National Aeronautics and
Space Administration

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Subcommittee on Space and Aeronautics
Committee on Science, Space, and Technology

U.S. House of Representatives

Statement by:
Dr. Michael A. Meyer
Mars Exploration Program Lead Scientist
Science Mission Directorate

117th Congress

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Chairman Beyer, Ranking Member Babin, and members of the Subcommittee, I am honored to appear before this Subcommittee to discuss Mars science and the role that the Perseverance rover plays in NASA's broader Mars Exploration Program.

NASA's Study of Mars

Mars has captured the public's imagination and has been the subject of science fiction for more than 140 years. As the one planet in our solar system most similar to Earth, Mars has captivated scientists as well. Mars provides an ideal landscape for understanding the early history of the solar system and how planets transform over time. The terrestrial planets Mercury, Venus, Earth, and Mars formed over 4.5 billion years ago from similar building blocks of minerals and elements. Yet, Earth and Mars are the only planets known to have been able to support life. Nevertheless, their transformation over time to the present has followed dramatically different paths. By studying Mars, we can learn about Earth's history as well.

NASA has studied Mars since the early days of the space age, starting with the first successful flyby of Mars by our Mariner 4 spacecraft in 1964. We have successfully conducted a number of Mars lander and rover missions, including Viking, Mars Pathfinder/Sojourner, Spirit, Opportunity, Phoenix, InSight, Curiosity and now, Perseverance.

We now know that Mars had rivers and large lakes and perhaps even a northern ocean. The history of Mars since this point is one of water lost, gradual loss of a significant portion of its atmosphere, and near-surface water turning into ice. Were the early wet conditions favorable for the emergence of life, and did this life persist if it did form? Microbial life on Earth that emerged early in its geological history occupies nearly every available niche that provides sufficient energy in the form of transportable nutrients, and even Earth's atmosphere currently bears the stamp of life, with most of the oxygen present in the atmosphere produced over time through plants. Likewise, methane in Earth's atmosphere is constantly replenished by a variety of biological sources. We have not yet found evidence of past or present life on Mars, or on any extraterrestrial body for that matter, although this fundamental question motivates our science missions like Perseverance.

NASA's Four High-Level Goals for Mars

NASA's Mars Exploration Program studies Mars as a planetary system in order to understand the formation and early evolution of Mars as a planet, the history of geological processes that have shaped Mars through time, the potential for Mars to have hosted life, and the future exploration of Mars by humans. The strategy has evolved as we have learned more about Mars and as more questions have arisen. We have gone from "Follow the Water" to "Explore Habitability" to "Seek Signs of Life."

NASA organizes its scientific exploration of Mars around four high-level goals: 1) life, 2) climate, 3) geology, and 4) human exploration.

Goal 1 - Determine if Mars Ever Supported Life: Mars and Earth may have been relatively similar worlds during their early histories, and because life arose relatively early on the Earth, we want to know whether life ever arose on Mars. The two objectives of the goal are to determine if environments having high potential for habitability and preservation of biosignatures contain evidence of either past or present life.

Goal 2 - Understand the Processes and History of Climate on Mars: There are fundamental questions about how the climate of Mars has evolved over time to reach its current state, the processes that have operated to produce this evolution, and whether the Martian atmosphere and climate reflect features that are universal to planetary atmospheres. This Goal is further divided into three objectives: A) Characterize the state of the present climate of Mars' atmosphere and surrounding solar wind environment, and the underlying processes, under the current orbital configuration; B) Characterize the history of Mars' climate in the recent past and the underlying processes under different orbital configurations; and C) Characterize Mars' ancient climate and underlying processes.

Goal 3 - Understand the Origin and Evolution of Mars as a Geological System: Scientists seek insight into the composition, structure, and history of Mars as a planet through deeper understanding of its surface and interior. Mars might once have hosted potentially habitable, Earth-like environments. This Goal is further divided into three objectives: A) Document the geologic record preserved in the crust and interpret the processes that have created that record; B) Determine the structure, composition, dynamics, and evolution of Mars' interior and how it has evolved; and C) Determine the manifestations of Mars' evolution as recorded by its two moons.

