National Aeronautics and
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MARS PERSEVERANCE
PRESS KIT

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Introduction

NASA's Mars 2020 Perseverance rover will land on Mars on Feb. 18, 2021. 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. It will collect carefully selected and documented rock and sediment 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 human exploration beyond the Moon.

Perseverance is also ferrying several cutting-edge technologies to the surface of Mars – including a helicopter named Ingenuity, the first aircraft to attempt powered, controlled flight on another planet.

7 Things to Know About the Mars 2020 Perseverance Mission

Very soon, the Perseverance rover, built at NASA's Jet Propulsion Laboratory in Southern California, will become the next robotic inhabitant of Mars, joining another rover, a lander, and multiple orbiters currently at work on or around the Red Planet. What sets this explorer apart?

1. Perseverance is searching for signs of ancient life.

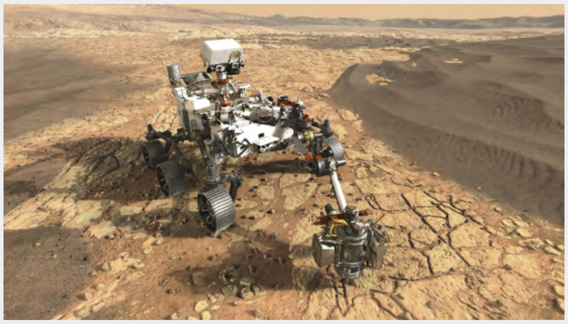


Image credit: NASA/JPL-Caltech

Previous NASA missions have discovered evidence that Mars once hosted running water before becoming a frozen desert. Earlier in its history, Mars had warmer environments at the surface that could have supported microbial life. Perseverance aims to take the next step, seeking, as a primary goal, to answer one of the key questions of astrobiology: Are there signs (or biosignatures) of past microbial life on Mars?

This demanding science goal requires a new suite of cutting-edge instruments to tackle the question from many angles.

Two of them will 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.

2. The rover is landing in a place with a high potential for finding these signs of past microbial life.

Image credit: ESA/DLR/FU-Berlin

Terrain that is interesting to scientists can be challenging to land on. Thanks to new technologies that enable Perseverance to target its landing site more accurately and avoid landing hazards autonomously, the spacecraft can safely touch down in an intriguing ancient river delta with steep cliffs, sand dunes, and boulder fields.

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 there flowed into a body of water about the size of Lake Tahoe, depositing sediments in a fan shape known as a delta. The Perseverance science team believes this ancient river delta and lake deposits could have collected and preserved organic molecules and other potential signs of microbial life.

3. Perseverance is also collecting important data about Mars' geology and climate.

Image credit: NASA/JPL-Caltech

Context is everything. Mars orbiters have been collecting images and data from Jezero Crater from about 200 miles (322 kilometers) above, but finding signs of ancient life on the surface requires much closer inspection. It requires a rover like Perseverance. Understanding Mars' past climate conditions and reading the geological history embedded in its rocks will give scientists a richer sense of what the planet was like in its distant past. Studying the Red Planet's geology and climate could also give us a sense of why Earth and Mars – despite some early similarities – ended up so different.

4. The Perseverance rover embodies the NASA – and the scientific – spirit of overcoming challenges.

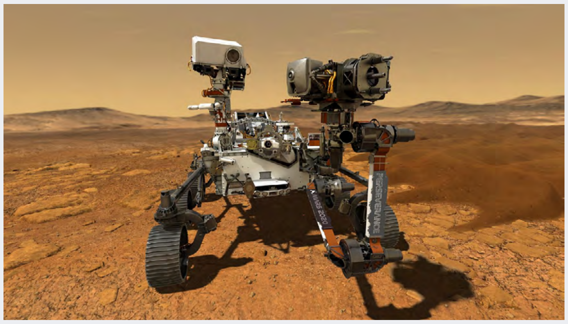


Image credit: NASA/JPL-Caltech

Getting the spacecraft to the launch pad during a pandemic, searching for signs of ancient life, collecting samples, and proving new technologies are no easy feats. Nor is a soft touchdown on Mars: Only about 50% of Martian landing attempts, by any space agency, have been successful.

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.

5. Perseverance is the first leg of a round trip to Mars.

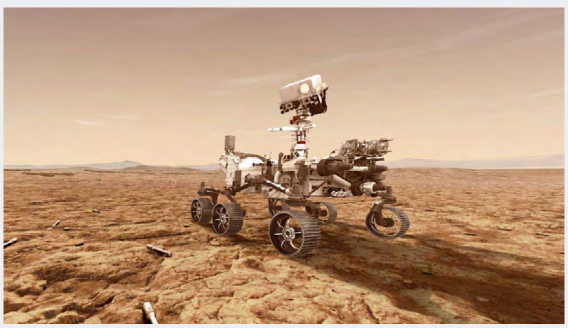


Image credit: NASA/JPL-Caltech

The verification of ancient life on Mars carries an enormous burden of proof. 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.

Rather than pulverizing rock the way Curiosity's drill does, Perseverance's drill will cut intact rock cores that are about the size of a piece of chalk and will place them in sample tubes that it will store until the rover reaches an appropriate drop-off location on Mars. The rover could also potentially deliver the samples to a lander that is part of the planned Mars sample return campaign by NASA and ESA (the European Space Agency).

