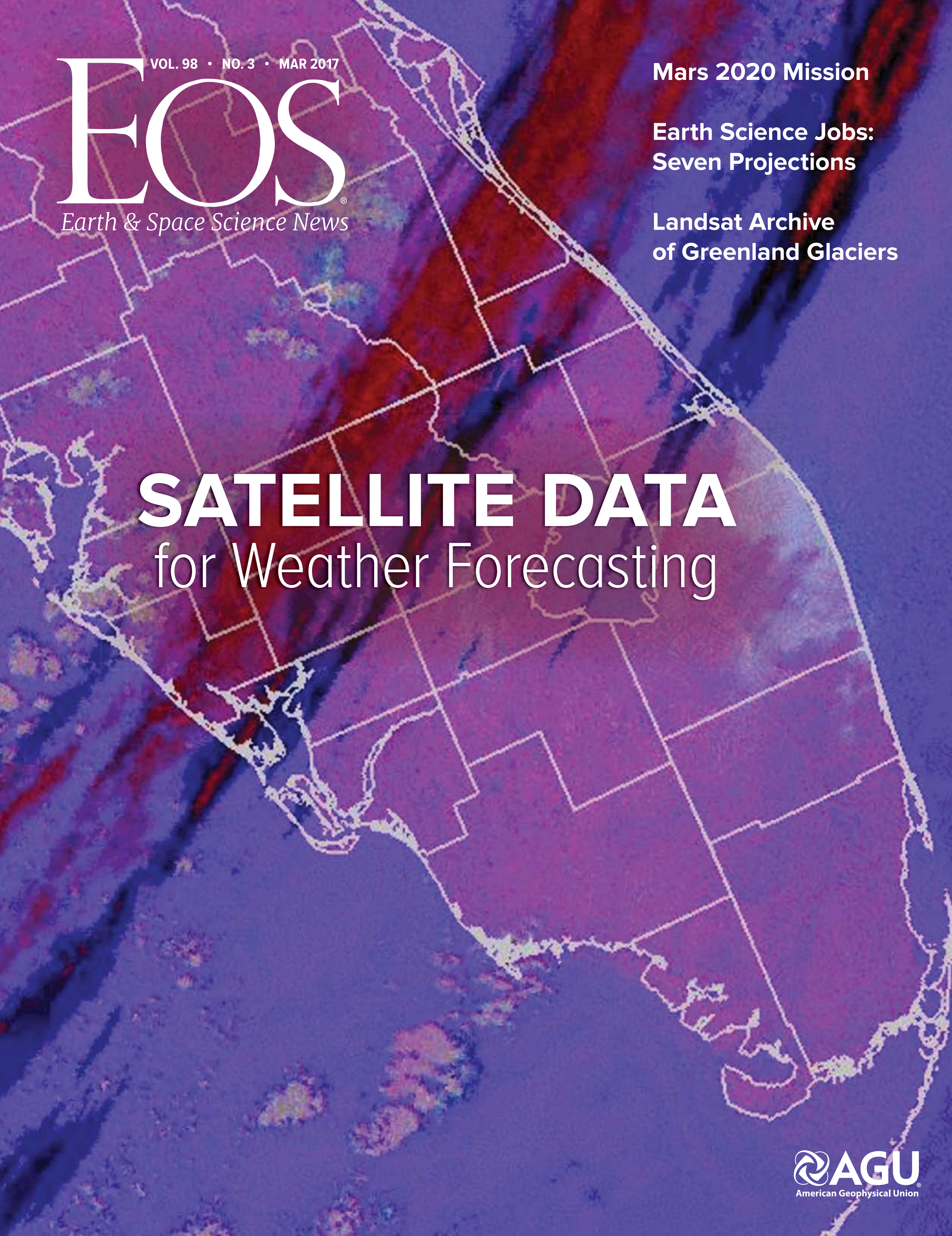

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