National Aeronautics and Space Administration

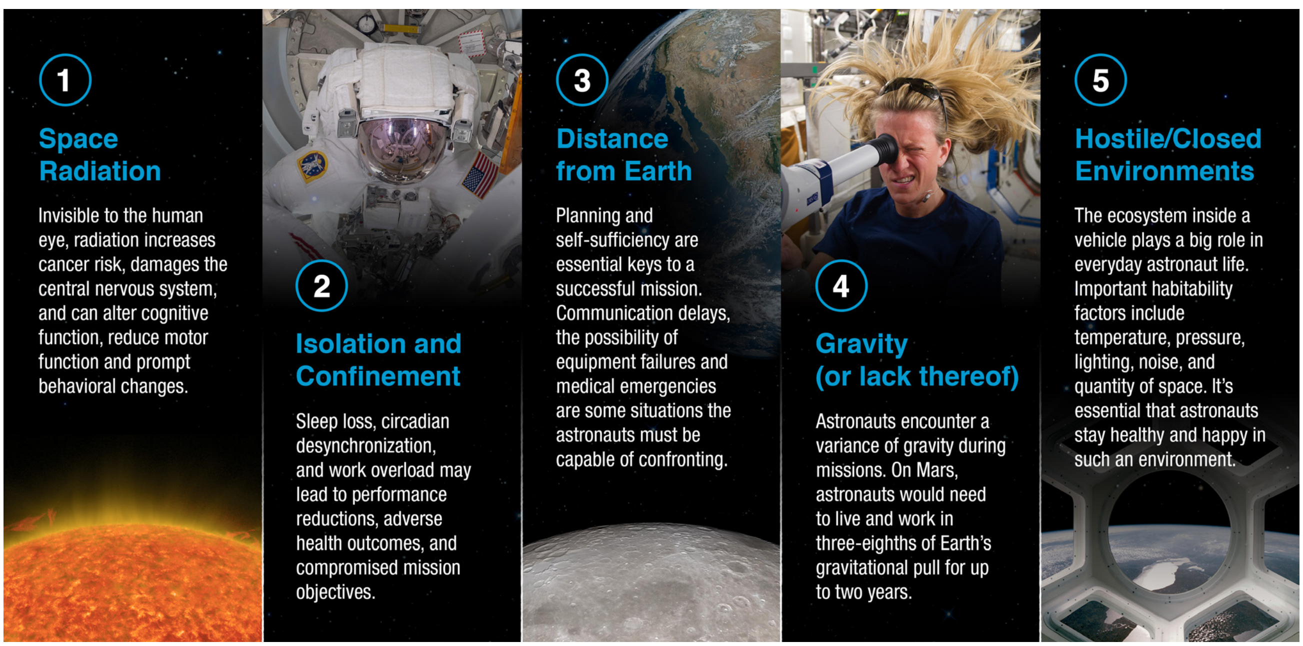
How Investing in the Moon Prepares NASA for First Human Mission to Mars

In summer of 2020, the world's eyes are set on Mars. As NASA prepares to launch the Perseverance Rover, China and UAE also take advantage of the launch window that occurs only every 26 months.

With dozens of planned robotic and human missions to the Moon as part of the Artemis program, NASA and its partners are designing Mars-forward technologies for the Moon in the 2020s to ensure smarter, safer human missions to Mars as early as the 2030s.

The top five hazards to crew during human spaceflight – altered gravity, radiation, hostile environment, isolation/confinement and distance from Earth – are already being studied through mission simulations on the ground and aboard the International Space Station in low-Earth orbit. Moving these simulations to the Moon, which is days away from home rather than hours, will allow the agency to test new deep space exploration systems and technologies, increasing the fidelity of the tests to prepare astronauts for long-duration spaceflight much farther from Earth.

To do so, NASA is prioritizing investments today in lunar exploration that will support successful human exploration of Mars in the future. These investments can be thought of in three categories: Understanding the Martian Environment, Common Moon-Mars systems and Mars-specific Technology Development.