Goal 4 - Prepare for Human Exploration: Robotic flight missions can help prepare for potential crewed missions to the Mars system, and these precursor missions can "buy down" risk that is inherent to any mission by acquiring information that can be acted upon during design, implementation, and operation of future crewed missions. This Goal is further divided into four objectives: A) Obtain knowledge of Mars sufficient to design and implement a human mission to Mars orbit with acceptable cost, risk, and performance; B) Obtain knowledge of Mars sufficient to design and implement a human mission to the Martian surface with acceptable cost, risk, and performance; C) Obtain knowledge of Mars sufficient to design and implement a human mission to the surface of either Phobos or Deimos with acceptable cost, risk, and performance; and D) Obtain knowledge of Mars sufficient to design and implement sustained human presence at the Martian surface with acceptable cost, risk, and performance.

Perseverance Rover

Perseverance rover embodies the NASA – and the scientific – spirit of overcoming challenges. Getting the spacecraft to the launch pad during a pandemic, searching for signs of ancient life, collecting and caching samples, and proving new technologies on a harsh planet are no easy feat. Nor is a soft touchdown on Mars: only 50 percent of Martian landing attempts, by any space agency, have been successful.

Perseverance arrived at Jezero Crater on February 18, 2021, after a seven-month journey from Cape Canaveral, Florida, and seven minutes of terror as it successfully completed its entry, descent, and landing. Jezero Crater is a 28-mile-wide (45-kilometer-wide) basin located in the Martian northern hemisphere. Sometime around 3.5 billion years ago, a river flowed into a body of water in the crater about the size of Lake Tahoe, depositing sediments forming a delta. The Perseverance science team believes these ancient river delta and lake deposits could have collected and preserved organic molecules and other potential signs of microbial life.

Jezero Crater has interested the scientific community for many years, but it had always been too hazardous for landing. Thanks to new technologies developed in partnership with the Space Technology Mission Directorate (STMD) that enabled Perseverance to target its landing site more accurately and avoid hazards (including steep cliffs, sand dunes, and boulder fields) autonomously, the spacecraft safely touched down about 1.7 kilometers from its pre-planned landing location after a 471-million kilometer (293-million-mile) journey from Earth.

Perseverance is the most sophisticated rover NASA has ever sent to the Red Planet, with a name that embodies NASA's passion, and our Nation's capability, to take on and overcome challenges. As such, Perseverance will contribute to all four of NASA's high-level goals for Mars. It will collect carefully selected and documented rock and regolith samples for future return to Earth, search for signs of ancient microbial life, characterize the planet's geology and climate, and pave the way for future human exploration of Mars.

Two of Perseverance's science instruments play a particularly important role in the search for potential signs of past life: SHERLOC (short for Scanning Habitable Environments with Raman & Luminescence for Organics & Chemicals), which can detect organic matter and minerals, and PIXL (short for Planetary Instrument for X-ray Lithochemistry), which maps the chemical composition of rocks and sediments. The instruments will allow scientists to analyze these features together at a higher level of detail than any Mars rover has done before.

Perseverance will also be able to use some instruments to gather science data from a distance. Mastcam-Z's cameras can zoom in on rock textures from as far away as a soccer field, while SuperCam will use a laser to zap rock and regolith (broken rock and dust) to study their composition in the resulting vapor. RIMFAX (short for Radar Imager for Mars' Subsurface Experiment) will use radar waves to probe geological features underground. The Norwegian Defense Research Establishment (FFI) contributed RIMFAX to Perseverance.