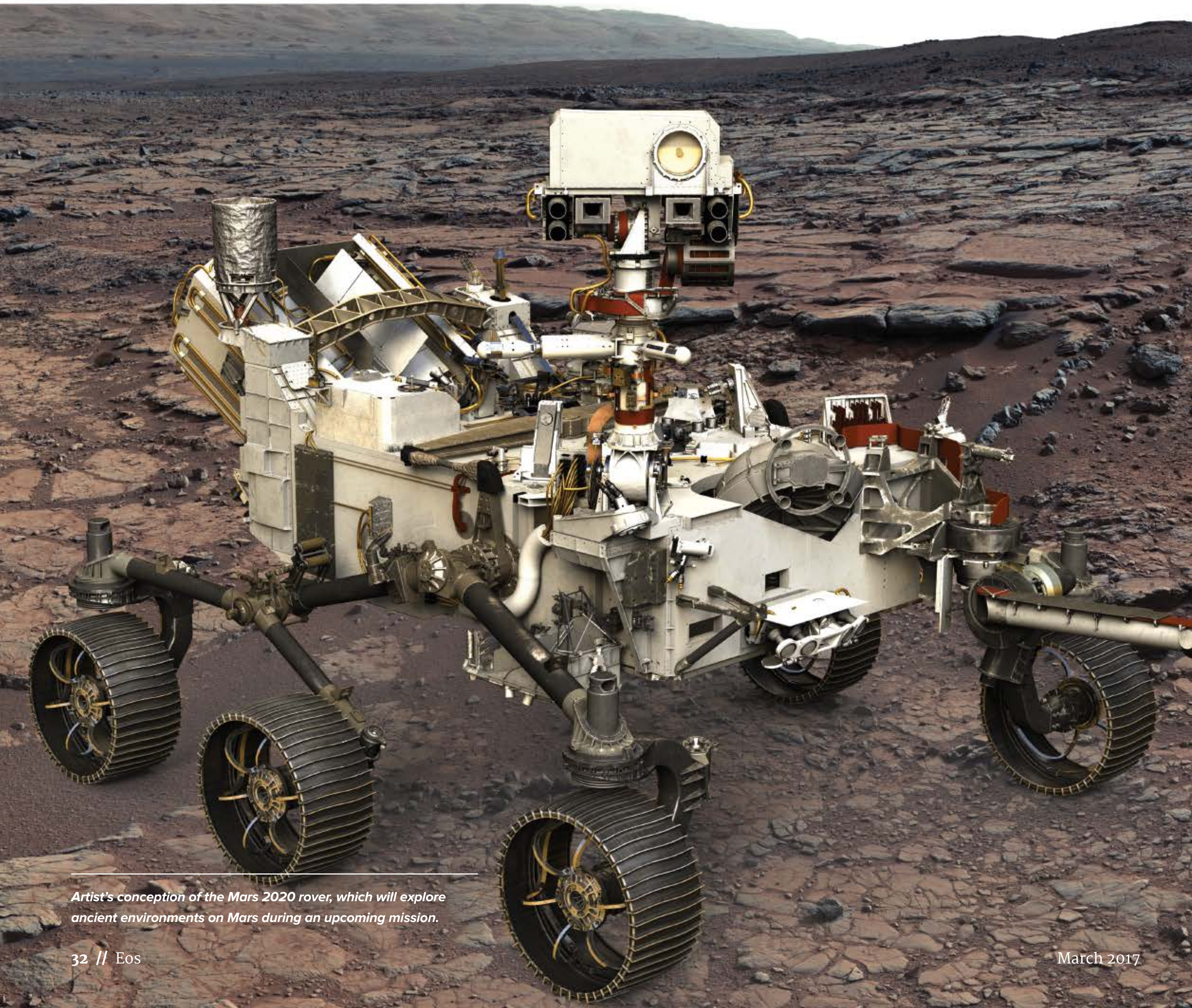
By K. A. Farley and K. H. Williford