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.

6. Perseverance carries instruments and technology that will help pave the way for future human missions to the Moon and Mars.

Among the future-looking technologies on the Mars 2020 Perseverance mission that will benefit human exploration is Terrain-Relative Navigation. As part of the spacecraft's landing system, Terrain-Relative Navigation is the main reason Perseverance can explore a place as interesting as Jezero Crater. It will enable the descending spacecraft to quickly and autonomously comprehend its location over the Martian surface and modify its trajectory. This technology will provide invaluable assistance for both robotic and crewed missions landing on the Moon.

Image credit: NASA

Perseverance will also have 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 – a proof-of-concept experiment – called Mars Oxygen In-Situ Resource Utilization Experiment (MOXIE). This instrument will produce oxygen from Mars' carbon dioxide atmosphere, demonstrating a way that future explorers might produce oxygen for rocket propellant as well as for breathing.

Two other instruments will help engineers design systems for future human explorers to land and survive on Mars: The MEDLI2 (Mars Entry, Descent, and Landing Instrumentation 2) package is a next-generation version of what flew on the Mars Science Laboratory mission that delivered the Curiosity rover, while the MEDA (Mars Environmental Dynamics Analyzer) instrument suite provides information about weather, climate, and surface ultraviolet radiation and dust.

7. You will get to ride along.

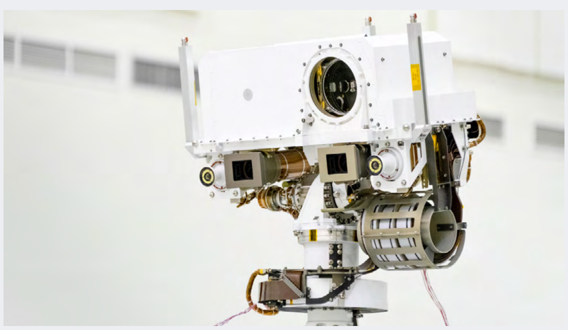


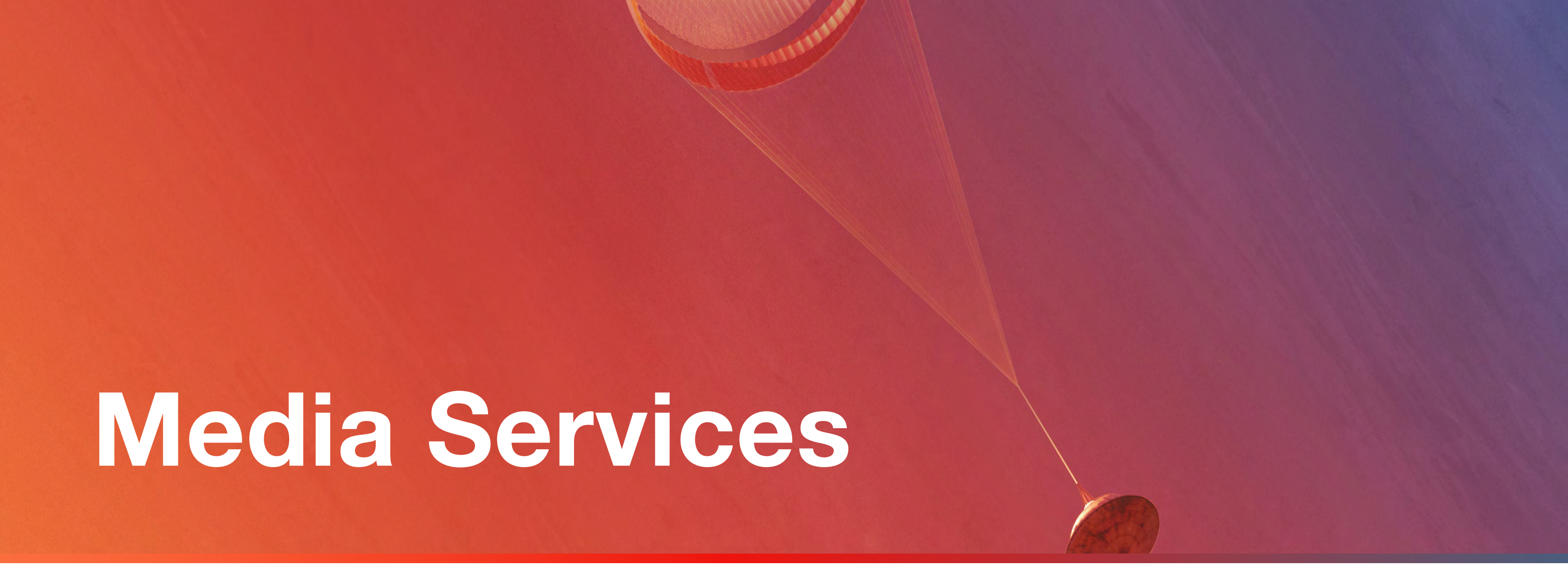
Image credit: NASA/JPL-Caltech

The Mars 2020 Perseverance mission carries more cameras than any 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. As with previous Mars missions, the Mars 2020 Perseverance mission plans to make raw and processed images available on the mission's website.

