stuff?" he asked, pointing to a bright yellow streak in Spirit's wheel trench.

I had no idea, but I would spend the next five years studying these bright soils that Spirit periodically churned up in its wake. They were sulfates and opaline silica, the kinds of minerals that form in hot spring environments — the ancient Mars equivalent of Yellowstone National Park. Just think, the minerals were buried only an inch below the surface, but had

Spirit's wheel not been broken, we would never have seen them.

Those bright soils are exactly what Spirit got stuck in on May 1, 2009, spelling the end of the rover's mission. Team members wore shirts that said "Free Spirit" while they practiced maneuvers with a test-bed rover at NASA's Jet Propulsion Laboratory (JPL) in Pasadena, California, trying anything and everything to excavate the rover from its sand trap. But Spirit's luck had finally run out.



OPPORTUNITY • 2004-18

OPPORTUNITY'S LANDING IN MERIDIANI PLANUM was an interplanetary hole-in-one: The rover wound up in a small impact crater just 72 feet (22 meters) across, facing a wall of exposed, layered bedrock. Bedrock is greatly coveted by Mars explorers — it is the planet's exoskeleton. This was the very first sedimentary bedrock encountered on Mars, made of sandstones that formed in shallow water. And, to boot, small spheres of hematite were embedded in the sandstone

layers. These "blueberries," as the team dubbed them, had formed from groundwater, precipitating out as the liquid trickled through the rocks. So, immediately after landing, Oppy had discovered two distinct episodes of water activity on ancient Mars.

That kind of success would follow Oppy throughout the rest of its mission. It climbed out of Eagle Crater and drove across the plains to the bigger, 430-foot-wide (130 m) Endurance Crater, which had even more sandstone layers exposed. Then it cruised over to Victoria Crater, half a mile (0.8 kilometer) wide, and finally, Endeavour, a behemoth of a crater 14 miles (22 km) across.

By 2015, Oppy had covered a marathon's distance. It was not a sprinter; Oppy's top speed was about 0.06 mph (0.1 km/h), which means it took close to an hour to drive the length of a football field. "Its traverses were characterized by lengthy periods of monotony, punctuated by astounding discoveries," Jeff says.

Sometimes, surprises would pop up during those long, boring stretches between craters. For example, Oppy drove right by its own heat shield. Next to it, the rover found a strangely pitted, metallic rock, unlike any seen on Mars before. The team measured its chemistry and concluded that it was not a Mars rock at all — it was an iron-nickel meteorite. Steve Squyres, the mission's principal investigator, quipped, "Quick, we've got to drive away from here! This is clearly the spot on Mars where big hunks of metal fall from the sky!"

Oppy's greatest luck was its longevity. "Oppy lasted like it was someone's grandmother," says Jeff, "continually sending good tidings in the form of data and images, fighting through another winter by adjusting its location for a warm orientation to the Sun, and benefiting from good wind and weather ... until it couldn't. It faced a quiet death with a fading memory, but it left a lasting legacy amid a bunch of tears."

Opportunity The Martian Marathoner

- Twin of Spirit
- "Golden child"
- Drove long distances
- Found two episodes of water
- Lived a long life but arthritic in end



NASA/JPL-CALTECH

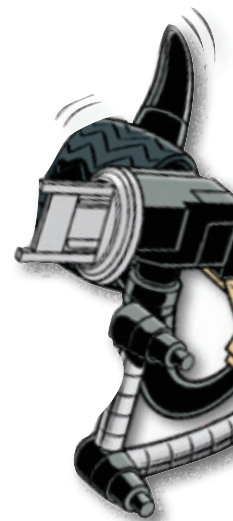
CURIOSITY IS A DIFFERENT KIND OF ROVER for a different era of Mars science. Whereas Spirit and Oppy were field geologists — scrappy, rugged explorers with a few tools on their belts — Curiosity is a meticulous lab scientist, hauling a truckload of sophisticated instruments. Weighing nearly 2,000 pounds (900 kilograms), it is more massive than all previous rovers combined. It needed a new landing system (the sky crane, as opposed to air bags) and a new power system (using the radioactive decay of plutonium rather than solar panels).

Its mast height is 7 feet tall (2.1 m), its arm 7 feet long (2.1 m), and the suite of instruments on its turret weighs close to 200 pounds (90 kg). That's so heavy that on Earth, Curiosity couldn't lift its outstretched arm under its own power. Curiosity is a true martian, built to survive and thrive in the Red Planet's low gravity.

It has a native diet, too: Curiosity eats Mars rocks for breakfast. It drills into them, crushes them, and ingests them. The Sample Analysis at Mars (SAM) instrument heats up the rock samples to hundreds of degrees and then analyzes the gases they emit. That can tell us what the rocks are made of and whether they contain organic molecules. Curiosity also blasts holes into rocks with a laser on its Chemistry Camera (ChemCam), which sits atop its mast like an off-center cyclops eye. I think of Curiosity as a beast, a dragon with a fire roaring in its belly.