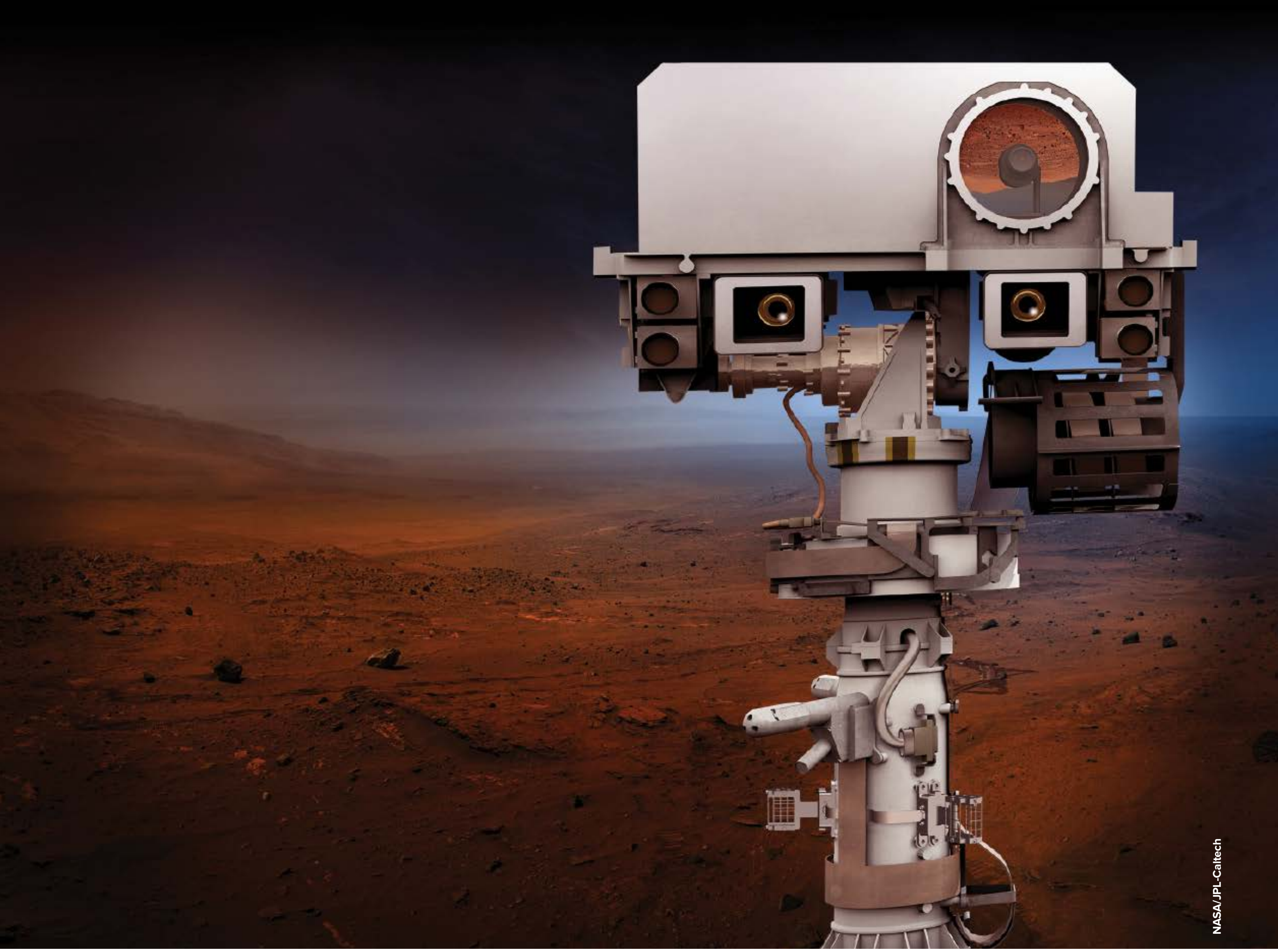
Artist's conception of the Mars 2020 rover, which will explore ancient environments on Mars during an upcoming mission.

# of Life and More: 2020 Mission

Rover: NASA/JPL-Caltech; background image: NASA/JPL-Caltech/MSSS

NASA recently confirmed that it plans to fly to Mars in 2020, sending the fifth in a series of increasingly ambitious rovers to investigate the Red Planet. The specific landing site hasn't been chosen yet, but the Mars 2020 mission will explore one of several possible paleoenvironments older than 3.5 billion years that might once have been conducive to microbial life.