Check-out of Perseverance

Perseverance's early images and sounds are part of a planned 90-sol (~92.5 Earth days) initial checkout period. The mission team is using this time to perform tests of all the rover's parts and science instruments to ensure everything – including the team – is ready for surface operations. For about 70 sols, the operations team will be working on Mars time, which means they will be setting their clocks to the Martian day, which, compared to Earth time, progresses 40 minutes every day. This allows them to respond quickly to any issue the rover may have during its workday and to make sure revised instructions are ready for the next sol.

The first readings from the SuperCam instrument have arrived on Earth. SuperCam was developed jointly by the Los Alamos National Laboratory (LANL) in New Mexico and a consortium of French research laboratories under the auspices of the Centre National d'Etudes Spatiales (CNES). Perched atop the rover's mast, SuperCam's 12-pound (5.6-kilogram) sensor head can perform five types of analyses to study Mars' geology and help scientists choose which rocks the rover should sample in its search for signs of ancient microbial life. The University of Valladolid in Spain provided calibration targets for the SuperCam instrument suite. The calibration target assembly contains rock, synthetic glass, and ceramic targets, which will calibrate SuperCam's instruments against materials of known compositions and spectral properties.

Early data from SuperCam tests – including sounds from the Red Planet – have been intriguing. SuperCam captured the sounds of Martian wind and the first audio of laser zaps on another planet. Some zaps sound slightly louder than others, providing information on the physical structure of the target rocks, such as its relative hardness. This information will be essential when determining which samples to cache and ultimately return to Earth through our groundbreaking Mars Sample Return Campaign, which will be one of the most ambitious feats ever undertaken by humanity.

The SuperCam team also received excellent first datasets from the instrument's visible and infrared (VISIR) sensor as well as its Raman spectrometer. VISIR collects light reflected from the Sun to study the mineral content of rocks and sediments. This technique complements the Raman spectrometer, which uses a green laser beam to excite the chemical bonds in a sample to produce a signal depending on what elements are bonded together, in turn providing insights into a rock's mineral composition. In another first, this is the first time an instrument has used Raman spectroscopy anywhere other than on Earth. Raman spectroscopy is going to play a crucial role in characterizing minerals on Mars. It will help us understand the geological conditions under which the rocks formed and detect potential organic and mineral molecules that might have been formed by living organisms.

Perseverance's Mars Environmental Dynamics Analyzer (MEDA), the next-generation weather package developed by STMD, has been taking daily weather measurements (weather, climate, surface ultraviolet radiation, and dust), wind speed being an important factor for permitting helicopter flights (mars.nasa.gov/mars2020/weather). The National Institute for Aerospace Technology through the Center of Astrobiology (INTA-CAB) in Spain provided MEDA to Perseverance. In addition, the Center for the Development of Industrial Technology (CDTI) in Spain provided the High-Gain Antenna (HGA) subsystem, which utilizes flight-spare equipment from the Mars Science Laboratory mission.

Much of the immediate science debate concerns whether the rocks in the immediate area are primarily of igneous or sedimentary origin, which can be difficult to discern until close-up observations can be made. Observations of the delta front off to the northwest of the rover show that the rocks there are almost undoubtedly sedimentary in origin, with cross bedding and other sedimentary layering, consistent with expectations of the delta environment seen from orbit and confirming that they will be a prime target for sampling. Furthermore, to support future exploration, the toaster-sized Mars Oxygen In-Situ Resource Utilization Experiment (MOXIE), provided by STMD, successfully converted some of the Red Planet's thin, carbon dioxide-rich atmosphere into oxygen on its first attempt to extract oxygen out of the Martian atmosphere.

Ingenuity

Perseverance also ferried several cutting-edge technology demonstrations to the surface of Mars – including the helicopter. On April 19, 2020, NASA's Ingenuity Mars Helicopter became the first aircraft in history to make a powered, controlled flight on another planet – a true Wright Brothers moment. With the Wright Brothers, there were only a photographer and a few others there to see the event. With Ingenuity, it beamed back its own images and Perseverance provided video of this historic flight from its nearby perch, the Jacob van Zyl overlook.