The top five hazards of human spaceflight.

UNDERSTANDING THE MARTIAN ENVIRONMENT

Eight nations have sent a total of 55 attempted robotic missions to Mars; of those, only 28 have been successful. The combination of orbiters, landers, and rovers have helped uncover a remarkable and potentially turbulent history for the fourth planet. Scientists believe that Mars was once a "goldilocks" planet, meaning it is the right distance from the Sun to allow temperatures for water. Throughout time though, it lost most of its atmosphere and what water is left is trapped in ice due to the extremely cold temperatures.

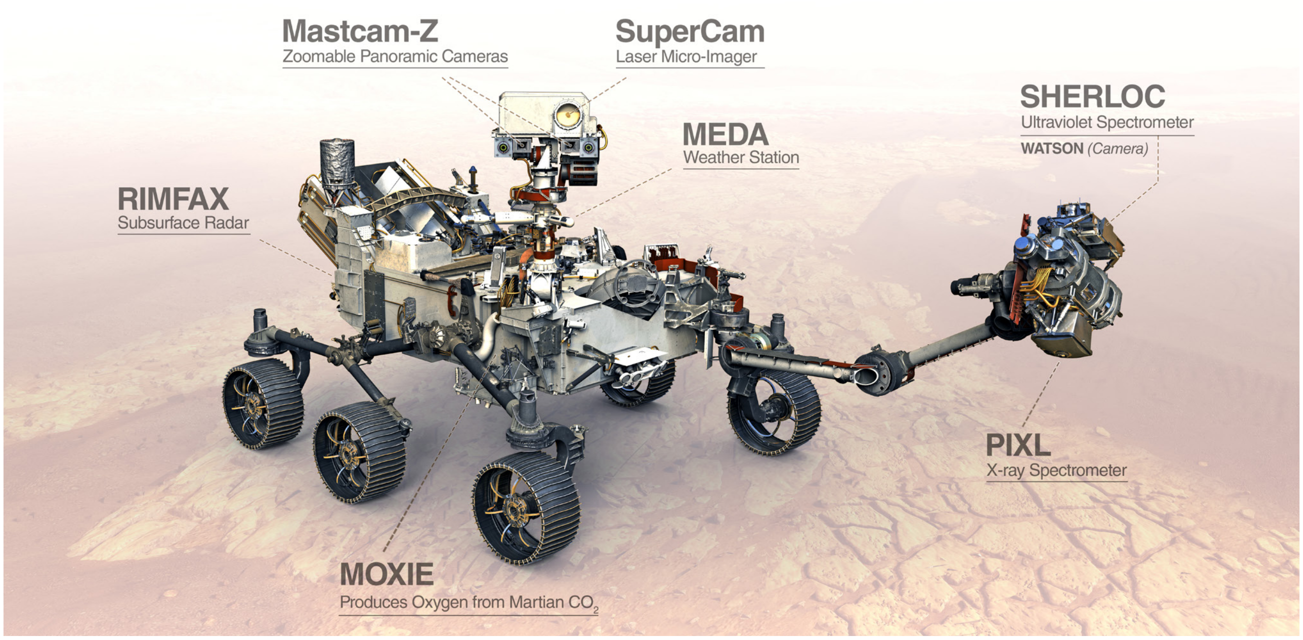
> "NASA has always set it sights on human exploration of Mars. Now with humans returning to the Moon in four years to establish sustainable lunar exploration by the end of the decade, we are able to clearly see the Moon is a critical stepping stone to the Red Planet. Learning to live and work on the Moon will bring us closer and closer to our next giant leap as we search for life farther in the solar system."

Jim Bridenstine,
NASA Administrator

That little bit of atmosphere remaining provides opportunity and challenge. An instrument on the Mars Curiosity rover determined the atmosphere is 95.9% carbon dioxide, with traces of other gases such as argon, nitrogen, oxygen and carbon monoxide. With this knowledge, we can develop technologies to harvest those elements and compounds from the atmosphere and break them down for other uses, such as breathing air for crew or propellant for spacecraft and other vehicles.

