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Fresh thinking about Mars

Pushed by scientists, NASA weighs a bigger role for small spacecraft PAGE 22

MARCH 2022 | A publication of the American Institute of Aeronautics and Astronautics | aerospaceamerica.aiaa.org

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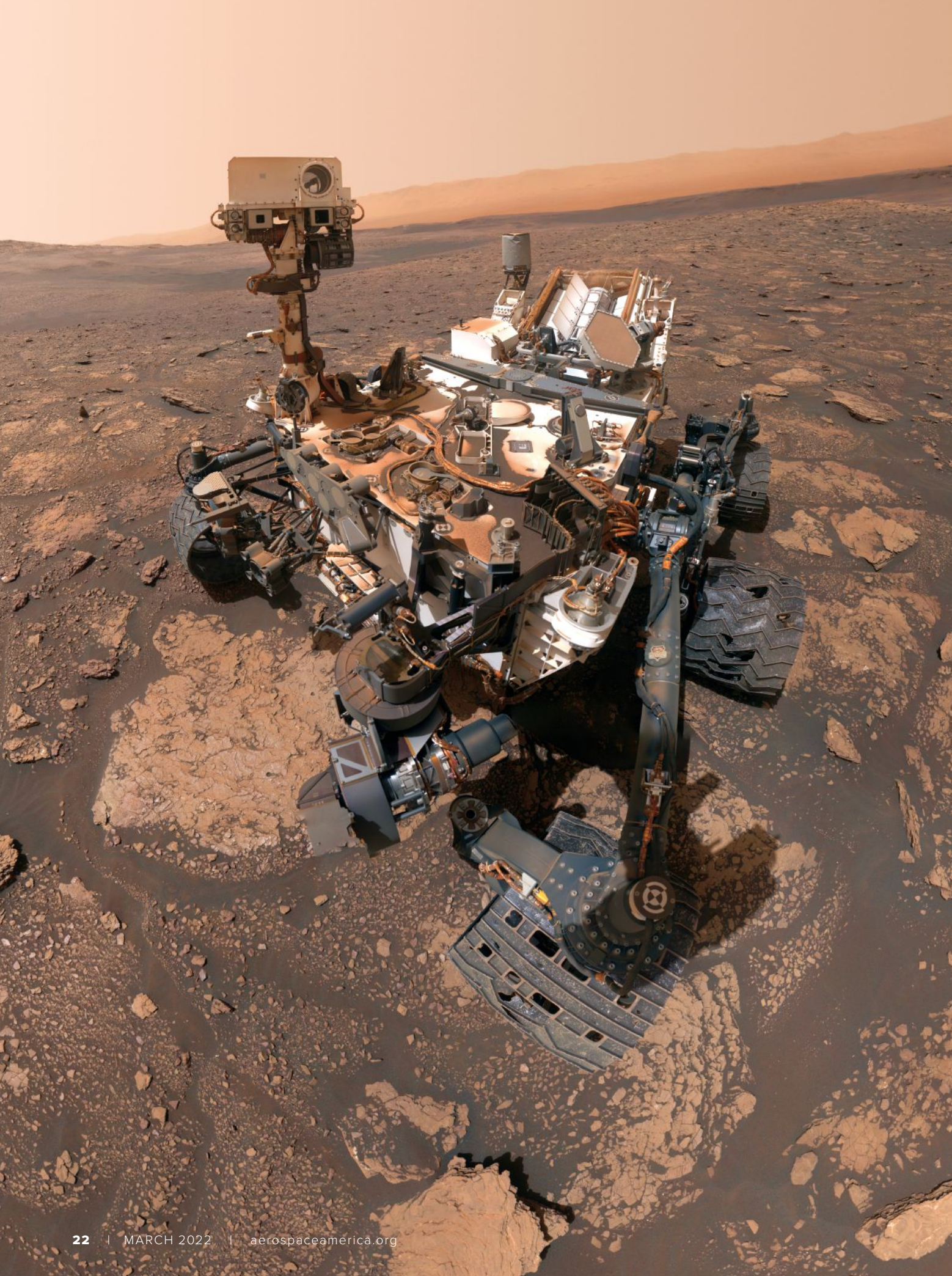
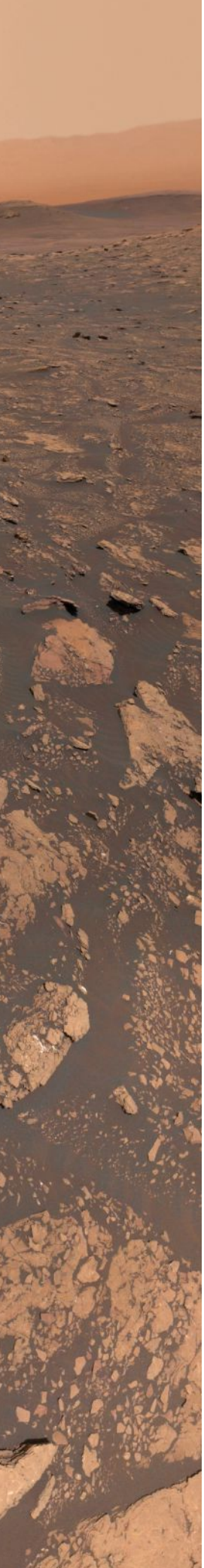




