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on the cover

As we celebrate the incredible legacy of NASA's Spitzer Space Telescope in this issue of *Mercury*, the cover image features one of Spitzer's most iconic infrared observations: shock waves generated by the massive star Zeta Ophiuchi as it speeds through the interstellar medium. *[NASA/SDO]*

Red Planet Rush

A quartet of space probes is heading to Mars soon looking to answer lots of new questions—and an old one.

By Steve Murray

The terrain of Jezero Crater, as imaged here by the HiRISE camera on NASA's Mars Reconnaisance Orbiter, promises to be a science gold mine for the Mars 2020 mission. *[NASA/JPL-Caltech/Univ. of Arizona]*

This year kicks off a busy decade for Mars. Four missions will transport two landers, three rovers, and two orbiters to the Red Planet, taking advantage of the biennial alignment that makes for a shorter trip. More capable instruments will tackle new science questions and dig deeper into an old one: *was there ever life on Mars?*

Treasure Hunt

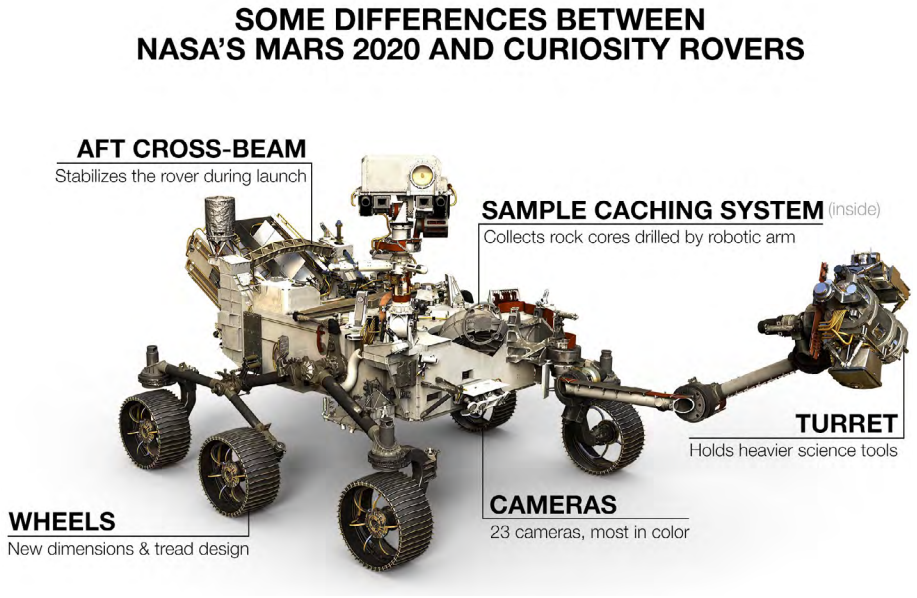
NASA will launch Mars 2020 on July 17 with some major new tools.

"Mars 2020 isn't your mother's Curiosity," said Michael Meyer, Lead Scientist for the NASA Mars Exploration Program. "Its instruments look similar, but they're vastly improved, and there's a very different approach to its experiments."

The new rover contains three "firsts." A small, solar-powered demonstration helicopter will pioneer heavier-than-air flight on another planet, and two microphones will capture the sounds of its own landing, the Martian winds and the audible effects of its laser (which can help determine a material's composition). Finally, the Mars Oxygen In situ resource utilization Experiment (MOXIE) will attempt to produce oxygen from atmospheric carbon dioxide, a capability that future astronauts will need on Mars.

Mars 2020 will also beef up the search for ancient life. Curiosity was designed to answer the question of whether Mars was ever habitable, but "Mars 2020 is taking that one step further," said Meyer, "and looking for signs of life. The difference is between determining whether or not Mars could have had life and determining whether or not Mars ever did have life." The new rover is scheduled for a February 2021 touchdown in Jezero Crater. Scientists believe the site was once an ancient lake in which its waters might have harbored life billions of years ago.

