SUBCOMMITTEE ON SPACE AND AERONAUTICS
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
U.S. HOUSE OF REPRESENTATIVES

HEARING CHARTER

What Do Scientists Hope to Learn with NASA's Mars Perseverance Rover?

Thursday, April 29, 2021
11:00 a.m.
Zoom

PURPOSE

The purpose of the hearing is to explore the science of the National Aeronautics and Space Administration's Mars 2020 Perseverance Rover mission, including key scientific objectives and plans, and overall Mars science exploration strategy, and other issues.

WITNESSES

- **Dr. Michael A. Meyer,** Lead Scientist, Mars Exploration Program, National Aeronautics and Space Administration
- **Dr. Bethany L. Ehlmann,** Professor of Planetary Science and Associate Director of the Keck Institute for Space Studies, California Institute of Technology; President, The Planetary Society; Co-Investigator, Mars 2020 Perseverance mission
- **Dr. Luther Beegle**, Principal Investigator of the Mars Perseverance Scanning Habitable Environments with Raman & Luminescence for Organics & Chemicals (SHERLOC) Instrument, Jet Propulsion Laboratory
- **Dr. Tanja Bosak**, Returned Sample Science Co-Lead, Mars 2020 Perseverance Rover; Professor and Lead of the Option in Geology, Geochemistry, and Geobiology, Department of Earth, Atmospheric, and Planetary Sciences, Massachusetts Institute of Technology

OVERARCHING QUESTIONS

- *What are the scientific goals of NASA's Mars 2020 Perseverance Rover mission?*
- *How do the Perseverance mission's scientific goals fit into the long-term objectives of NASA's Mars Exploration Program and the search for life beyond Earth?*
- *What is the scientific significance of Mars Perseverance's landing site in Jezero Crater?*
- *What are the new or enhanced capabilities and technology innovations on the Perseverance Rover, and how do they help enable the rover's science activities?*

BACKGROUND

On February 18, 2021, NASA's Perseverance rover touched down safely on the surface of Mars. Perseverance had traveled 293 million miles since launching on July 30, 2020 from Cape Canaveral in Florida on a United Launch Alliance Atlas V rocket. The NASA Mars 2020 Perseverance rover mission plans to spend at least one Martian year (687 Earth days) on the red planet, studying its geology and atmosphere, searching for signatures of past life, and preparing samples of surface material for eventual return to Earth for further study.

Perseverance[1] is the ninth U.S. spacecraft to successfully land on Mars, the fifth rover to successfully operate on the surface,[2] and the first mission that will collect samples on Mars for later return to Earth.

Mars

Mars is the fourth planet from the Sun. Like Earth, Mars is a terrestrial planet, made primarily of rock, though Mars is about half the size (by radius) and only about a tenth of the mass of Earth. The smaller mass means that gravity on Mars is about a third as strong as what we feel on Earth. With this relatively weak gravitational pull, and with no magnetic field to protect from the harsh solar wind, Mars cannot hold on to as much atmospheric material as the Earth. The Martian atmosphere of today is thin, with a density under one percent of the Earth's sea level atmospheric density. The atmosphere is approximately 95 percent carbon dioxide (CO_2) by volume at the surface.

A Martian day, or "sol," is 24.6 hours, though a Martian year is nearly twice as long as an Earth year, because Mars orbits about 50 percent farther from the Sun. Mars is tilted on its axis at nearly the same angle as the Earth is tilted. Therefore Mars, like Earth, also experiences seasonal, diurnal (night/day), and latitudinal variations in sun exposure, and thus has wind, weather, and temperature variations. For example, though the global average surface temperature is about -80°F, daytime temperatures near the equator can occasionally climb close to or even above freezing (32°F).[3]

Though the Mars of today is largely cold and dry, Martian geology and surface features show evidence of significant climate changes on geologic timescales; the planet may have gone through multiple ice ages, for example.[4] With evidence built from successive orbiting and

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[1] The name "Perseverance" was given by seventh grader Alexander Mather, of Burke, Virginia, who submitted the winning entry to NASA's "Name the Rover" essay contest for the Mars 2020 Rover mission. https://www.nasa.gov/press-release/virginia-middle-school-student-earns-honor-of-naming-nasas-next-mars-rover.