If all goes well, the public will be able to experience in high-definition what it's like to land on Mars – and hear the sounds of landing for the first time with an off-the-shelf microphone affixed to the side of the rover. Another microphone on SuperCam will help scientists understand the property of rocks the instrument is examining and can also listen to the wind.

If you are among the 10.9 million people who signed up to send your name to Mars, your name is stenciled on one of three silicon chips embedded on a plate on the rover that carries the words "Explore as one" in Morse code.

You can also follow Perseverance's adventure on social media via **@NASAPersevere** and **@NASAMars** on Twitter and Facebook, and the hashtag **#CountdownToMars**.



Media Services

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Scanning Habitable Environments with Raman & Luminescence for Organics & Chemicals (SHERLOC)

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Products and Events

News Releases, Features, and Status Reports

Mission news, updates, and feature stories about the Mars 2020 Perseverance mission will be available at nasa.gov/perseverance and mars.nasa.gov/perseverance

The latest information about landing activities can be found on the mission's landing page.

Video and Images

A Mars 2020 Perseverance mission media reel is available at the NASA Image and Video Library at https://go.nasa.gov/perseverance-b-roll.
A collection of Perseverance rover and Ingenuity Mars Helicopter videos is also available at https://vimeo.com/showcase/7377243.

Additional images related to the Perseverance rover are available at the NASA Image and Video Library, the mission website's gallery, and Planetary Photojournal.

The NASA image use policy is available here.
The JPL image use policy is available here.

Media Events

The most up-to-date information about upcoming Mars 2020 Perseverance mission media events and where they may be viewed can be found on the Mars 2020 Landing Toolkit page. More information on NASA Television and streaming channels can be found below in the Watch Online section.

Briefings and Availabilities

A virtual news conference previewing the Mars landing will take place on **Jan. 27, 2021**, at **4:30 p.m. EST (1:30 p.m. PST)**. Members of the media may dial into a telecon line to ask questions by contacting Rexana Vizza, rexana.v.vizza@jpl.nasa.gov. Members of the public can submit questions via social media with the tag **#CountdownToMars**.

Pre-landing news conferences open to accredited news media are scheduled for **Feb. 16** and **17**, originating from JPL. Because of the ongoing coronavirus pandemic, media participation in these briefings will be virtual. Members of the media interested in asking questions during the briefing should contact Rexana Vizza, rexana.v.vizza@jpl.nasa.gov.

A post-landing news conference at JPL is expected to begin approximately an hour and a half after landing.

Additional news conferences after landing will be scheduled as events warrant.

All news briefings will be broadcast and streamed.

Interviews with mission team members may be arranged by calling the JPL newsroom at **818-354-5011** or filling out the form at https://bit.ly/mars-landing-media.

Live Landing Feed

A live video feed of key landing activities and commentary from the mission control areas at JPL will be broadcast. This live commentary show is expected to begin at **2:15 p.m. EST (11:15 a.m. PST)** and last for about two hours.

A Spanish-language simulcast will also be available on the NASA en Español YouTube channel.

On-Site Media Logistics

News media representatives who would like to cover the Mars 2020 Perseverance landing in person at JPL must be accredited in advance.

Due to the ongoing COVID-19 pandemic, JPL will be credentialing a limited number of media for on-site access. State and local restrictions, as well as federal guidelines, will determine the scope of and rules for in-person activities and are subject to change. Only U.S. citizens or green card holders representing U.S. media outlets and U.S.-based reporters for international outlets will be considered for credentials. Requests must have been submitted by **Jan. 14, 2021**, to Rexana Vizza, rexana.v.vizza@jpl.nasa.gov.

NASA will provide ample opportunities for members of the media to cover the landing remotely, including virtual participation in news briefings.

Members of the media interested in in-person interviews (subject to coronavirus restrictions) may call the JPL newsroom at **818-354-5011**.

How to Watch (Live and On Demand)

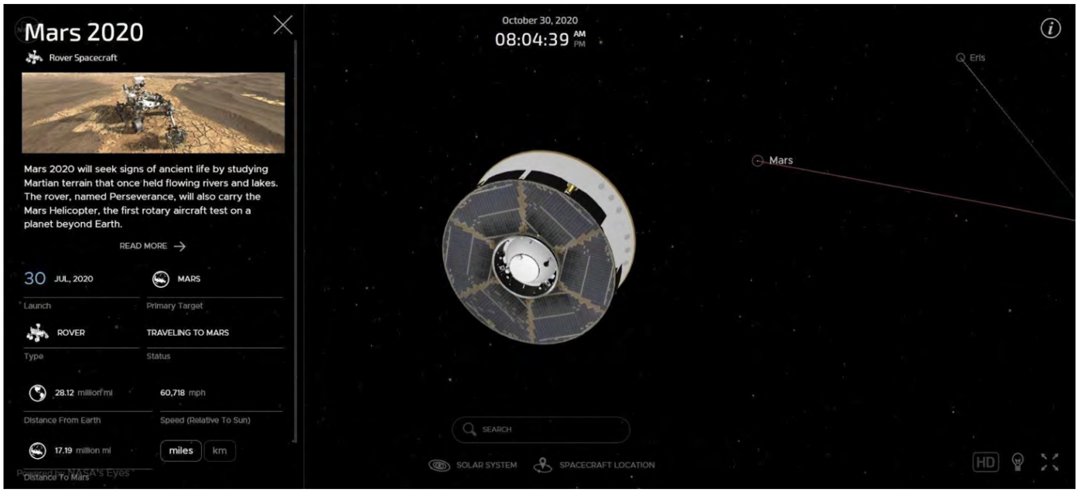
News briefings and landing commentary will be streamed on NASA TV, NASA.gov/live, and YouTube.com/NASA. (On-demand recordings will also be available after the live events have finished on YouTube.) Any additional feeds or streams will be listed in the Watch Online section of the Mars 2020 Perseverance mission website.