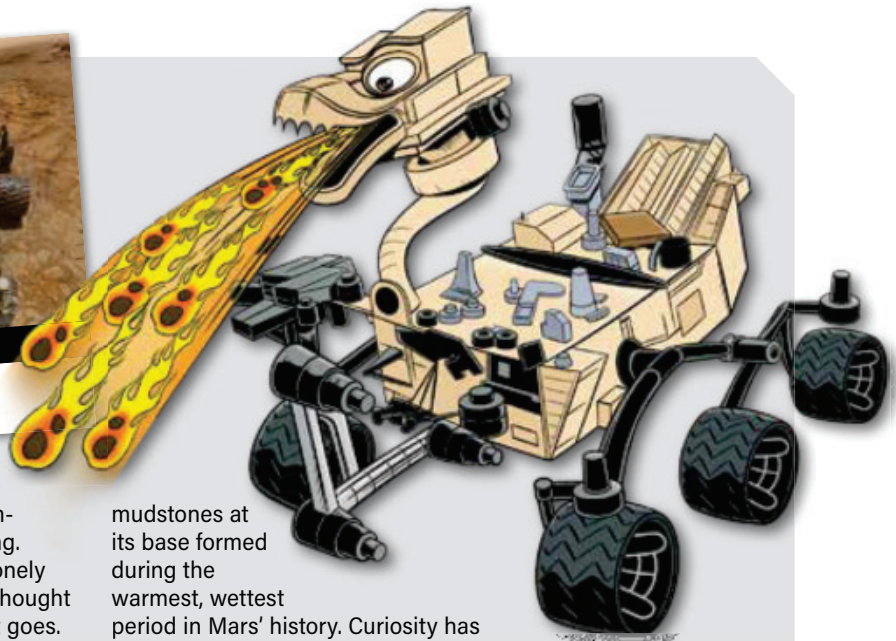
On the one-year anniversary of its landing,

The rovers' missions each had a unique personality shaped by engineering quirks, scientific fortunes (and misfortunes), and the people on their teams.



Curiosity The Rock Eater

- Big and tall; self-reliant
- First without solar panels
- Eats and spits Mars rocks
- Rappelled out of a jetpack
- Sang "Happy Birthday" to itself



Curiosity sang "Happy Birthday" to itself — the team commanded the SAM instrument to play the tones of the song. The collective response on the internet was pity: Poor, lonely Curiosity had to celebrate its birthday all by itself! But I thought it was badass: Curiosity makes its own party wherever it goes.

Curiosity "was at first like your uber-cool uncle who lived an adventurous lifestyle," says Jeff. "It felt like we really needed to consult the owner's manual a lot more to understand all the features this rover provided. As a result, we started slowly and worked up to its full capabilities." Curiosity was also "retrospective and vain enough to want to take selfies, perhaps more often than necessary," he says.

Curiosity's landing site in Gale Crater was next to Mount Sharp, a towering mountain of sedimentary rocks. The

mudstones at its base formed during the warmest, wettest period in Mars' history. Curiosity has been up its flanks, fast-forwarding through martian time, studying the planet's changing climate as recorded in the bedrock.

All the driving over the past 10 years has wreaked havoc on Curiosity's wheels, which have been shredded by pointy rocks. But as of this writing, that's not slowing things down. "By now, it's a can-do machine with bad feet that probably won't stop until it's at the top of a mound with a spectacular view back toward its beginnings," Jeff says.

PERSEVERANCE • 2021-PRESENT

PERCY LOOKS LIKE A CLONE OF CURIOSITY, but it has very different objectives.

Instead of just studying rocks on Mars and sending data back to Earth, Percy is laying the groundwork for sending rocks themselves back to Earth.

With its mind-bogglingly complicated sampling system, Percy is drilling rock cores, putting them in sophisticated tubes, and capping those with hermetic

seals. The plan is for Percy to deliver its best samples to the next mission — a collaboration between NASA and the European Space Agency (ESA), scheduled to arrive in 2028. The samples will get launched into orbit around Mars and rendezvous with a spacecraft there, which will deliver the rocks to Earth in the 2030s. As a backup, Percy will drop a smaller cache of samples in a safe spot on the floor of Jezero Crater.

On Percy's operations team, there is much less emphasis on exploration and discovery than in previous missions; the team is laser-focused on the big-picture objectives. As part of the decadelong, international process of Mars Sample Return (MSR), the mission's character is necessarily bureaucratic. Jeff thinks of Percy "like a high-powered lawyer who works in high-rise offices with a lot riding on every decision. The rover is smart, quick, and delivers."