This is an amazing accomplishment, as flying in a controlled manner on Mars is far more difficult than flying on Earth. The Red Planet has significant gravity (about one-third that of Earth's) but its atmosphere is just one percent as dense as Earth's at the surface, equivalent to approximately 10 miles in altitude, making it very difficult to generate lift. During Martian daytime, the planet's surface receives only about half the amount of solar energy that reaches Earth during its daytime, and nighttime temperatures can drop as low as minus 130 degrees Fahrenheit (minus 90 degrees Celsius), which can freeze and crack unprotected electrical components.

To fit within the available accommodations provided by the Perseverance rover, the Ingenuity helicopter had to be small. To fly in the Mars environment, the rotor blades had to be large, but the helicopter had to be lightweight. To survive the frigid Martian nights, it had to have enough energy to power internal heaters. The system – its rotors, solar panels, electrical heaters, and its control systems – had to be in sync – making necessary trajectory changes around 500 times per second – to be successful. We will now attempt longer and more complex flights, building our detailed understanding of interactions with Mars' atmosphere and preparing for future missions that will take advantage of this understanding to explore in new ways, both for future robotic and future human missions to Mars.

Perseverance Will Help Pave the Way for Future Human Missions to the Moon and Mars

Among the future-looking technologies on the Perseverance mission that will benefit human exploration is Terrain-Relative Navigation. As part of the spacecraft's landing system, Terrain-Relative Navigation uses camera images and computer processing to identify known surface features and calculate a spacecraft's course based on the location of those features in reference models or images. This system is the main reason Perseverance can explore a place as interesting as Jezero Crater. It enables descending spacecraft to quickly and autonomously comprehend location over the Martian surface and modify trajectory to avoid hazards. This technology will provide invaluable assistance for both robotic and crewed missions landing on the Moon and Mars.

Perseverance has more autonomy on the surface than any other rover, including self-driving smarts that allow it to cover more ground in a day's operations with fewer instructions from engineers on Earth. This fast-traverse capability (courtesy of upgraded sensors, computers, and algorithms) can translate into more science over the length of the mission. What's more, it will make exploration of the Moon, Mars, and other celestial bodies more efficient for other vehicles.

In addition, Perseverance carries a technology demonstration called MOXIE. This instrument is expected to extract oxygen at least nine more times over the course of a Martian year from Mars' carbon dioxide atmosphere, demonstrating a way that future explorers might produce oxygen for rocket propellant as well as for breathing.

Perseverance will help us understand the atmospheric structure and the behavior of spacecraft at Mars with the Mars Entry, Descent, and Landing Instrumentation 2 (MEDLI2) package, developed by STMD, an upgraded version of the instrumentation flown on the Mars Science Laboratory entry capsule.

All of Us Get to Ride Along with Perseverance

The mission team draws inspiration from the name of its rover, with particular awareness of the challenges the entire world is experiencing at this time. With that in mind, the mission installed a special plate to honor the dedication and hard work of the medical community and first responders around the globe. The team hopes to inspire the entire world, and future explorers, to forge new paths and make discoveries on which the next generation can build.

The Perseverance mission also carries more cameras than any other interplanetary mission in history, with 19 cameras on the rover itself and four on other parts of the spacecraft involved in entry, descent, and landing. These cameras allowed NASA to watch its own mission land on another world for the first time, and the public also was able to experience what it is like to land on Mars.

As with previous Mars missions, the Perseverance mission makes raw and processed images available on the mission's website as soon as they are received. In addition, a microphone on SuperCam is listening to the wind on Mars and later will help scientists understand the properties of rocks the instrument is examining. You can also follow Perseverance's adventure on social media via @NASAPersevere and @NASAMars on Twitter and Facebook, and the hashtag #CountdownToMars.