The challenge of the extremely thin Martian atmosphere is that it doesn't provide enough drag, or resistance, to make parachutes as useful as they are on Earth, so landing human-scale systems on Mars is a dangerous and difficult endeavor.

The Mars 2020 Perseverance rover mission is an important next step in exploration of Mars before we send humans 140 million miles away from home. The rover will have seven instruments aboard, two of which are paramount in the continued quest to get to know the Martian atmosphere:

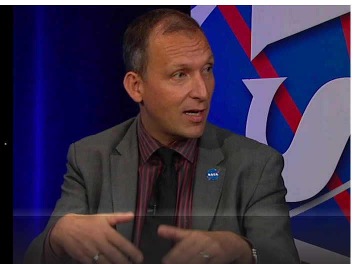


The Perseverance rover carries seven instruments to conduct its science and exploration technology investigations.

- MOXIE (Mars Oxygen In-Situ Resource Utilization Experiment) is an experiment that will produce oxygen from the Martian atmosphere; this type of technology could provide breathable oxygen and propellant to enable future human missions.
- MEDA (Mars Environmental Dynamics Analyzer) is a surface weather station contributed by Spain that will measure temperature, pressure, humidity, winds, radiation, and dust properties. This knowledge is important for designing systems for future human exploration and developing weather forecasting.

Future planned missions to Mars, such as the NASA collaboration with the Canadian Space Agency called Mars Ice Mapper, will give us more information about the planet and its resources in advance of human missions.

"We've been studying Mars for more than 50 years and maintained a robotic presence there since 1997. With the Perseverance rover, Ice Mapper and the Mars Sample Return missions all on the horizon, we're getting closer to answering questions like whether there was - or is - microbial life on the Red Planet. Sending robots on early missions to study the Martian environment, collect data and test technologies are critical to helping us determine where to best send astronauts to Mars in the future."



Thomas Zurbuchen, NASA Science Mission Directorate Associate Administrator

COMMON MOON-MARS SYSTEMS

Artemis missions will serve as a unique opportunity for the agency and its partners to test, refine, and perfect many of the technologies and complex operations needed for human exploration of Mars as early as the 2030s.

Starting next year, the agency is sending dozens of new science investigations and technology experiments on commercial robotic Moon deliveries about twice per year prior to a human return in 2024. These robots will test everything from landing technologies to searching for and measuring space-based resources, monitoring radiation and more.

The Artemis Space Launch System rocket that will send the Orion spacecraft and crew to lunar orbit can also send astronauts to deep space to board their Mars-bound transit habitat. NASA plans to test that habitat for several years as a visiting spacecraft aboard the Gateway in lunar orbit. Once it is cleared for Mars, future commercial cargo suppliers can deliver Mars supplies to outfit the transit habitat and refuel it for the journey.

On the lunar surface, NASA will build Mars-forward systems whenever possible. Rovers, spacesuits, surface habitation, and small power plants will be built with future Mars applicability in mind so that astronauts can gain experience using them and provide early feedback for improvements. As a result, nearly all of the systems deployed on the lunar surface will serve as prototypes for future Mars surface systems, including advanced life support technologies needed for the long transit to Mars.

Concept image showing multiple technologies at the Moon that can be applied to Mars.

The three companies working on NASA's Artemis human landing system (HLS) will face different entry, descent and landing (EDL) challenges than a Mars lander will, but the agency expects to glean significant Mars-forward experience from the ascent part of the HLS system that launches crew back to orbit after their expedition is complete. The mechanics of the ascent system and the cryogenic propellant storage solutions used to prevent loss or "boiloff" of cryogenic fuels will be particularly applicable to future Mars missions. Modern human landing systems also will use advanced terrain-relative navigation technologies to support autonomous precision landing that will provide real-time avoidance of hazards such as large rocks and steep slopes or previously emplaced mission assets.