[2] Successful U.S. Mars surface missions and launch dates: Viking 1 and 2, two landers (1975); Mars Pathfinder, lander and rover (1996); Mars Exploration Rovers, Spirit and Opportunity, two rovers (2004); Phoenix, lander (2007); Mars Science Laboratory, Curiosity rover (2011); InSight, lander (2018). Details available at: https://mars.nasa.gov/mars-exploration/missions.

[3] Smithsonian National Air and Space Museum, "Today, Mars is Warmer Than Earth. See How We Compare," January 5, 2018. Available at: https://airandspace.si.edu/stories/editorial/today-mars-warmer-earth-see-how-we-compare.

[4] Levy, Joseph S., et al., "Surface Boulder Banding Indicates Martian Debris-Covered Glaciers Formed Over Multiple Glaciations," Proceedings of the National Academy of Sciences, 118 (40, January 26, 2021. Available at: https://www.pnas.org/content/118/4/e2015971118.

surface missions, scientists have determined that, in the distant past, the surface of Mars was probably much warmer and much wetter,[5] and the atmosphere was also much thicker,[6] potentially providing conditions for liquid water on the surface at one point in Mars' history. Observations from the Curiosity rover, which continues to operate on Mars, showed that liquid water likely once flowed in at least some locations on the surface.[7] Further Curiosity measurements have found evidence that some locations on ancient Mars, at the same time as having liquid water present on the surface, also harbored the acidity (pH) and salinity conditions that scientists understand to be necessary for life.[8] Much of the ancient surface liquid water may be locked in minerals in the crust of the planet still today.[9] Water ice may also exist in large, concentrated quantities below the surface, and may even be potentially accessible by surface investigations.[10]

Top Priorities of Mars, Planetary Science Research

Every ten years, under the auspices of the National Academies of Sciences, Engineering, and Medicine, the U.S. planetary science community convenes to determine consensus priorities and recommendations for the most compelling science questions, and accompanying program elements, for the next decade of Solar System research and exploration. NASA is the primary funder of these planetary science "decadal surveys," and the recommendations are directed to NASA to guide the content of its planetary science portfolio.

The most recent decadal survey, *Vision and Voyages for Planetary Sciences in the Decade 2013-2022*,[11] identified three high-priority science goals of the exploration of Mars in the ensuing decade: determine if life ever arose on Mars, understand the processes and history of climate, and determine the evolution of the surface and interior. The committee identified the single highest-priority Mars science goal "to address in detail the questions of habitability and the potential origin and evolution of life on Mars," and found that sample return—that is, "analysis of carefully selected samples from geologically diverse and well-characterized sites that are returned to Earth for detailed study"—would have "significantly higher science return and a much higher science-to-dollar ratio" than further *in situ* rovers alone could in pursuit of that scientific goal.

[5] Ramirez, Ramses M. and Craddock, Robert A., "The Geological and Climatological Case for a Warmer and Wetter Early Mars," *Nature Geoscience*, 11, pp 230-237, 2018. Available at: https://arxiv.org/abs/1810.01974.

[6] Jakosky, Bruce, "MAVEN Explores the Martian Upper Atmosphere," *Science*, Vol. 350, Issue 6261, p. 643, Introduction to Special Issue, November 6, 2015. Available at: https://science.sciencemag.org/content/350/6261/643.

[7] Skibba, Ramin, "History of Mars' Water, Seen Through the Lens of Gale Crater," *EOS*, April 5, 2018. Available at: https://eos.org/articles/history-of-marss-water-seen-through-the-lens-of-gale-crater.

[8] NASA, "NASA Rover Finds Conditions Once Suited for Ancient Life on Mars," March 12, 2013. Available at: https://www.nasa.gov/mission_pages/msl/news/msl20130312.html.