NASA RETHINKS ITS MARS STRATEGY

A chorus of scientists wants NASA to add small robotic spacecraft to its Mars Exploration Program in a shift from today's near-total focus on multibillion-dollar rover missions and preparations with Europe to return samples of Martian soil and rocks to Earth. Will these scientists get their way? Leonard David looks at the odds.

BY LEONARD DAVID | newsspace@aol.com

Despite NASA's best efforts over the decades, Mars remains largely enigmatic. No proof has been discovered that life of some form once existed on the planet or that it still does, although there is tantalizing evidence for those possibilities. Meanwhile, NASA is outspoken in its desire to send astronauts to Mars, and Elon Musk has vowed to colonize the planet, even if scientists caution that they don't yet have sufficient knowledge about Mars to guide such endeavors.

It's in that context that NASA has begun collecting advice from scientists about how to renovate the agency's Mars program, an effort that includes welcoming a fresh look at the size and kind of spacecraft that should be sent how often and to which regions.

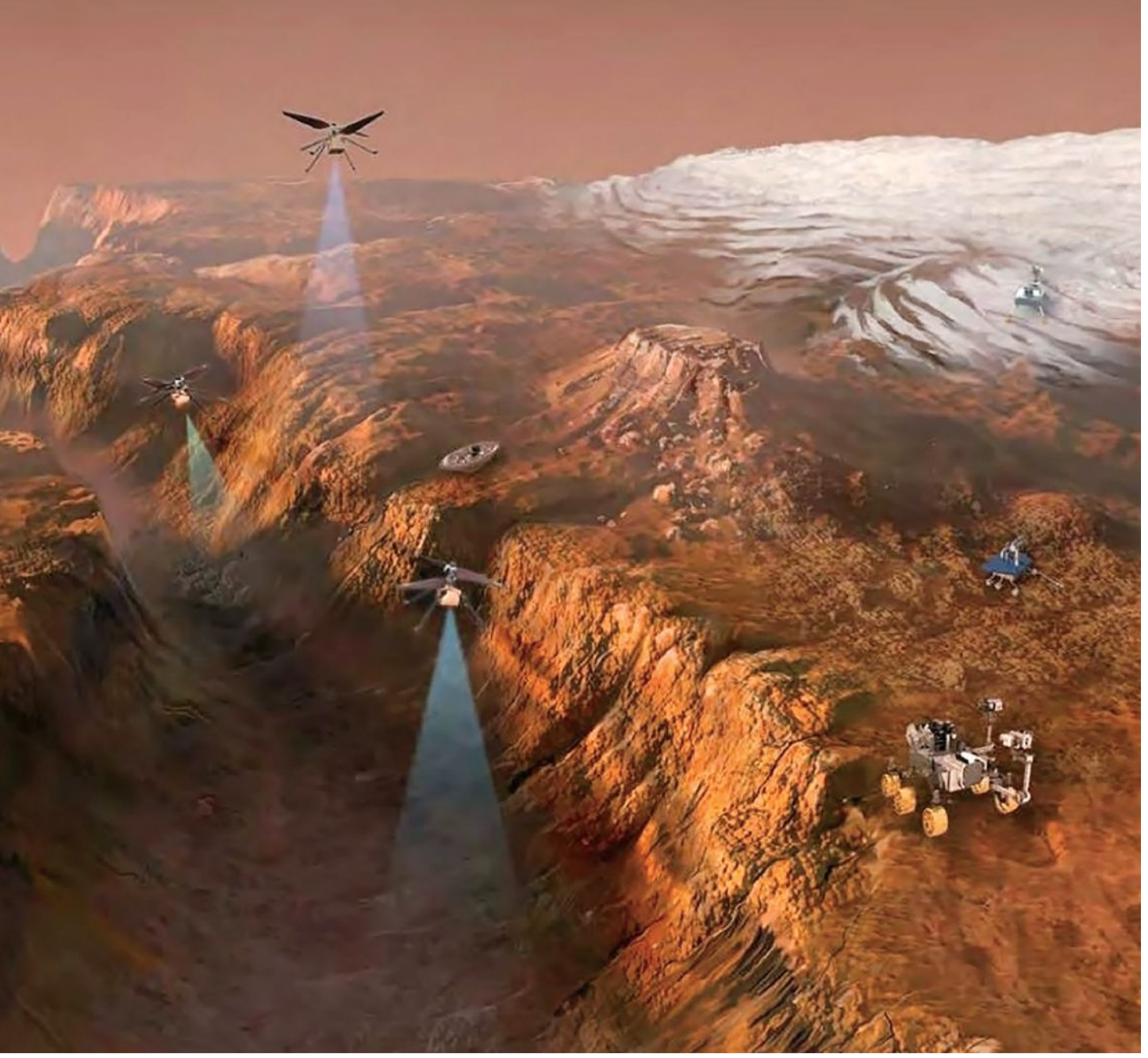
To date, NASA's Mars Exploration Program has focused on launching a succession of multimillion-dollar and multibillion-dollar landers and rovers about every six years on average, mostly to the equatorial region of Mars. The Mini Cooper-sized Curiosity rover landed in August 2012 and was followed in February 2021 by the nearly identical Perseverance rover, with its small Ingenuity helicopter making history not long after. Up next, a NASA-funded lander is supposed to touch down in 2028 carrying a European Space Agency-funded small fetch rover that will roll out and collect the samples of Martian soil and rocks that are currently in the process of being left behind in titanium tubes by Perseverance. An ascent rocket would blast those samples into space, where an orbiter would grab them and boost them toward Earth for a 2031 arrival.