After establishing an Artemis Base Camp on the lunar South Pole and subsequently expanding the Gateway's capabilities in orbit around the Moon, NASA will conduct a dress rehearsal for sending the first human to Mars. This includes sending a crew of four astronauts to the Gateway where they will split up for a multi-month mission to simulate a Mars operation.

For this practice run, two crew members will live and work aboard the orbiting outpost while the other two head to the lunar surface in a reusable human landing system. Eventually they will reunite back in space to continue working together aboard the Gateway before returning home in Orion.

In the process, we will learn about how to conduct human-led science in hostile space environments. For instance, we will learn how to collect and properly curate (how to store the samples to protect them from our environment and protect us from any hazards related to those samples) alien materials to ensure that scientists can conduct the most important scientific analyses on them back here on Earth.

MARS-SPECIFIC TECHNOLOGY DEVELOPMENT

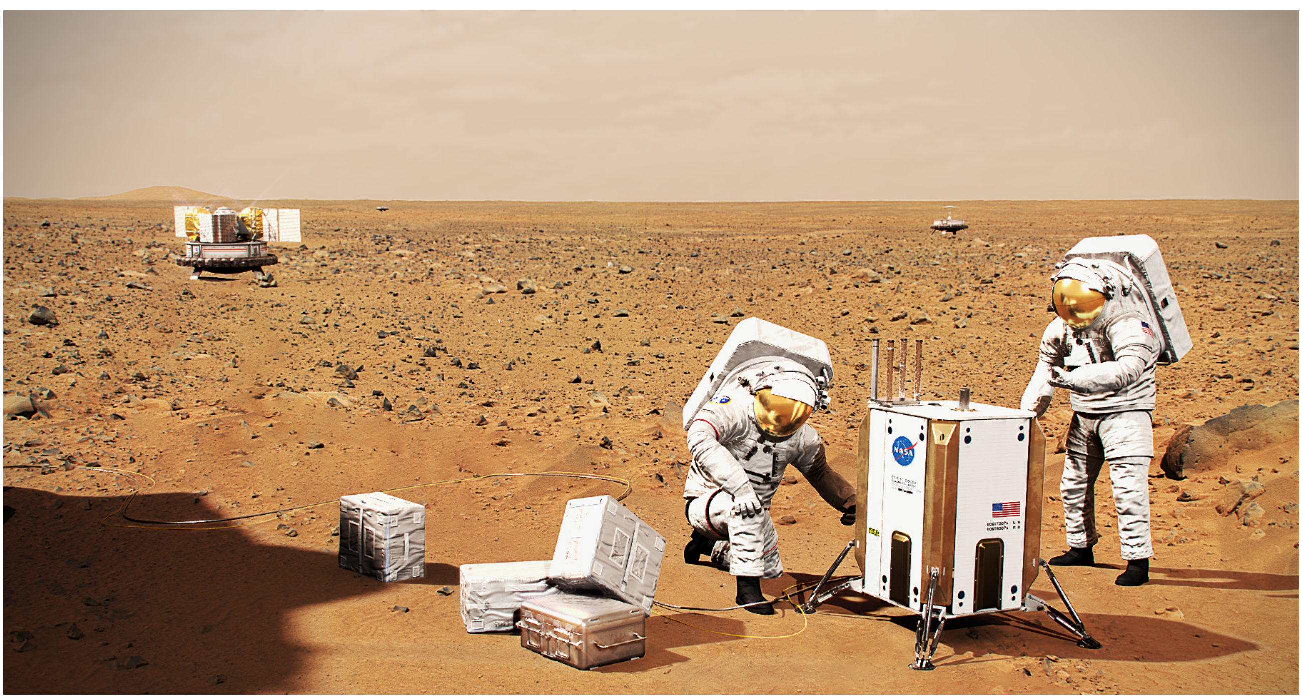
The top two key Mars-specific technologies that NASA is developing today include nuclear propulsion systems and EDL systems that represent the final sequence of events that take place before astronauts can step foot on Mars.