[9] Andrews, Robin George, "Where Did Mars' Liquid Water Go? A New Theory Holds Fresh Clues," *National Geographic*, March 16, 2021. Available at: https://www.nationalgeographic.com/science/article/where-did-mars-liquid-water-go-new-theory-holds-fresh-clues.

[10] Dundas, Colin M., et al., "Exposed Subsurface Ice Sheets in the Martian Mid-Latitudes," *Science*, Vol. 359, Issue 6372, pp. 199-201, January 12, 2018. Available at: https://science.sciencemag.org/content/359/6372/199.

[11] National Research Council. 2011. *Vision and Voyages for Planetary Science in the Decade 2013-2022*. Washington, DC: The National Academies Press. https://doi.org/10.17226/13117.

The decadal survey recommended that the highest-priority planetary science flagship (large) mission of this decade should be the Mars Astrobiology Explorer-Cacher (MAX-C) and the first step in a sample return campaign. The MAX-C mission concept, described in the decadal survey as a partnership between NASA and the European Space Agency (ESA), evolved into NASA's Mars 2020 Rover, later named Perseverance.[12]

Perseverance Rover Mission

NASA initiated the development of the Mars 2020 Rover mission in 2013. The mission is part of the Exploration Program (MEP) of the Planetary Science Division (PSD) of NASA's Science Mission Directorate (SMD). The mission is managed for SMD by the Jet Propulsion Laboratory (JPL), a division of the California Institute of Technology (Caltech).

The Perseverance landing site, Jezero Crater, was selected in 2018, after a five-year process involving the mission science team and the broader planetary science community.[13] Jezero Crater is 28 miles across and located just north of the Martian equator, fully within the impact basin of a much larger (750 miles across) crater left by a meteorite earlier in ancient Mars history. By studying observations made with satellites orbiting far above the surface, scientists see evidence of past water flow into Jezero Crater and observe a feature that may be an ancient river delta; these surface environments could have held the right conditions for microbes to survive.[14] Perseverance's instruments will collect data and samples to determine if those past conditions were habitable and if there are any signs of long-past life still there today.

Perseverance's primary mission is one Martian year, or 687 Earth days. The rover is spending its first few months on Mars conducting tests of its hardware, software, and systems to assess health and performance, while also studying the conditions and terrain of the actual landing location. Concurrently, the mission is conducting a technology demonstration of the Ingenuity helicopter. Following the technology demonstration and the rover's system checks, the full science campaign and sample collection activities will begin.[15]

Science Objectives

Perseverance has four science objectives, which reflect decadal survey priorities:

- Geology: Explore an astrobiologically relevant ancient environment on Mars to decipher its geological processes and history, including the assessment of past habitability.

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[12] The midterm assessment of progress on the decadal found that this mission concept met the recommendation. National Academies of Sciences, Engineering, and Medicine. 2018. *Visions into Voyages for Planetary Science in the Decade 2013-2022: A Midterm Review*. Washington, DC: The National Academies Press. https://doi.org/10.17226/25186.

[13] NASA, "NASA Announces Landing Site for Mars 2020 Rover," 2018. Available at: https://www.nasa.gov/press-release/nasa-announces-landing-site-for-mars-2020-rover.

[14] Ehlmann, Bethany L., et al., "Clay Minerals in Delta Deposits and Organic Preservation Potential on Mars," *Nature Geoscience,* 1, pp. 355-358, 2008. Available at: https://repository.si.edu/bitstream/handle/10088/16530/200840.pdf?sequence=1&isAllowed=y.

[15] O'Callaghan, Jonathan, "The First 100 Days on Mars: How NASA's Perseverance Rover Will Begin Its Mission," *Scientific American,* February 18, 2021. Available at: https://www.scientificamerican.com/article/the-first-100-days-on-mars-how-nasas-perseverance-rover-will-begin-its-mission/.