Momentum has mounted for a new approach that would keep Mars Sample Return but add small, less expensive spacecraft. A turning point could come as soon as late March with the planned release of the U.S. Planetary Science and Astrobiology Decadal Survey by the U.S. National Academies of Sciences, Engineering and Medicine. This survey will be the latest in the once-a-decade reports that distill a variety of competing scientific views into a set of recommended priorities for NASA, in this case for planetary science starting in 2023.

Will NASA heed what looks like a tidal wave of calls for it to embrace the smallsat revolution currently seen mainly in low-Earth orbit? NASA isn't saying, given the pending decadal survey, but it is leaving no doubt that it plans to update its Mars strategy:

"Development of this strategy will be critical to determine the placement of new Mars initiatives among other Planetary Science Division priorities and for securing the requisite budget to support them," said Lori Glaze, director of NASA's Planetary Science Division, in a statement via a spokesperson.

The agency will consider the decadal survey recommendations, Glaze continued, "combined" with two other reports: One issued a few weeks ago by KISS, the influential Keck Institute for Space Studies in California, in which NASA and industry authors called for launching small satellites at a regular cadence under an approach dubbed "Frequent, Affordable, Bold." A little over one year earlier, a NASA-chartered



▲ This illustration from the cover of the Keck Institute for Space Studies' February Mars report captures the think tank's recommendation for NASA to send a variety of small robotic spacecraft to regions inaccessible to today's landers and rovers.