NASA TV channels are digital C-band signals carried by QPSK/DVB-S modulation on satellite Galaxy-13, transponder 11, at 127 degrees west longitude, with a downlink frequency of 3920 MHz, vertical polarization, data rate of 38.80 MHz, symbol rate of 28.0681 Mbps and 3/4 FEC. A Digital Video Broadcast-compliant Integrated Receiver Decoder is needed for reception. For more information about NASA TV's programming schedule, visit http://www.nasa.gov/ntv.

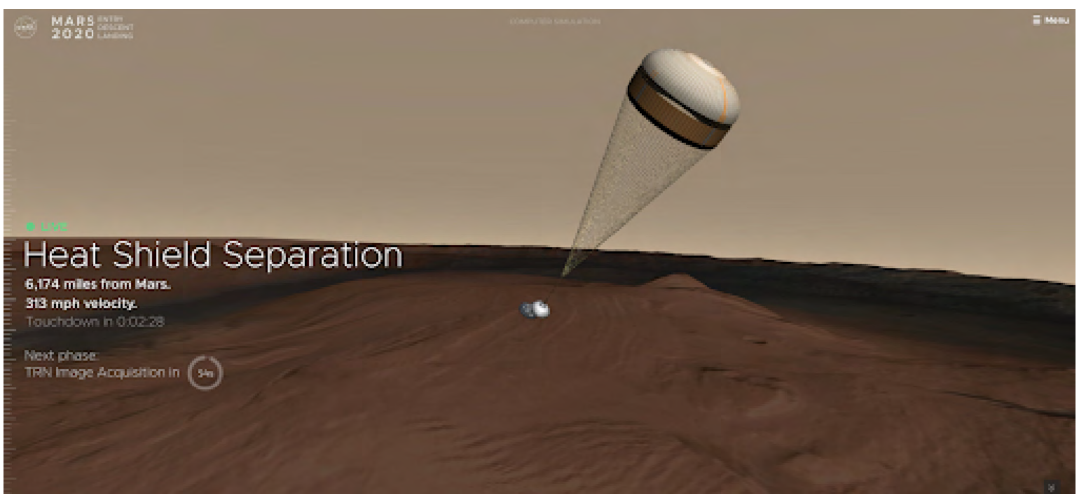
A clean feed of mission activities will also be available on the NASA TV media channel and YouTube.com/JPLRaw.

Eyes on the Solar System

Follow the journey of Mars 2020 Perseverance in real time through NASA's Eyes on the Solar System.



Follow along as Perseverance lands on mars at https://eyes.nasa.gov/apps/mars2020.