- Astrobiology: Assess the biosignature preservation potential within the selected geological environment and search for potential biosignatures.
- Sample Caching: Demonstrate significant technical progress towards the future return of scientifically selected, well-documented samples to Earth.
- Preparation for Humans: Provide an opportunity for contributed Human Exploration and Operations Mission Directorate or Space Technology Program[16] participation, compatible with the science payload and within the mission's payload capacity. [17]

The science objectives will be pursued both by conducting *in situ* measurements and analyses with the instruments mounted on Perseverance and by collecting and storing samples of rocks and soil as it traverses the Martian surface.

Science Instruments

Perseverance carries seven competitively selected science instruments led by principal investigators from U.S. universities, JPL, Los Alamos National Laboratory, and institutions in Spain and Norway:

- Mastcam-Z is a camera system mounted to the mast of the rover. Its twin cameras are capable of taking high-definition video, panoramic color and three-dimensional images of the Martian surface and atmosphere, with a zoom functionality for distant and small targets.
- Mars Environmental Dynamics Analyzer (MEDA) is a suite of weather and environmental sensors to monitor air and ground temperatures, wind speed and direction, temperature, humidity, dust counts, and radiation.
- Mars Oxygen In Situ Resource Utilization Experiment (MOXIE) will collect carbon dioxide (CO_2) from the Martian atmosphere and use it to produce oxygen (O_2). MOXIE is a test model (1 percent scale) of the technology that future human astronauts on Mars could potentially use to make oxygen for breathing and rocket fuel.
- Planetary Instrument for X-ray Lithochemistry (PIXL) is mounted at the end of Perseverance's robotic arm, and it will get up close to use x-ray sensors to study rocks and soil textures and chemical elements at tiny scales (less than a millimeter).
- Radar Imager for Mars' Subsurface Experiment (RIMFAX) will use radar to map the geologic features below the surface (stratigraphy) where the rover sits. Depending on the material, the radar can penetrate as far as 30 feet down.
- Scanning Habitable Environments with Raman & Luminescence for Organics and Chemicals (SHERLOC) will look for signs of past microbial life in the fine-scale structure of minerals and organic molecules that it may find on the Martian surface using a laser and ultraviolet cameras and spectrometers. SHERLOC is mounted on the end of Perseverance's robotic arm with PIXL.

[16] Now the Space Technology Mission Directorate.
[17] Mustard, J.F., et al., "Report of the Mars 2020 Science Definition Team," 154pp., posted July, 2013, by the Mars Exploration Program Analysis Group (MEPAG). Available at: http://mepag.jpl.nasa.gov/reports/MEP/Mars_2020_SDT_Report_Final.pdf.

- SuperCam will use cameras and a laser spectrometer from the rover's mast to determine the chemical composition and fine-scale structure of rocks and soil on the Mars surface, in order to look for organic compounds that could contain the signatures of ancient life.

Figure 1 shows the seven science instruments on a digital rendering of Perseverance. The rover is approximately the size of a compact car; it is ten feet long (not including the fully extended robotic arm), nine feet wide, and seven feet tall, and weighs 2,260 pounds. The rover body and configuration are based on that of NASA's Mars Science Laboratory Curiosity rover, which landed on Mars in 2012. All data collected by the science instruments, including measurements, images, videos, and sound recordings, are transmitted from radio antennae on Perseverance to NASA and ESA satellites orbiting Mars. The more powerful antennae on the orbiters then relay the data back to Earth through the Deep Space Network.