The rover will assess the geology of the landing site and analyze surface targets for signs of ancient life using imaging, organic and inorganic geochemistry, and mineralogy. Notably, the rover, also called



Artist's conception of the instrument mast for NASA's Mars 2020 rover, which will carry out new objectives using the basic engineering of NASA's Mars Science Laboratory/Curiosity.

Mars 2020 (see http://go.nasa.gov/2iMOKW8), will be the first to select, collect, and cache a suite of samples from another planet for possible future return to Earth, fulfilling the vision of the most recent planetary science decadal survey to take the first step toward Mars Sample Return [*National Research Council,* 2011].

A Shift in Strategy

Previous rovers used sophisticated analytic instruments and prepared rock and soil specimens for analysis on board the rover itself. Mars 2020, however, will be the first rover tasked with detailed exploration of the surface to support the collection of a large, high-value sample suite designated for possible later study in laboratories back on Earth.

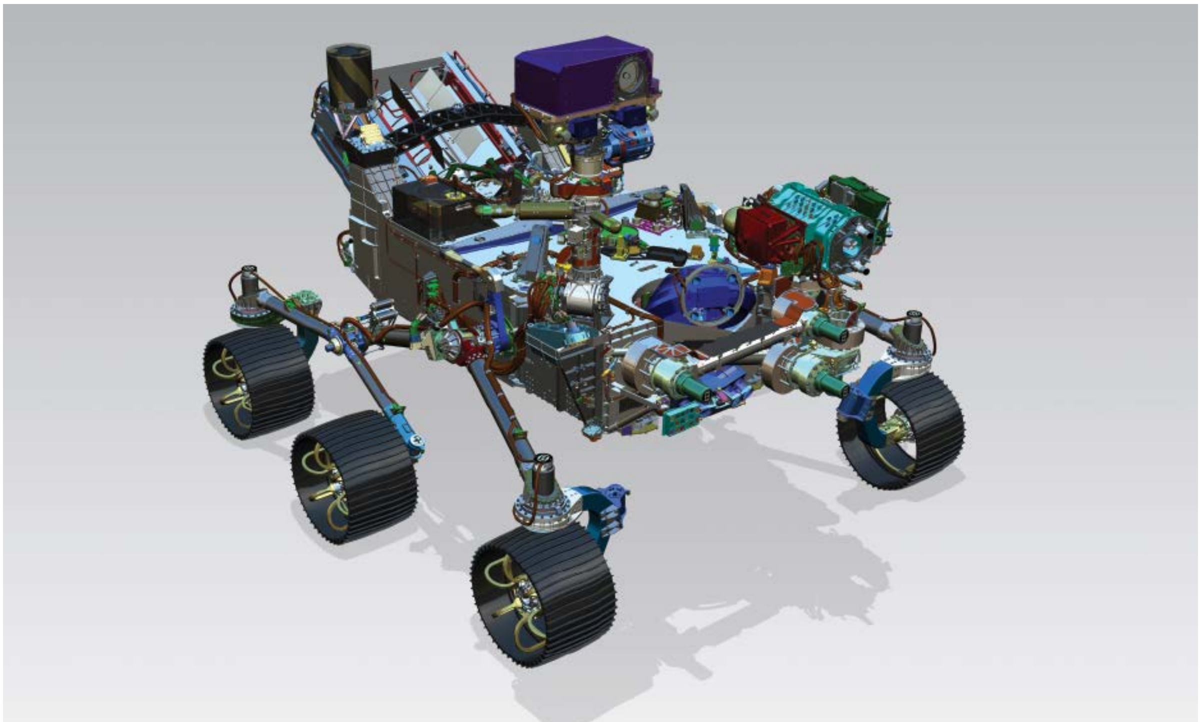
Conceptually, Mars 2020 marks a transition from missions in which sampling guided exploration to one in which exploration guides sampling. In other words, the rover's scientific instruments will observe the surrounding terrain and provide the critical context for choosing where samples will be collected. Ultimately, this context will also be used to interpret the samples. This evolution is familiar on Earth, where initial field observations and limited sampling in the service of geologic mapping lead to hypotheses that are eventually tested through focused sample collection and laboratory analysis.