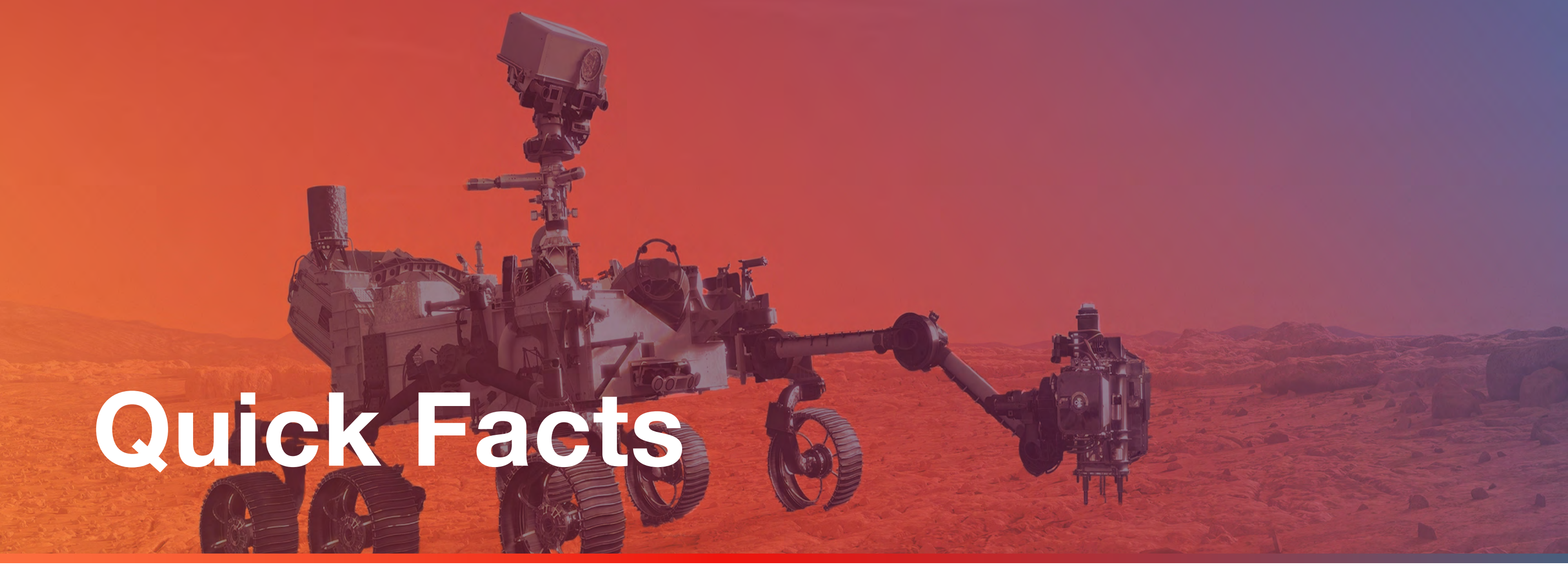
Additional Resources on the Web

Online and PDF versions of this press kit are available at go.nasa.gov/perseverance-landing-press-kit.
The Ingenuity Mars helicopter press kit is available at go.nasa.gov/ingenuity-press-kit.
Additional detailed information about the Perseverance rover is available on the mission's website.

Social Media

Join the conversation and get mission updates from the Perseverance rover, the Ingenuity Mars Helicopter, JPL, and NASA via these accounts:

- Twitter: @NASAPersevere, @NASAJPL, @NASAMars, @NASA
- Facebook: /NASAPersevere, /NASAJPL, /NASAMars, /NASA
- Instagram: @NASAJPL, @NASA



Quick Facts

Mission Names

Mars 2020

The overall name of the mission, which includes the rover.

Rover

Perseverance, submitted by Alex Mather of Lake Braddock Secondary School in Burke, Virginia.

Spacecraft

Mars 2020 Perseverance mission major components

Perseverance rover, cruise stage (to fly to Mars), aeroshell (which includes the back shell and heat shield to protect the rover as it descends toward the surface), and descent stage (which performs the sky crane maneuver to lower the rover to the surface).

Image credit: NASA/JPL-Caltech/KSC

Perseverance Rover

Image credit: NASA/JPL-Caltech

Weight: About 2,260 pounds (1,025 kilograms) on Earth, including the robotic arm with a 99-pound (45-kilogram) turret at the end, and about 866 pounds (393 kilograms) on Mars.

Dimensions: About 10 feet long (not including the arm), 9 feet wide, and 7 feet tall (about 3 meters long, 2.7 meters wide, and 2.2 meters tall); the robotic arm is about 7 feet (2.1 meters) long.

Payload Instruments: 130 pounds (59 kilograms) for seven instruments: Mastcam-Z, Mars Environmental Dynamics Analyzer (MEDA), Mars Oxygen In-Situ Resource Utilization Experiment (MOXIE), Planetary Instrument for X-ray Lithochemistry (PIXL), Radar Imager for Mars' Subsurface Experiment (RIMFAX), Scanning Habitable Environments with Raman & Luminescence for Organics & Chemicals (SHERLOC), and SuperCam.

Sample Caching System: One bit carousel with 9 drill bits for sample acquisition and surface abrasion, one 1.6-foot-long (0.5-meters-long) internal sample handling arm, and 43 sample collection tubes, including 5 "witness" tubes.

Power: Multi-Mission Radioisotope Thermoelectric Generator (MMRTG) provided by the U.S. Department of Energy that uses the heat from the radioactive decay of plutonium-238 to generate a steady flow of about 110 watts of electricity. Two lithium-ion rechargeable batteries are available to meet power and energy demands during rover activities and are recharged by the MMRTG's electrical output during quiescent periods.

Microphones: One on SuperCam to support instrument science and one on the port side of the rover for entry, descent, and landing, surface engineering, and public engagement.

Cameras

The Mars 2020 mission is ferrying 25 cameras to the Red Planet – the most ever flown in the history of deep-space exploration. Twenty-three are part of the Mars 2020 spacecraft and 2 are on the Ingenuity Mars Helicopter.

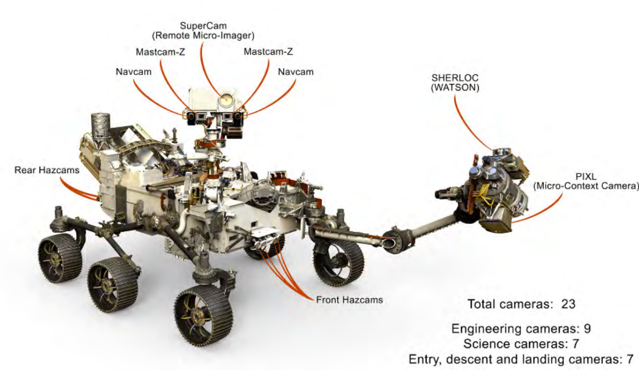


Image credit: NASA/JPL-Caltech

19 cameras on the rover: 9 color cameras for engineering; 3 cameras for entry, descent, and landing (1 black-and-white dedicated to Terrain-Relative Navigation and 2 color for public engagement and engineering reconstruction of entry, descent, and landing); 2 color cameras with zoom for Mastcam-Z; 1 color camera for SuperCam; 2 color cameras for SHERLOC; 1 for black-and-white with some color capabilities for PIXL; and 1 black-and-white for MEDA.