Percy is a go-getter with a haircut you can set your watch to. It finds ways to solve seemingly impossible problems without ever losing its cool. A global pandemic is raging during the launch window? No

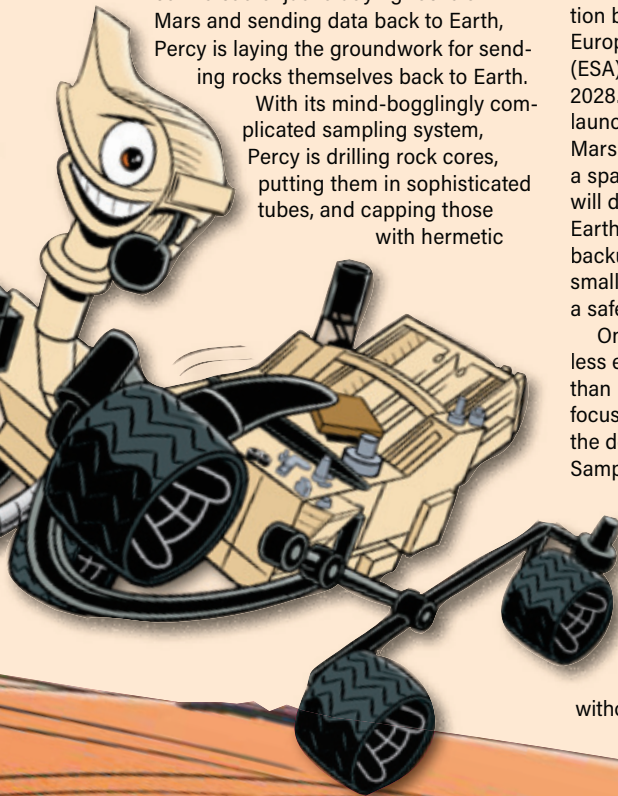
Perseverance The Steely-Eyed Missile Rover

- Launched during COVID
- Smart, quick, and delivers
- Team player; can-do attitude
- Inherited Curiosity's appearance
- Collecting samples for return to Earth



problem — Percy launched right on schedule. The pandemic means that scientists can't travel to JPL? No worries — we operated the rover via videoconference from our living rooms across the world. Percy accidentally pulverized its first rock sample while drilling it? Its next rock sample worked great.

During NASA's Apollo era, there was no greater praise for a flight controller than to be called a "steely-eyed missile man." According to astronaut Jim Lovell in his memoir *Lost Moon*, "There weren't many steely-eyed missile men in the NASA family. [Wernher] Von Braun was certainly one, [Chris] Kraft was certainly one, [Gene] Kranz was probably one too." In my mind, Percy is the first steely-eyed missile rover in the NASA family.

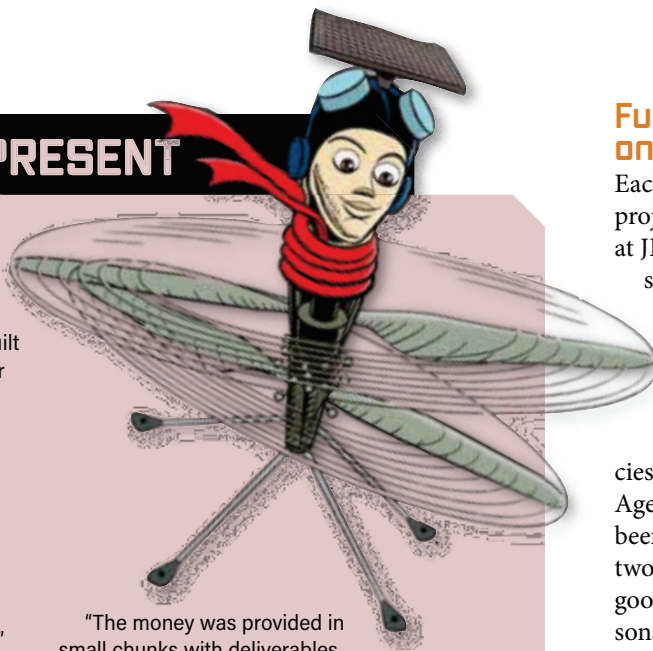


INGENUITY • 2021-PRESENT

THE INGENUITY HELICOPTER, which hitchhiked to Mars with Percy, was the first spacecraft to attempt powered flight in the atmosphere of another planet. Sojourner and Ingenuity have similarities: Both were built as tech demos by small teams working under incredible time pressure. But there are some differences, too.

Sojourner's mission had a number of science objectives and a science team; Ingenuity's mission has neither. Flying five times was the extent of Ingenuity's goals. Ingenuity reminds me of Amelia Earhart, another no-nonsense aviation pioneer, who said, "I lay no claim to advancing scientific data other than advancing flying knowledge."