Keck Institute for Space Studies (KISS)/Chuck Carter

working group laid the foundation for the ongoing discussions by issuing a similar call for small spacecraft.

Millions, not billions

The working group's 2020 report, "Mars, the Nearest Habitable World — A Comprehensive Program for Future Mars Exploration," recommended that NASA carry out missions whose design, development, launch and operational costs fall within the range of $100 million to $300 million. By contrast, NASA spent $2.4 billion to build and launch Perseverance and expects $300 million in operating costs on top of that for a total of $2.7 billion. For Mars Sample Return, an independent review board in 2020 placed NASA's contribution between $3.8 billion and $4.4 billion. There's no comparable estimate of the European Space Agency's contribution, but during a pre-launch press conference for Perseverance in 2020, ESA's director of human and robotic exploration David Parker put the agency's portion at 1.5 billion euros ($1.75 billion).

Nevertheless, the working group was careful not to criticize the Mars Sample Return as it cautioned against overstating its likely scientific significance:

"As important as Mars Sample Return (MSR) is — and it will result in a major step forward for planetary science — examination of material from a single site will not tell us everything that we need to know about Mars," the working group wrote.

Bruce Jakosky, the University of Colorado, Boulder scientist who chaired the working group, summarizes the thinking like this: "We've seen an incredible expansion in capabilities of small spacecraft in the last few years. Concepts that were inconceivable just a few years ago can be done relatively easily today," he says.

▲ The first color photo from Perseverance, taken by one of the rover's Hazard Avoidance Cameras shortly after its February 2021 landing, shows the kind of benign terrain NASA chose for Perseverance and the nearly identical Curiosity rover. The agency could choose more daring landing spots for smaller, less expensive spacecraft.

NASA/JPL-Caltech

"We want to use small missions to address fundamental science objectives and not just send a spacecraft that can make a few interesting measurements," he adds.

Such spacecraft can also help set the stage for human explorers, in his view: "In that sense, small missions fit into the broader objective the same way as do larger missions — by measuring environmental characteristics that enable human missions and by identifying the science context and objectives that can be addressed by human missions."

This month, a different working group plans to hold a primarily in-person scientific workshop in Pasadena to discuss "Low-Cost Science Mission Concepts for Mars Exploration." Organizers want to bring forward ideas from the community about how a new class of lower-cost missions might advance the full range of Mars science study.

Meanwhile, the February report from KISS, located near the NASA-funded Jet Propulsion Lab in Pasadena, also went to lengths not to target Mars Sample Return. The discussion of its "Frequent, Affordable, Bold" proposal begins like this: "As we prepare to conduct the first sample return from Mars, now is the prime time to consider, 'what comes next?'"

The KISS report wants a succession of small spacecraft to be launched at a "predictable high cadence" under a coordinated "programmatic approach," according to the report, "Revolutionizing

> "We want to use small missions to address fundamental science objectives and not just send a spacecraft that can make a few interesting measurements."
>
> — Bruce Jakosky, Mars Architecture Strategy Working Group

Access to the Mars Surface." While the name is reminiscent of NASA's Faster, Better, Cheaper missions of the 1990s, those missions were planned individually, according to the authors.

While Jakosky is heartened by all the ongoing discussion, studies and workshops on pursuing a more pricetag friendly science strategy for Mars, he adds a note of caution similar to the one issued by Glaze, the NASA planetary science manager.