Instruments on Board

The architecture of this mission closely follows the highly successful Mars Science Laboratory (MSL) and its Curiosity rover, but Mars 2020 will be modified with new scientific instruments and capabilities that allow more intensive and efficient use of the rover (Figure 1).

Two instruments will be mounted on the rover mast: Mastcam-Z, a high-resolution, color stereo zoom camera, and SuperCam, a multifaceted instrument that collects spectroscopic data using visible–near-infrared (Vis-NIR), Raman, and laser-induced breakdown spectroscopy (LIBS) techniques. SuperCam will analyze data from rock and regolith materials that may be several meters away from the rover to characterize their texture, mineralogy, and chemistry.

Two instruments on the robotic arm will permit researchers to study rock surfaces with unprecedented spatial resolution (features as small as about 100 micrometers). The Planetary Instrument for X-ray Lithochemistry (PIXL) will use X-ray fluorescence to map elemental composition, whereas Scanning Habit-



NASA/JPL-Caltech

Fig. 1. The Mars 2020 rover closely follows the design of Curiosity, but it has new scientific instruments and a sampling and caching system for the drilling and storage of samples for possible return to Earth.

able Environments with Raman and Luminescence for Organics and Chemicals (SHERLOC) will use deep-UV Raman and fluorescence spectroscopy to map the molecular chemistry of organic matter and select mineral classes. SHERLOC also includes a high-resolution color microscopic imager.

The rover will be able to assess subsurface geologic structure using a ground-penetrating radar instrument called Radar Imager for Mars' Subsurface Experiment (RIMFAX). The rover will characterize environmental conditions, including temperature, humidity, and winds, using the Mars Environmental Dynamics Analyzer (MEDA) instrument. The Mars Oxygen In-Situ Resource Utilization Experiment (MOXIE) will demonstrate a critical technology for human exploration of Mars by converting carbon dioxide in the atmosphere to oxygen as a potential source of rocket propellant.

Table 1. Requirements for the Samples to Be Prepared for Caching by the Mars 2020 Mission

CATEGORY	REQUIREMENT
Number of samples	at least 31
Sample mass, each	10- to 15-gram cylindrical cores
Contamination limits	
Inorganic	limits on 21 key geochemical elements based on Martian meteorite concentrations
Organic	<10 parts per billion total organic carbon <1 part per billion of 10 critical marker compounds
Biologic	less than one viable Earth organism per sample
Drilling and storage temperature	<60°C at all times, including during depot on Mars surface
Individual sample tube sealing	hermetic (to prevent volatile loss as well as contamination)
Sample disaggregation	maintain large pieces during drilling, storage, and possible Earth return to retain petrologic context

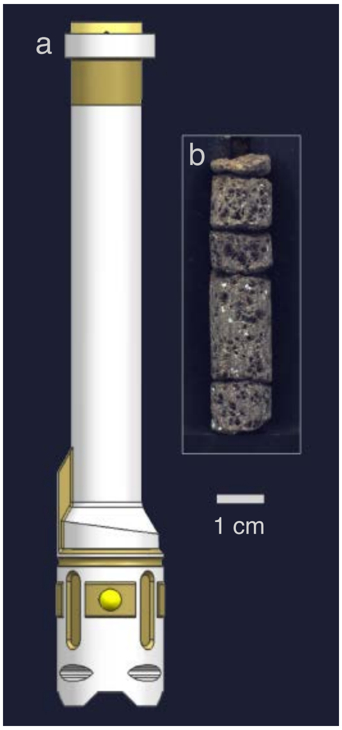
Rover Hits the Ground Running

In addition to the new scientific instruments, Mars 2020 builds on the innovative MSL "sky crane" entry, descent, and landing system. The sky crane lowers the rover to the surface from a rocket-powered descent stage rather than using air bags to provide a soft landing. New onboard navigational capabilities will enable the rover to land closer to regions with abundant rock outcroppings, which are scientifically desirable but potentially hazardous for landing. The rover will also have stronger wheels to reduce the puncture problems that plague the Curiosity rover.

New onboard software provides the rover with more autonomy for driving and for science investigations. New Earth-based tools and practices will enable the operations team to assess results and develop the next planning cycle over a much shorter timeline.