NASA is looking at multiple propulsion options for a human mission to Mars and evaluating each system's pros and cons. Nuclear propulsion systems are among the possibilities, including nuclear electric and nuclear thermal propulsion. NASA, the U.S. Department of Energy, and industry are studying both systems for a round-trip human Mars mission duration of about two years.

EDL systems are particularly challenging because of that thin Martian atmosphere that renders parachutes only slightly effective. Over the years, NASA has developed multiple successful Mars EDL technologies, but the largest payload landed to date—the Curiosity rover—was only about a metric ton; human landers will weigh about 20 times that much, so NASA is actively developing new solutions to gently land large payloads.

WHAT WILL THE FIRST HUMAN MISSION TO MARS LOOK LIKE?

NASA anticipates its first humans to land on Mars will spend about 30 days on the surface. Because Earth and Mars orbit the Sun at different speeds, Mars-bound spacecraft must chase Mars around the Sun. Once our spacecraft reach Mars, Earth is no longer where we left it, so our spacecraft will need to chase Earth back around the Sun to return home.



Concept image showing two astronauts set up a science experiment on Mars. The shadow of their rover looms from the left. In the background, landers that were pre-deployed to deliver the propellant and the ascent vehicle that they will use to launch back to orbit for their return trip home.

Conjunction class Mars missions prize energy-efficiency, launching from Earth when the two planets are aligned for the lowest energy transfer, and loitering in Mars vicinity for more than a year until the planets again align for optimum return. Conjunction-class missions are efficient--but very long--requiring astronauts to be away from Earth for up to three years.
Opposition class missions prize speed over efficiency by taking advantage of higher-energy propulsion technologies to shorten one leg of the transit. With a 30- to 45-day stay in Mars orbit before the return window closes, an opposition-class mission can reduce crew round-trip time to two years. With limited surface infrastructure on this first mission, NASA is eying this opposition-class mission, which limits crew time on surface.

Before humans arrive, NASA will pre-deploy surface systems and confirm their safe landing before sending crew. Chief among those systems is the Mars ascent vehicle and its required propellant that will ensure astronauts will be able to ascend back to Mars orbit to return home to Earth. A reliable surface power system will be needed to maintain critical ascent vehicle systems and recharge robotic assets as they scout the local area to identify the safest site for the crew to touch down. Because Mars has a day/night cycle similar to Earth and seasonal dust storms that can last for weeks or months, solar power is less reliable on Mars. A compact fission power system is being developed jointly by NASA and the Department of Energy and will be demonstrated on the Moon to power Artemis lunar surface assets. On Mars, such a surface power system, combined with the robust communications assets needed for this mission will enable crew-delivered science instruments to continue returning scientific data long after the first Mars crew has returned to Earth.

Artemis activities coupled with past and future robotic missions will pave the way for sending the first humans to Mars and showcasing why both robotic and human missions are necessary. Due to NASA's long history of robotic successes at Mars, humanity knows more about the Red Planet than we did about the Moon when we sent the first astronauts there in 1969 – but our innate human desire to explore cannot be satiated by robotic exploration alone.

"Astronauts bring understanding and emotion behind new discoveries – not just the facts, but their cumulative meaning to push the boundaries of exploration. People are intuitive, able to make rapid decisions as they take in new information, and they can cover more ground in a shorter amount of time. We also excel at adjusting in real-time: quickly adapting to change, solving unexpected challenges, and improvising to get the job done."

Kathy Lueders, NASA Human Exploration and Operations Mission Directorate Associate Administrator

Although human spaceflight has always focused around the Earth and Moon, the Artemis program will bridge the gap between what is needed for making humanity's next giant leap – human exploration of Mars – a reality.