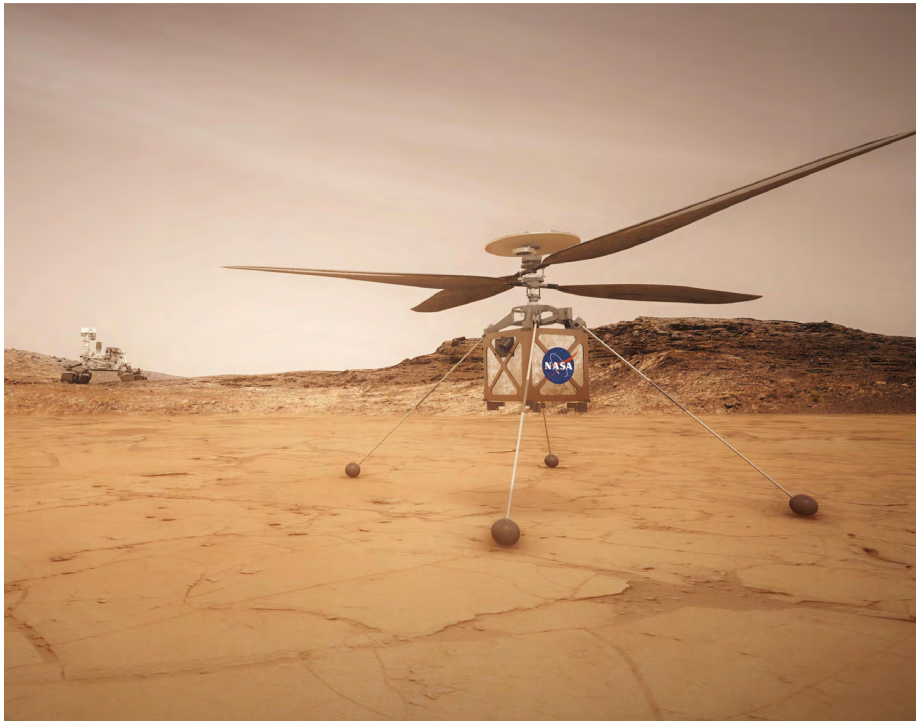
The Curiosity rover found promising signs of organic molecules



NASA's Mars 2020 rover looks virtually the same as Curiosity, but there are a number of differences in the suite of scientific instruments it will use on the Red Planet. *[NASA/JPL-Caltech]*

by processing soil samples in its onboard chemical lab. Compelling evidence for life, however, will almost certainly require direct study of samples in Earth-based labs. Therefore, Mars 2020 will take a more powerful approach to the task by collecting and storing surface samples in special tubes for a future Earth return mission. "One of the reasons Jezero Crater was picked," said Meyer, "was because of its evident diversity in minerals. For the first sample return from another planet, having a diversity of materials is key."

NASA and European Space Agency (ESA) missions are pursuing very different strategies in their search for ancient life signs (or biosignatures). Mars 2020 is sticking with surface exploration, like that of Curiosity, while the ESA rover will drill beneath the surface to recover samples that have largely avoided the damaging effects of galactic cosmic rays, solar radiation, and weathering. "When the sci-



An artist's impression of the Mars 2020 helicopter, a small autonomous rotorcraft that will be tested for surface operations. *[NASA/JPL-Caltech]*

entific community designed the kind of rover they wanted, it actually had a combination of instruments and the ability to drill down a couple of meters," said Meyer. But instruments plus a drill make for a complex and expensive mission.

"We decided that you have two options," he added. "You could either go deep or you could go far. We said, this is the first sample return mission, so let's go for horizontal mobility because we could get a greater diversity of samples.

"The Europeans wisely said, OK we'll take the other approach; we'll take the vertical approach. So they'll be doing something that we're NOT doing and I think that's a good complement for us and for them."

Going Deep

A collaboration between ESA and the Russian space agency Roscosmos will put an ambitious instrument suite on Mars that can hunt for signs of life beneath the planet's surface.