3 color cameras on the back shell, looking up to capture parachute inflation.

1 color camera on the descent stage, looking down to view the rover from above.

Mission

Launch: July 30, 2020, 7:50 a.m. EDT (4:50 a.m. PDT).

Launch site: Space Launch Complex 41, Cape Canaveral Air Force Station, Florida.

Launch vehicle: United Launch Alliance (ULA) Atlas V 541.

Spacecraft's distance to travel, Earth to Mars (July 30 launch): 293 million miles (471 million kilometers).

Surface Mission

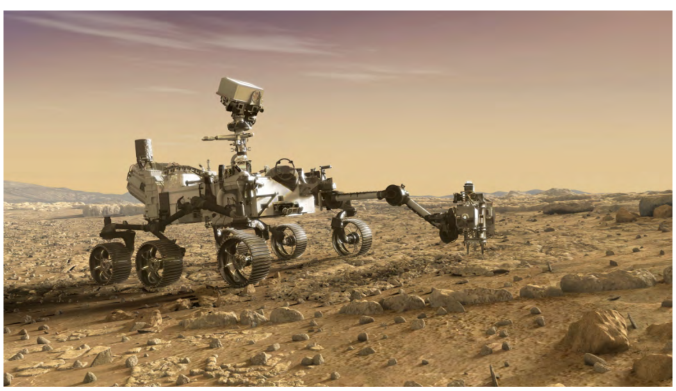


Image credit: NASA/JPL-Caltech

Time of Mars landing: Feb. 18, 2021, 3:55 p.m. EDT (12:55 p.m. PDT). The time of day at the landing site will be 3:53 p.m. local mean solar time. Landing site: Jezero Crater, about 18 degrees north latitude, 77 degrees longitude

One-way light time (the time it takes radio signals to travel): Mars to Earth, on Feb. 18, 2021: about 11 minutes, 22 seconds.

Prime mission duration: One Mars year (about 687 Earth days).

Sampling capability: More than 30 samples.

Mars

Image credit: NASA/JPL-Caltech

Size: About half the diameter of Earth but twice the diameter of Earth's Moon. As a desert planet, Mars has about the same amount of surface area as the dry land on Earth.

Mass: About 10% that of Earth

Gravity: About 38% as strong as Earth's

Orbit: Elliptical and about 1.5 times farther from the Sun than Earth is (about 141.5 million miles or 227.7 million kilometers from the Sun, on average)

Year: 1 Mars year (1 revolution about the Sun) takes 687 Earth days

Day: 1 Mars day or sol (1 rotation) is 1.027 longer than an Earth day (24 hours, 39 minutes, 35 seconds)

Atmosphere: About 1% the density of Earth's atmosphere at the surface

Temperature: Surface temperature averages minus 64 degrees Fahrenheit (minus 53 degrees Celsius); varies from minus 199 degrees Fahrenheit (minus 128 degrees Celsius) during polar night to 80 degrees Fahrenheit (27 degrees Celsius) at equator during midday at the closest point in orbit to the Sun

Distance from Earth on Feb. 18, 2021: 127 million miles (205 million kilometers).

Program

NASA has invested approximately $2.4 billion to build and launch the Mars 2020 Perseverance mission. The estimate to land and operate the rover during its prime mission is approximately $300 million.

Mission: Overview

The Mars 2020 mission spacecraft, carrying the Perseverance rover, launched from Cape Canaveral, Florida, on July 30, 2020. The spacecraft will arrive at Mars about six-and-a-half months later, on Feb. 18, 2021.

Key phases of the Mars 2020 mission are launch, cruise, arrival (also known as entry, descent, and landing), and Mars surface operations.

During a prime mission that will last one Mars year (about 687 Earth days), Perseverance's exploration of Jezero Crater will address high-priority science goals for Mars exploration. A key objective for Perseverance's mission on Mars is astrobiology, including the search for signs of ancient microbial life. The rover will also characterize the planet's climate and geology, pave the way for human exploration of the Red Planet, and be the first planetary mission to collect and cache Martian rock and regolith (broken rock and dust).

The Ingenuity Mars Helicopter, a technology demonstration, is also riding along to Mars, attached to the belly of Perseverance. More information about its mission is in the helicopter's press kit.

Launch

The Mars 2020 spacecraft, with the Perseverance rover and the Ingenuity Mars Helicopter inside, lifted off from Space Launch Complex 41 at Cape Canaveral Air Force Base on July 30, 2020, at 7:50 a.m. EDT (4:50 a.m. PDT) aboard a two-stage United Launch Alliance (ULA) Atlas V 541 launch vehicle.