Perseverance is the First Leg of a Round Trip to Mars

Perseverance is the first rover to bring a sample caching system to Mars that will package promising samples for return to Earth by a future mission. Jezero Crater was carefully selected as the site for Mars sample collection because it contains the remains of an ancient, partially eroded delta, which formed by flowing water entering a lake or a sea and dropping the sediment it was carrying (i.e., just like the Mississippi River delta here in the U.S.). This sediment could contain the remains of life, if it were there. On Earth, mud from a delta is an excellent target for material that has concentrated and can preserve information about the life that once existed there. Mars does not have liquid water today at its surface, so our best way of understanding the role of water in Martian processes is to study the geologic record of places where water once existed.

The rocks surrounding Jezero Crater consist of even older crustal rocks that formed at a time when we think life first arose on the Earth. These will be key to understanding the earliest part of Mars' geological history. The surface of Mars is currently inhospitable due to being cold and dry and constantly bathed in damaging cosmic and solar ultraviolet radiation, so it is not expected that Martian organisms could live today near the surface of Jezero Crater.

The Mars Sample Return (MSR) campaign is a joint project between NASA and the European Space Agency (ESA). Three missions are involved: 1) Perseverance will select and collect the samples, 2) ESA's small "fetch" rover will retrieve the samples and load them into NASA's Mars Ascent Vehicle (MAV) rocket that will launch them into Mars orbit, and 3) ESA's Earth Return Orbiter will capture the NASA sample container and fly it the rest of the way to Earth. In summary, NASA is leading the sample collection rover, the lander, the ascent vehicle, and the sample container, while ESA is leading the fetch rover, the sample transfer arm to get the samples to the rocket, and the Earth Return Orbiter.

The returned samples from Mars are expected to consist of rocks, regolith, dust and gas. The number of samples to be returned depends on what is discovered by the Perseverance sample-collecting activities and on the health of that mission, but it is anticipated to be in the range of 10-30 samples. The samples are about the size of your pinky or a stick of chalk, and the total amount of sample material to be returned will fit in a volume the size of a basketball. That will be enough material to carry out a wide range of scientific investigations on each sample.

Once the samples are here on Earth, we can examine them more precisely with instruments too large and complex to send to Mars, providing far more information about them than even the most sophisticated rover could. Returned samples will also tell us how Mars' surface conditions changed with time—a key factor in understanding when and how a planet may have hosted life.

Sample return missions are the "gift that keeps on giving" to future generations. Scientists are still making new discoveries today based on lunar samples brought back by the Apollo astronauts more than 50 years ago. Many of the discoveries from Apollo samples are being made today by scientists who were not even alive when those rocks came back, using instruments that had not been invented yet, and addressing questions that no one had thought of when humans returned from the Moon in 1972.

Similarly, the samples gathered by Perseverance and returned by MSR will pave the way for generations of future scientists. Students who are in pre-school through high school today will be part of the teams of scientists who work on the returned samples. If we are successful, their children and grandchildren will still be making discoveries from those samples long after they are retired.

NASA's Future Exploration of Mars

We are not done studying Mars. NASA's InSight mission will spend its extended mission listening for more marsquakes using its seismometer instrument, despite its drilling operations ending early due to low friction in the Mars subsurface. NASA's other rover on Mars (Curiosity) continues to make exciting discoveries during its gradual climb up Mount Sharp, the 3-mile-tall (5-kilometer-tall) mountain it has been exploring since 2014. The rover is just now entering the "sulfate" unit – expected to provide a window into Mars history when the planet became cold and dry.