The ExoMars (for "exobiology") launch includes the Russian Kazachok ("Cossack") lander and the ESA Rosalind Franklin rover, named after the chemist who helped discover the structure of DNA. "One of the most important requirements for ExoMars was to go old," said Jorge Vago, ESA ExoMars Program Scientist, "so we actually tried to find a place that was four billion years in age." The mission will touch down in March 19, 2021 on Oxia Planum, a plain that once held water in its distant past.

ExoMars is actually a two-part program that began in 2016 with the launch of the Trace Gas Orbiter (TGO) and Schiaparelli lander. The TGO was successfully inserted into orbit, where it continues to study Mars' atmosphere and serve as a communications relay, but Schiaparelli crashed during its landing attempt. The 2020 mission would therefore be the first Mars lander by the European-led program. Engineering difficulties, however, have also beset the new effort. The mission's braking parachutes—the largest ever used at Mars—experienced two test failures in mid-2019 that put the launch schedule in jeopardy. Although new design modifications seem to be working, some critical parachute tests still lie ahead.

The Kazachok lander will measure radiation, subsurface structure, and water distribution in its local environment as the Rosalind Franklin searches over a wider domain using ground penetrating radar, three types of spectrometers, and other instruments. To search for evidence of ancient life, however, the rover will operate a first-ever drill that can bore 6.5 feet (2 meters) down into the Martian surface.

Why dig? "Ionizing radiation from the sun is a very destructive

agent for biomolecules," said Vago. "It penetrates through the atmosphere and into the subsurface, but its effects go down with depth, so we go deep with the drill. The subsurface of Mars is also a wonderful freezer; it's a great way to preserve organic molecules."

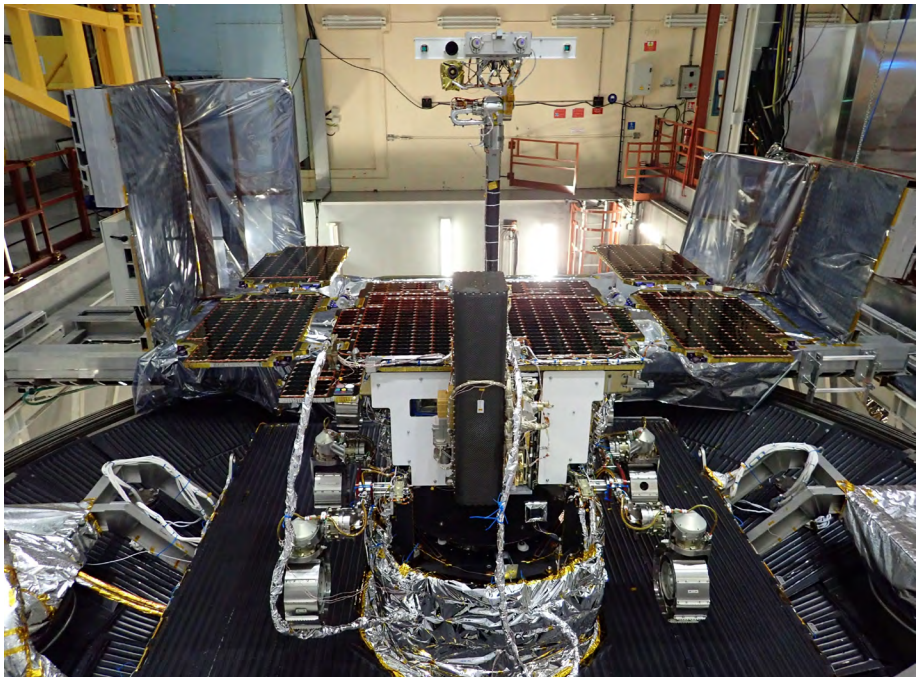
The Rosalind Franklin will also have a new tool set to tackle an old chemistry problem. Life searches from Viking to Curiosity have tried to detect organics by heating surface samples and examining the resulting gases. Most of these heating tests were thwarted, however, because of something in Martian dirt that we now better appreciate: perchlorates. "No one knew they were going to encounter perchlorates when Curiosity was designed," said Vago. "But they dissociate at around 200 degrees Centigrade and destroy any organics."