Studying the Samples

Mars 2020 will carry an entirely new subsystem to collect and prepare samples. As studies of lunar samples returned by the Apollo missions demonstrated, specimens brought back from Mars would be analyzed for an extraordinary



NASA/JPL-Caltech

Fig. 2. (a) Illustration of a sample tube. Sample tubes will be coated with titanium nitride (gold color) to limit organic molecule adsorption and with aluminum oxide (white) to reduce solar heating while the tubes are on Mars's surface. The tube is mounted within a rotary-percussive drill bit, and sample core material is introduced directly into the tube through an opening (located at the top in the orientation shown here). Features at the bottom of the tube are used for robotic tube manipulation. (b) Samples are cylindrical cores, typically 7.5 centimeters in length. Samples frequently break into fragments during drilling, as illustrated by this terrestrial basalt test core. Both images are at the scale indicated.

diversity of purposes. Notable examples include igneous and sedimentary petrology, geochemistry, geochronology, and astrobiology.

Samples brought back to Earth would also help researchers assess hazards associated with possible human exploration of Mars. And, of course, the samples would be analyzed for the presence of current life on Mars.

Readying samples for such study creates demanding requirements on this subsystem (Table 1). These requirements and their implementation are informed by previous studies [e.g., *McLennan et al.*, 2012; *Summons et al.*, 2014], as well as by the mission's Returned Sample Science Board (see http://bit.ly/Mars-returned-samples). Notable among these requirements are capabilities to ensure that contamination from Earth, brought over by the spacecraft, is limited to less than 10 parts per billion of total organic carbon and statistically less than one viable Earth organism in each of the returned samples.

Coring, Sealing, and Storing

The rover will carry a rack of about 40 sample tubes, each capable of holding a single core of rock or regolith measuring about 7.5 cubic centimeters and weighing about 10–15 grams (Figure 2). To collect a sample, the rover will withdraw a clean tube from the tube silo and insert it into a reusable coring drill bit. This assembly will then be inserted into the drill mechanism on the robotic arm and placed on the target.

The drill bit will use rotary motion with or without percussion to penetrate the rock and to force the core into the sample tube. After the core is broken off from the surrounding rock, the drill bit will be returned to storage. The sample and tube will be handed off to an assembly that carries the tubes through a series of stations: The sample will be photographed, the sample volume will be confirmed, and a cap will be inserted that provides a hermetic metal-on-metal seal that prevents contamination and loss of volatile components.

As a quality assurance check, the rover will carry and process multiple blank sample tubes. If the sample tubes pick up any Earth-sourced elemental, organic, or biologic contamination during the mission and possible Earth return, the blank samples will indicate the presence and nature of this contamination.

Mars 2020 has adopted an approach to caching in which sample tubes are filled and stored on board the rover. When the rover obtains an adequate number of samples, it will deposit them as a cache in a "depot" on the Martian surface for possible return to Earth.

The depot's location will be carefully selected to prevent blowing sand and dust from obscuring the individual tubes. A vehicle from a possible follow-on element of the Mars Sample Return campaign could easily locate and pick up the samples. The tubes are designed to survive for at least a decade after being deposited on the surface and another decade in space on the potential return journey.

Making Preparations

Mars 2020 is currently under development at the Jet Propulsion Laboratory in Pasadena, Calif. The mission has a 2-month launch window in midsummer 2020, followed by landing in February 2021. Mars 2020 has a prime mission of at least 1 Mars year (just under 2 Earth years).

Eight potential landing sites are now being considered. Scientists have hypothesized that environments at these sites range from ancient rivers, lakes, and deltas to extensive hydrothermal systems, similar to hot springs found on Earth.

Over the next few years, the landing site list will be honed down to a single site and a backup site that meet scientific desires and engineering constraints. The most recent Mars 2020 landing site workshop (see http://go.nasa.gov/2ilOgVL) was held 8–10 February 2017. We highly encourage the continued involvement of the broad scientific community, including scientists who may someday analyze the returned samples, in site selection.

Acknowledgment

This project is being developed at the Jet Propulsion Laboratory, California Institute of Technology, for NASA.

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