NASA also is studying Mars from orbit with the Mars Reconnaissance Orbiter, Mars Atmosphere and Volatile EvolutioN (MAVEN), Odyssey, and Mars Express missions. In addition, NASA recently signed a Statement of Intent with three space agencies (the Canadian Space Agency, the Italian Space Agency, and the Japan Aerospace Exploration Agency) to establish a joint concept team to assess mission potential, as well as partnership opportunities, on a future orbital mission to prospect for ice and volatiles on Mars. In response to a recommendation from the National Academies of Sciences, Engineering, and Medicine (NASEM), NASA recently commissioned a Mars Architecture Strategy Working Group (MASWG) to conduct a detailed analysis of the science and mission needs for exploring Mars beyond the planned MSR mission. The MASWG report was published in November 2020 with a variety of recommendations, which NASA will consider.

Investments in technology and in research and analysis (R&A) have continued to provide improvements in our capabilities to explore and understand Mars. Technology boosts, developed in partnership with STMD, are exemplified by Perseverance's landing, going to an exciting place only becoming accessible with improvements made by Terrain Relative Navigation. For R&A, using data from multiple spacecraft, the science community has been able to piece together the anatomy of a global dust storm, such as the one in 2018 that ended the Opportunity mission. We now understand the probable frequency and the progression of a global dust storm and its effects in warming the Mars atmosphere, changing circulation, and enhancing the loss of water to space. Another recent example is the now-recognized importance of water being absorbed into the crust – another significant process removing water from the Martian atmosphere.

Conclusion

Mars continues to be a popular place in our solar system. The United Arab Emirates and China both sent missions to Mars in 2020, traveling the “road” to Mars with Perseverance. NASA’s Mars Exploration Program continues to lead the world in learning about Mars and developing the technology that allows us to delve ever deeper into the secrets of the Red Planet, making significant progress on its goals: of searching for life, understanding Mars’ climate and geology, and preparing for human exploration.

I would be happy to answer any questions you may have.

Dr. Michael A. Meyer
Lead Scientist for the Mars Exploration Program
NASA Headquarters

Michael Meyer is a Senior Scientist at NASA Headquarters in the Science Mission Directorate. He is the Lead Scientist for NASA's Mars Exploration and for Mars Sample Return Programs, responsible for the science content of current and future Mars missions. Dr. Meyer is also Program Scientist for the Mars Science Laboratory/Curiosity mission. In 2009, Dr. Meyer was awarded Exceptional Service Medal and the Presidential Rank Award for Meritorious Professional Service.

Dr. Meyer was the Senior Scientist for Astrobiology from 2001 to 2006. The Program, which is dedicated to the study of the life in the universe, started in 1997 with Dr. Meyer as the Discipline Scientist. Since 1993, Dr. Meyer managed NASA's Exobiology Program and from 1994 to 1997, was also the Planetary Protection Officer for NASA, responsible for mission compliance to NASA's policy concerning forward and back contamination during planetary exploration. Dr. Meyer was the Program Scientist for the 2001 Mars Odyssey mission, which was launched in 2001 and is still orbiting Mars, and for the Mars Microprobe mission (DS-2) and for two Phase I Shuttle/Mir experiments. He was detailed from the Desert Research Institute, University of Nevada, where he was an assistant research professor from 1989-97. From 1985 to 1989, he served as associate director and associate in research for the Polar Desert Research Center, Department of Biological Science, Florida State University. In 1982, he was a visiting research scientist at the Culture Centre for Algae and Protozoa in Cambridge, England.

Dr. Meyer's primary research interest is in microorganisms living in extreme environments, particularly the physical factors controlling microbial growth and survival. He has conducted field research in the Gobi Desert, Negev Desert, Siberia, and the Canadian Arctic. He is also a veteran of six research expeditions to Antarctica, to study microbial ecosystems in the McMurdo Dry Valleys (1985/87), investigate krill-phytoplankton relations (1978/81), and research primary productivity in the Weddell Sea (1977). His experience also includes two summers working as a treasure salvager off the coasts of Florida and North Carolina.

Dr. Meyer earned his Ph.D. and M.S. in oceanography from Texas A&M University (1985 and 1981) and his B.S. in biology from Rensselaer Polytechnic Institute (1974).