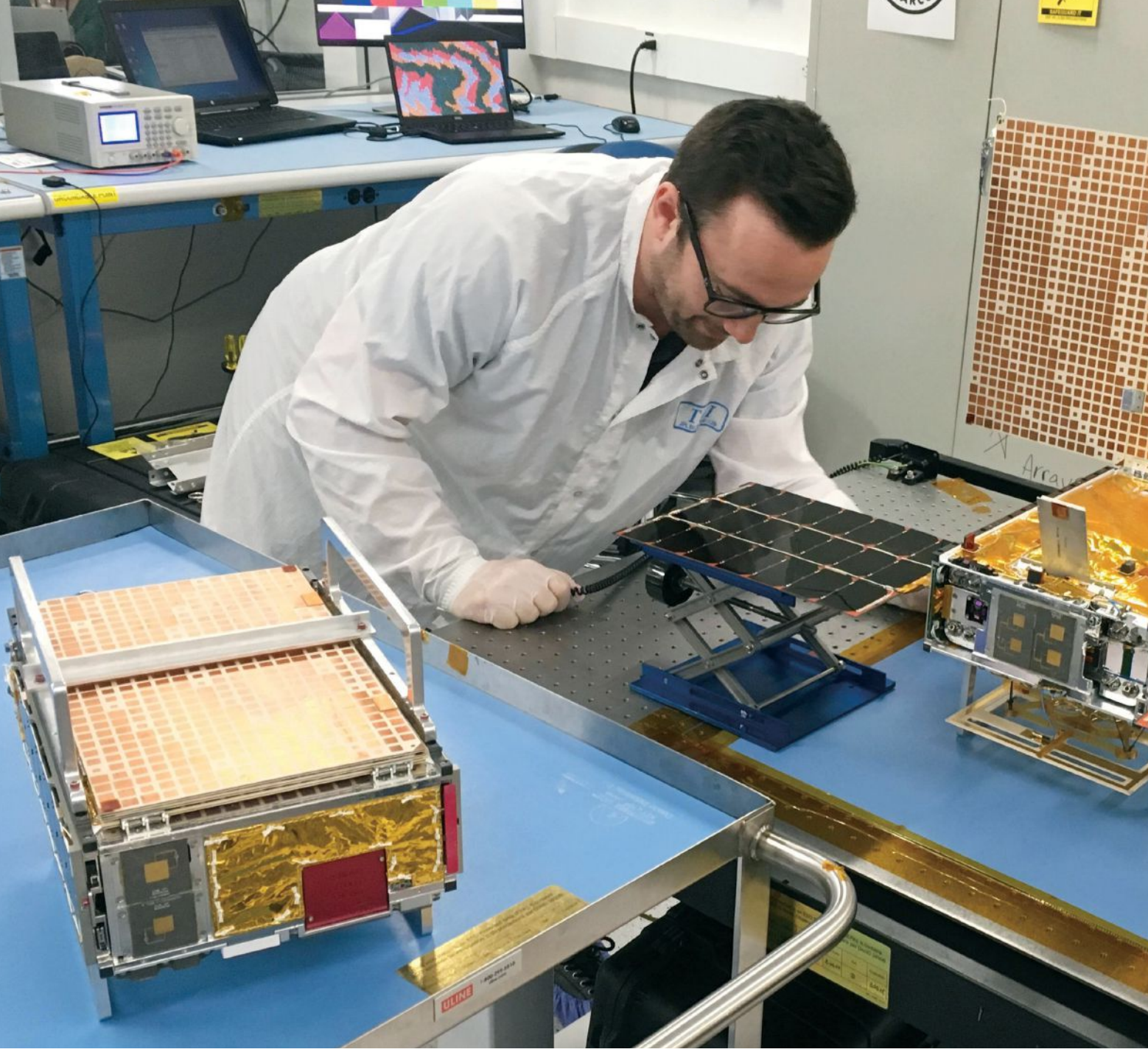
"To be blunt, whether any of this has any impact will depend on what the Planetary Science Decadal says about Mars exploration in the context of solar system exploration and whether the administration can be convinced to invest in reinvigorating a Mars program," Jakosky says.

The first step, Jakosky notes, will be for NASA managers and Mars investigators to determine whether significant science objectives can in fact be addressed by small spacecraft. "Although I believe that the answer is yes, it is imperative that we hear ideas and concepts from the community and identify the most substantive ones as a basis for moving forward."

Elusive answers

The red planet is a taunting globe, shadowed by questions of whether this real estate was, or is even now, a host for life of some kind, such as microbes.