The ExoMars team thinks it has two solutions to this dilemma. First, the rover will use a laser desorption mass spectrometer (a device that hasn't been tried on planetary missions before) to shoot crushed soil samples with high-power ultraviolet energy. This process avoids heating and should therefore avoid the effects of perchlorates. Second, the rover will analyze small crushed samples in one of 30 single-use ovens but will heat them gradually. "You heat the samples stepwise," said Vago, "and see what comes out at each stage." Measurements will be taken at a series of temperatures both below and above the perchlorate dissociation point.

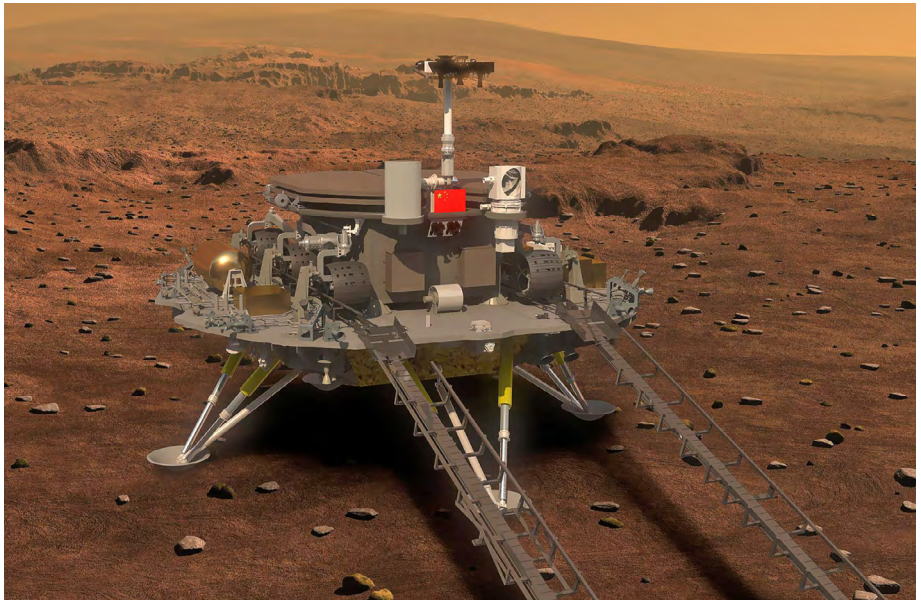
Even with these new methods, however, evidence of life might still be ambiguous. "We're not dealing with pristine biomolecules," said Vago. "We're dealing with their residues. I'd say that the probability of finding something to suggest there may have been life at the landing site is, maybe 50 percent.

"Being able to prove there was life? That's a much tougher call."

An artist's impression of the ExoMars rover Rosalind Franklin on Mars. *[ESA]*



The ExoMars rover undergoing environmental tests before launch. *[ESA]*



An artist's concept of China's Mars lander and rover on the surface of the Red Planet. *[Xinhua/Alamy]*

A Daring Trifecta

China will also be heading to Mars in 2020, and in a very a big way. The Mars Global Remote Sensing Orbiter and Small Rover (Huoxing-1 or "Mars-1") program follows the impressive 2013 and 2019 Chang'e lunar missions and will include an orbiter, a lander, and a rover on a single launch.

Huoxing-1 is actually China's second shot at Mars. An orbiter launch in 2009 failed when the Russian rocket that carried it crashed. China has designed its new mission as an independent project, using a Chang Zheng 5 (Long March 5) rocket to carry its complex payload.

After its arrival at Mars in February 2021, Huoxing-1 will spend two months surveying landing sites from orbit before sending the lander and rover to the surface. News sources indicate that they're currently considering two sites in the Utopia Planitia region and many believe that they'll try to land on or near April 24—China's Space Day.

Like other 2020 rovers, Huoxing-1 will examine soil chemistry, employ a ground penetrating radar to probe for water and ice, and will look for biomolecules during a nominal 90-day mission lifetime. Joint studies by the orbiter and rover will also help to refine maps of Mars' surface topography.