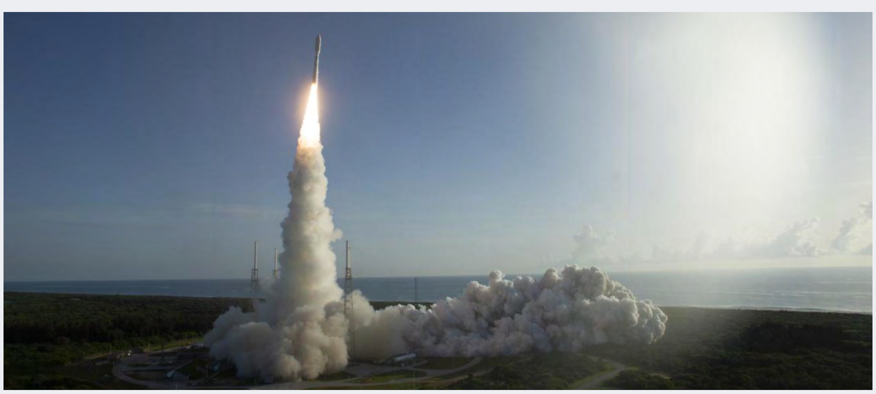


Image credit: NASA/Joel Kowsky

Why did Perseverance launch in the summer of 2020? As Earth and Mars race around the Sun, with Earth on the inside track, Earth laps Mars about once every 26 months. Launch opportunities to Mars occur at the same frequency, when the planets are positioned so that a spacecraft launched from Earth will be on a relatively short track to Mars (taking on the order of months rather than years to arrive at Mars). This planetary clockwork, plus the launch vehicle's lift capability, the spacecraft's mass, and the desired geometry and timing for the landing on Mars were all factors in determining the range of possible launch dates.

One priority for choosing this launch period and arrival date was to make sure Perseverance could land when NASA orbiters at Mars will be passing over the landing site. Such scheduling allows the orbiters to receive radio transmissions from the spacecraft carrying Perseverance during its descent through the atmosphere and landing. Landing on Mars is always difficult, and NASA prioritizes communications during this critical event.

Interplanetary Cruise

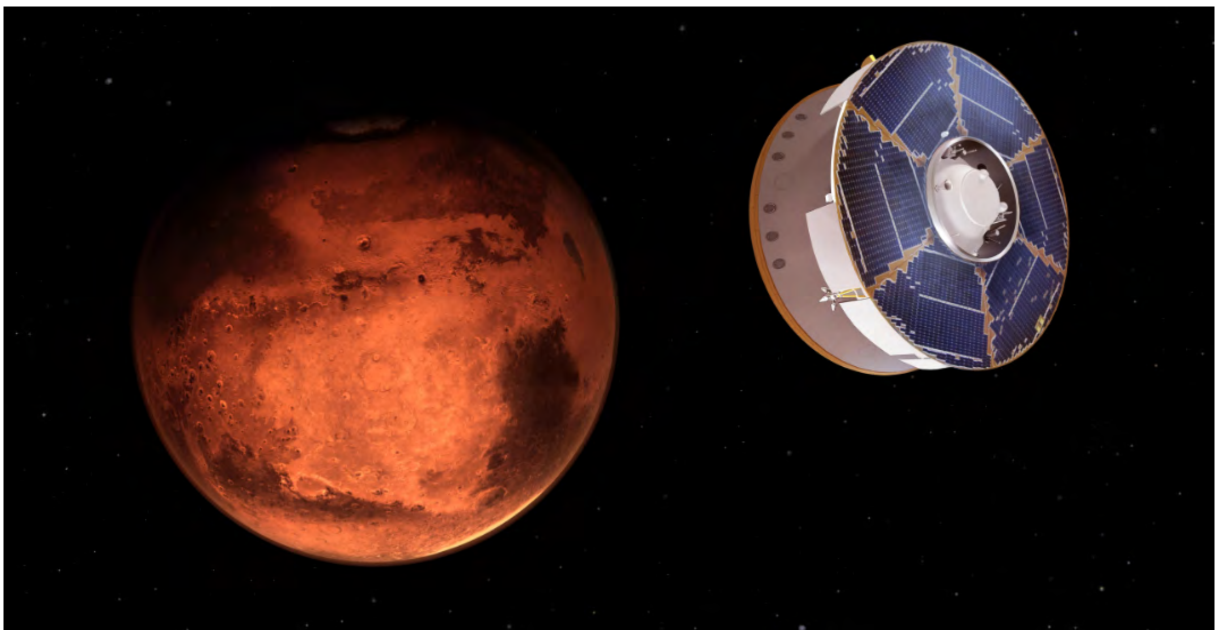


Image credit: NASA/JPL-Caltech

Perseverance requires 203 days to travel about 293 million miles (471 million kilometers) from Earth to Mars. This is the cruise phase of the mission. The final 45 days of the cruise phase make up the approach subphase.

During cruise, the Perseverance rover and its descent stage are protected inside a capsule known as an aeroshell, which is attached to the ring-shaped, solar-powered cruise stage. For more information about the cruise stage, aeroshell, and descent stage, visit the Spacecraft section of this press kit.