Mars does not put out a welcome mat for life as we know it. For one, it is bathed in ultraviolet rays



that sanitize the uppermost layers of Martian soil. But it may have been a nicer-to-life globe in the distant past. Mars orbiter imagery suggests that, long ago, liquid water might have flowed in channels and collected in lakes and ponds. Plausibly, the planet once supported an ocean.

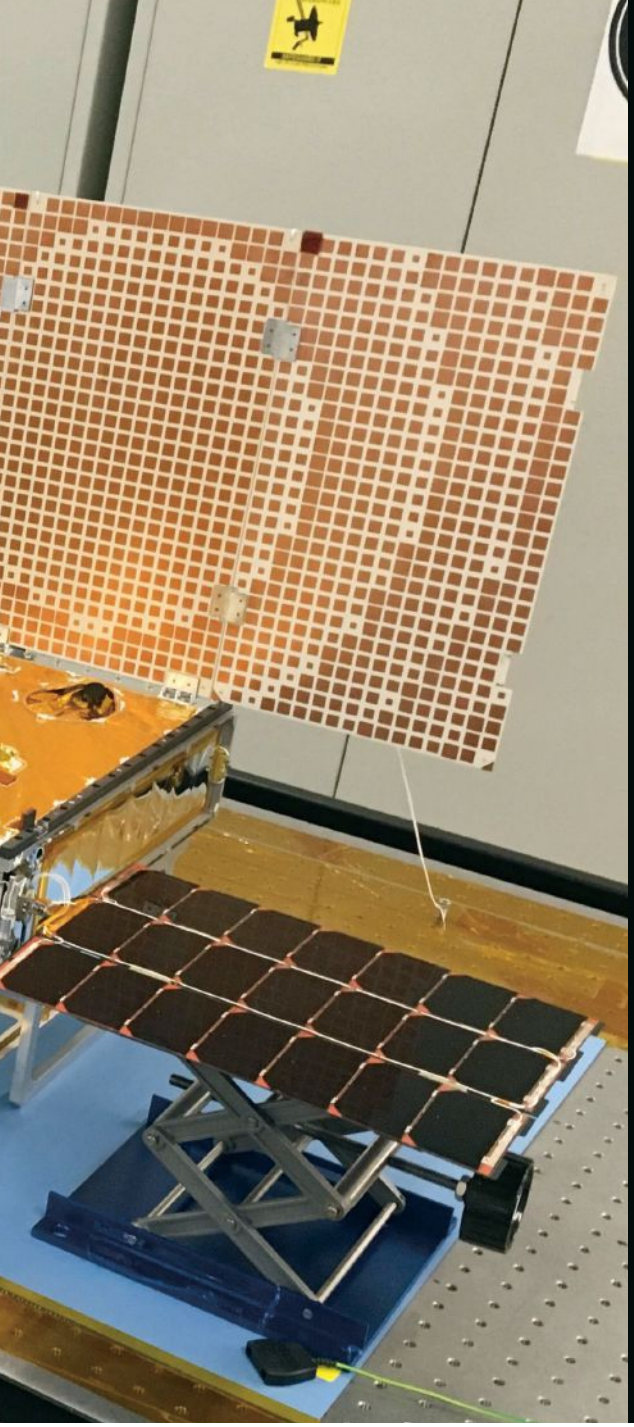
Early wet and warm Mars could have given rise to simple forms of life. There may be a fossil record of ancient microorganisms, if scientists look in the right places.

Scientists have all sorts of wild ideas about the possibility that microbial life has persisted to the present day. Perhaps underground alcoves sustained microbial habitats even as surface conditions became ever more inhospitable over the eons.

Bethany Ehlmann, a professor of planetary science at Caltech, says the search for Mars life is part of the reason NASA must get to the Martian surface with a variety of missions. In her view, Mars is like Earth in that multiple types of potential habitats existed at different times and places, including in lakes, rivers, hydrothermal ground water and soils. Such opportunities to define how life formed and possibly vanished are rare in the solar system.

"Mars, Earth, and Venus are the only places we can test our understanding of what makes a habitable Earth-like world, or not, over a long time," she says.

It is time to strategize new ways to gather more data from a variety of places on Mars, says Ehlmann.