It's possible (but not confirmed) that the rover may even attempt to cache samples as part of its science profile. Such a capability would hint at a possible future sample return mission. Huoxing-1, therefore, could be the opening move in a burgeoning Chinese Mars program.

Hope From a Young Nation

The United Arab Emirates is looking to 2020 as the year that it joins the community of Mars exploring nations. The Emirates Mars Mission (EMM, or "Hope") orbiter would be the first space mission beyond Earth orbit for the UAE, and would represent an interplanetary first for the Arab world. Its scheduled arrival at Mars in early 2021 would also coincide with the 50th anniversary of the nation's founding. It's a bold effort, as the United Arab Emirates Space Agency was only established in 2014.

Hope will launch aboard a Japanese rocket and will study how hydrogen and oxygen escape from Mars' atmosphere and how the loss of these water components has affected the Martian climate. The Laboratory for Atmospheric and Space Physics (LASP) at the University of Colorado Boulder, is constructing the Emirates eXploration Imager (EXI), an ultraviolet spectrometer, while Arizona State University is building the Emirates Mars Infrared Spectrometer (EMIRS). The partnership with US universities assists the UAE on several levels.

"A key objective of EMM is to be fundamentally disruptive to our

education and science sectors," said Omran Sharaf, EMM Mission Lead. "As teaching institutions, [universities] could facilitate a learning relationship whereby our engineering and science experts could upskill throughout the joint development process."

The universities supporting the Hope mission had deep experience in Mars atmospheric science. "The MAVEN mission to Mars was built at Colorado, and was focused on the upper atmosphere," said Philip Christensen, Regents Professor in the Department of Geological Science at Arizona State University, "while we at ASU had built an instrument for the Mars Global Surveyor that measured properties of the lower atmosphere.

"Oxygen and hydrogen get ionized in the upper atmosphere by the solar wind, and then get stripped off into space," he explained. "Those high energy ionized particles show up best at ultraviolet wavelengths. Deeper in the atmosphere, you'll find warmer gases with larger particles like water droplets, CO2 molecules, and dust that emit energy at much longer infrared wavelengths. So, with both instruments on the same orbiter, you could simultaneously study the atmosphere from the surface all the way up to the top."

Artistic rendition of what the Hope satellite will look like. It's essentially designed to be a state-of-the-art weather satellite. *[UAE Space Agency]*

Hope will become the first probe to develop an integrated picture of Martian atmospheric chemistry over the entire globe, and to characterize its long-term seasonal changes. "We see EMM as an inflection point in the development of the Emirates' efforts in the space sector and planetary sciences," added Sharaf. "It will help in developing all of our innovation and science capabilities."

An Eventful Decade Ahead

If all this hard work is successful, 2021 will see three new rovers on the surface of Mars and two new orbiters in its skies. And the decade to follow should also see even more sophisticated visits to and near the Red Planet. A joint NASA/ESA Mars Sample Return mission is already being planned for a 2026 launch. The project includes a stationary lander, an ESA Sample Fetch Rover and a Mars Ascent Vehicle that would return the [Mars 2020] samples back to Earth in 2031. The Japan Aerospace Exploration Agency (JAXA) is preparing a Martian Moons eXploration (MMX) mission to orbit Phobos and Deimos. The probe is scheduled to enter orbit in 2025 and even return a sample of Phobos in 2029.

Since the Mariner 4 Mars fly-by in 1965, increasingly capable machines have explored on and above Mars, and that trend will continue through the 2020s with better measuring, imaging, and collecting. So when humans eventually walk the sands of the Red Planet, our best and most experienced "astronauts" will already be there. ✪

Editor's note: Just before this issue went to print, NASA announced the name of the Mars 2020 rover. After a national school competition, Virginia seventh-grader Alexander Mather won with his suggestion: "Perseverance." Read more.

STEVE MURRAY is a freelance science writer & NASA Solar System Ambassador. A former research engineer, he follows developments in astronomy, space science, & aviation.