Ingenuity almost didn't happen. Matt Golombek, a Mars scientist who had worked on the Spirit and Opportunity missions, originally submitted a proposal to NASA in 2014 for Percy to carry a "Mars Helicopter Scout" to help the rover plan its traverses, but it wasn't selected. However, NASA was intrigued by the idea and sent Matt's team some seed money to start working on the concept.



"The money was provided in small chunks with deliverables at the end of each," Matt says. "So during development, we never knew if we were really going to fly. We started using the phrase WENDY, for 'We're Not Dead Yet!'"

Ingenuity completed its first five flights with flying colors, so to speak, and it is still WENDY.

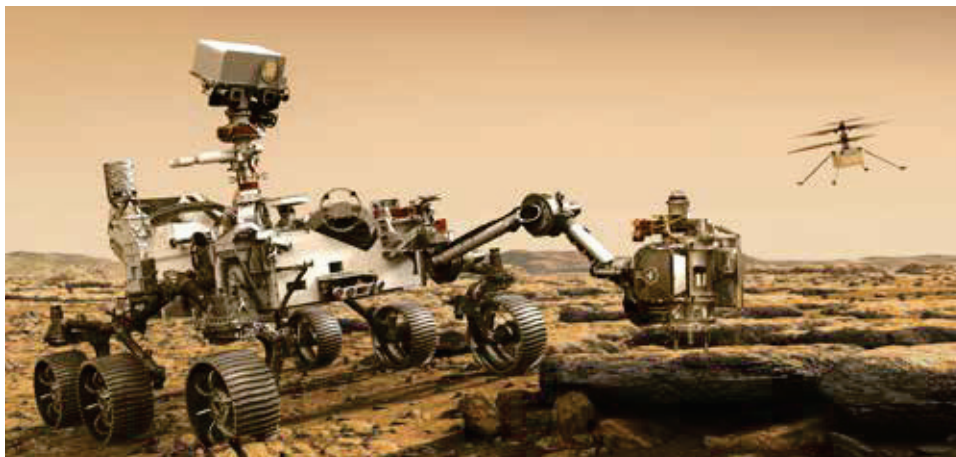
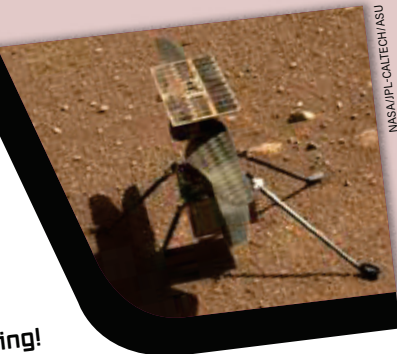
It flies ahead of Percy, taking images that have helped the mission team plan the rover's traverse and identify outcrops to sample.

But it's the flying that's the point. Ingenuity is not a scientist's sidekick. It's more like a daredevil stunt pilot from the 1920s, showing off the capabilities of their sturdy aircraft and wowing crowds the world over.

NASA/JPL-CALTECH/ASU

Ingenuity The Red Planet Barnstormer

- Pioneer aviator
- First in flight
- 40 flights and counting!
- Hitchhiked to Mars with Percy
- Called "WENDY" [WE're Not Dead Yet]



Ingenuity (right) has been serving as an aerial scout for Perseverance (left), but its primary purpose was to demonstrate that a helicopter drone could be built to fly on Mars. FUKUME/DREAMSTIME/NASA

Future personalities on Mars

Each of these missions are NASA projects operated by teams based at JPL; they all "grew up" in the same household. If these robot siblings turned out to have such distinct personalities, just imagine how different the missions from completely different space agencies must be! The Chinese Space Agency's first rover, Zhurong, has been exploring Mars for nearly two years. I do not yet have a good sense for Zhurong's personality, although I'm excited to learn more about its adventures as the mission continues.

Looking ahead, ESA will send its Rosalind Franklin rover to Mars in 2028 for the most ambitious life-seeking mission yet. The mission has suffered a decade of delays for various reasons, so already, its defining traits are patience, persistence, and grit. But what personality will it develop once the rover starts digging into Oxia Planum?

And then there's the big Mars Sample Return mission — a collaboration between NASA and ESA that will include a lander and two Ingenuity-like helicopters. The plan is for Percy to deliver its samples to the lander itself, but the helicopters can assist with grabbing samples if needed. What will the personality of a massive, multiagency mission like MSR look like? All I can predict is that just like every mission that has come before, it will be utterly unique. ♪

Melissa Rice is an associate professor of planetary science at Western Washington University and a science team member of NASA's ongoing Curiosity and Perseverance rover missions.