NASA's Mars Cube One spacecraft are one example of how Mars could be explored via less expensive means. The pair of cubesats, pictured here in 2018 at NASA's Jet Propulsion Lab in California, relayed X-band signals from NASA's InSight lander, providing mission controllers real-time status updates about the InSight lander's November 2018 entry, descent and landing on Mars.

NASA/JPL-Caltech

New kinds of exploration

In the search for life, scientists have a variety of terrain and depths in mind beyond the equatorial regions and near surface explored by Curiosity and Perseverance.

Perhaps the deep subsurface harbors promising microbial habitat. "This is where smaller missions could come in, characterizing the subsurface and identifying promising drill sites," says Michael Meyer, lead scientist for NASA's Mars Exploration and Mars Sample Return programs at NASA headquarters in Washington, D.C. Large landers could then be sent to do the drilling.

Speaking of landers, Charles Edwards Jr., manager of JPL's Advanced Studies Office, envisions low-cost "rough" terrain landers touching down with electromagnetic sounders or trace gas "sniffers" to sense methane emissions that could be associated with biological processes.

In fact, such lander technology has been under development for several years at JPL. It's called SHIELD, short for Small High Impact Energy Landing Device. If the technology works, Mars could someday be dotted with dozens of SHIELD landers, each loaded with 5 kilograms of sensors.

Numerous landers would be affordable because none would need complex propulsive systems or parachutes to decelerate. Instead, each would deploy a drag brake to slow itself to roughly 50 meters per second, and then a crushable nose cone would absorb the impact energy.

One of Perseverance's navigation cameras took this photo of the rover's first sample collection attempt in August 2021, the first phase of the European Space Agency-NASA joint Mars Sample Return mission. Those samples aren't scheduled to return to Earth until 2031, so scientists hope NASA will fund development of smaller spacecraft in the meantime.

NASA/JPL-Caltech

"The flight system avionics are small satellite electronics but have been ruggedized to survive a 1,500 Earth-g impact," says JPL's Nathan Barba, systems engineer for SHIELD.

So far, SHIELD has undergone drop tests, instrumented to measure actual landing loads to demonstrate the feasibility of the concept.

Barba says SHIELD could tote weather sensors, cameras and mass spectrometers to the planet. "A low-cost lander like SHIELD could enable first-time measurements or pathfinder exploration like ground-truthing information that is critical for larger, more expensive missions," he says.

Perhaps the greatest fresh thinking about Mars stems from the flights of Perseverance's Ingenuity helicopter in Jezero Crater.

Shannah Withrow-Maser, the Mars Science Helicopter Vehicle Systems lead at NASA's Ames Research Center in Silicon Valley, is bullish about the prospect of a future hexacopter hauling payloads and flying greater distances than Ingenuity.

In fact, NASA is assessing the possibility of releasing a hexacopter part way through the entry, descent and landing phase of a future mission. Such an aircraft could scrutinize cliffs, polar caps and layered deposits, or zip over possible ancient springs.

Of special interest for scientists, and those who hope to send humans to Mars, are the planet's ancient lava tubes. Over the years, researchers reviewing orbiter photos have spotted pit craters that they believe are where the roof of a lava tube has partially collapsed and created a "skylight." In fact, the U.S. Geological Survey's Astrogeology Science Center has mapped the locations of at least 1,000 cave entrance candidates on Mars. Perhaps a rotorcraft could fly into a lava tube skylight and measure the feature's temperature and humidity.

"This could tell if the environment of the cave was more habitable than the surface," says Carol Stoker, a research scientist in the Space Science Division at NASA Ames. "This is not sampling for life, but it would be useful information and could be helpful reconnaissance for human missions that may want to use the lava tubes."

Overall, suggests JPL's Edwards, what's happening now are conversations over how best to incorporate low-cost mission ideas to create a mix of small and large missions, since that is what will be needed to address the complete spectrum of Mars science questions. Establishing an inventive exploration plan for Mars may well produce a ripple effect through NASA's planetary science enterprise.

"I believe that many of the technologies and approaches we might utilize in low-cost Mars exploration could have application to other solar system targets," Edwards says. ★