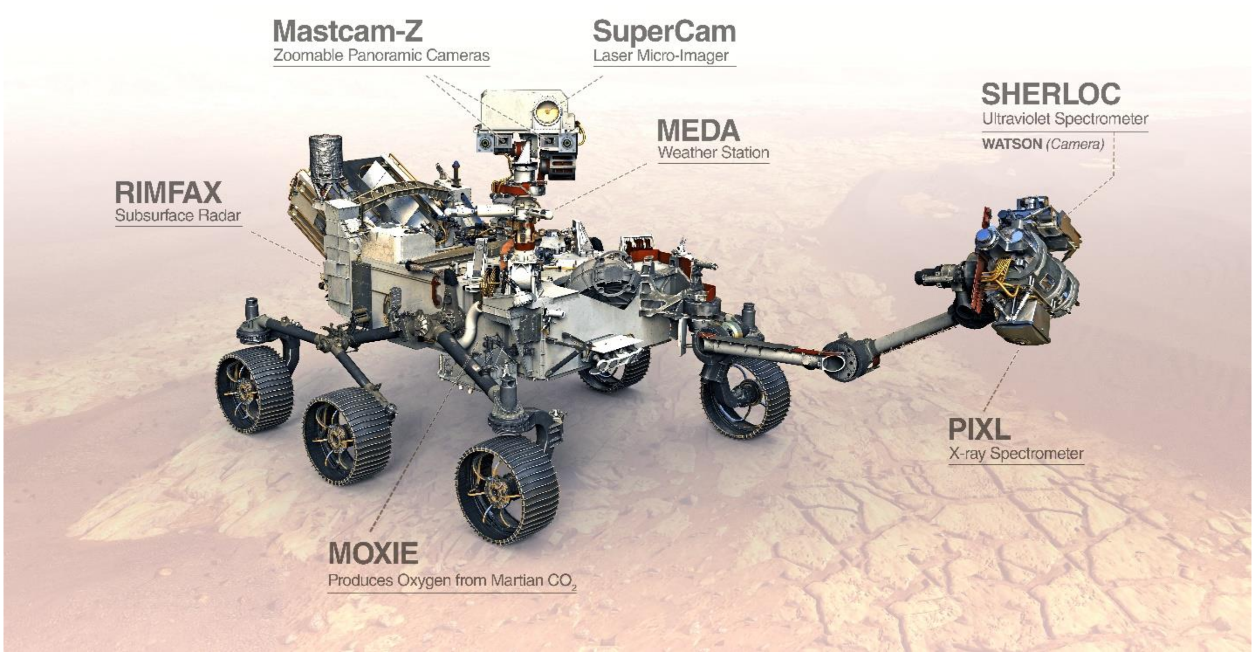

Figure 1. Science Instruments on NASA's Perseverance Mars Rover (digital rendering). Credit: NASA/JPL.[18]

Sample Collection

In addition to conducting investigations, the scientific instruments will help in identifying candidate rocks and soil for sample collection. A drill is mounted on the large robotic arm on the front of the rover (where PIXL and SHERLOC are also mounted), while all of the rest of the tools and supplies for the actual collection and storage of samples are in the "belly" of the rover, the underside between the wheels. This includes drill bits, 43 sample tubes, and a small robotic arm that will transfer sample tubes back and forth between the storage area in the belly of the rover and the large robotic arm. There are also five "witness tubes," which will each be opened, one at a time, to simply "witness" the environment around the rover by being put through the

[18] Available at: https://mars.nasa.gov/resources/25045/science-instruments-on-nasas-perseverance-mars-rover/.

steps of sample collection without actually collecting any sample, simply capturing any ambient exhaust or outgassing from the rover itself, to later be compared with the samples.

Once a sample has been taken, the tube is returned to the belly of the rover, sealed, and then stored safely until the mission science team determines where on the surface they wish to deposit one or more samples for eventual retrieval by the notional second stage of the Mars Sample Return campaign.

NASA, in collaboration with ESA, has been formulating a concept for a Mars Sample Return campaign to follow Perseverance with missions to retrieve the collected samples and return them to the Earth for study. In December 2020, NASA approved the campaign to enter the first phase of mission development for concept and technology development, notionally targeting a launch date of 2026.[19]

[19] NASA, "NASA Moves Forward with Campaign to Return Mars Samples to Earth," December 17, 2020. Available at: https://www.nasa.gov/press-release/nasa-moves-forward-with-campaign-to-return-mars-samples-to-earth.