During cruise, engineers perform a series of events to check the spacecraft subsystems and instruments. They also plan to execute four trajectory correction maneuvers. For these feats of navigation, mission team members estimate where the Mars 2020 spacecraft is and where it will be, and precisely fire the cruise stage thrusters to alter its path to make sure it arrives at a particular location at the top of the Martian atmosphere. These trajectory correction maneuvers will not significantly change the time Perseverance lands on Mars.

The final 45 days leading up to landing constitute the approach subphase, which focuses primarily on navigation activities and preparing the vehicle for entry, descent, and landing. Two trajectory correction maneuvers are planned during this subphase for any last adjustments (if needed) to the entry target.

Entry, Descent, and Landing

Image credit: NASA/JPL-Caltech

The intense entry, descent, and landing (EDL) phase begins when the spacecraft reaches the top of the Martian atmosphere, traveling at about 12,100 mph (19,500 kph). EDL ends about seven minutes later, with the rover stationary on the Martian surface. Many engineers refer to the time it takes to land on Mars as the "seven minutes of terror." Not only is the choreography of EDL complex, but the time delay involved in communicating with Earth means that the spacecraft has to accomplish this choreography all by itself.

While all landings on Mars are difficult, Perseverance is landing in the most challenging terrain ever targeted. Jezero Crater is a 28-mile-wide (45-kilometer-wide) impact basin with an intriguing ancient river delta as well as steep cliffs, sand dunes, boulder fields, and smaller impact craters. Landing at Jezero Crater is only possible because of new EDL technologies such as Range Trigger and Terrain-Relative Navigation. (Find more information on both below.)

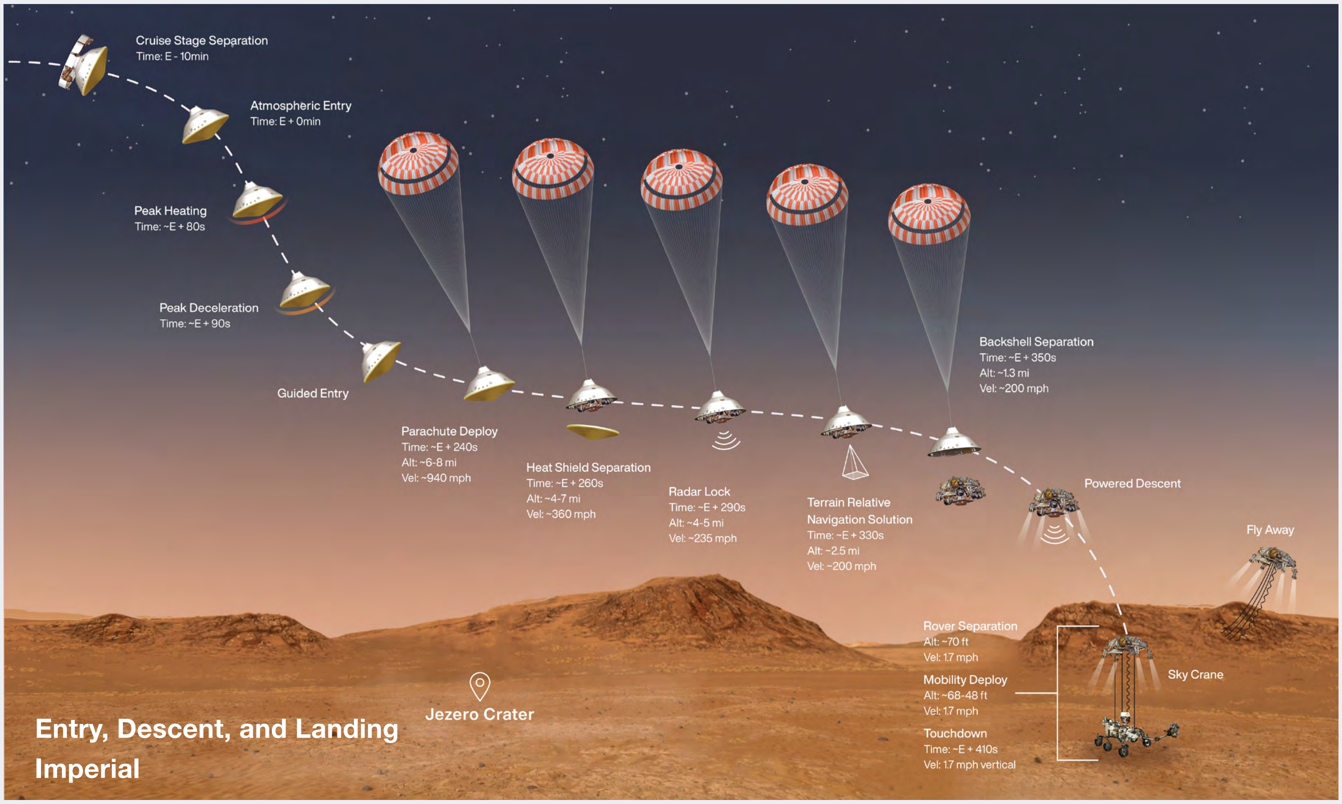


Image credit: NASA/JPL-Caltech

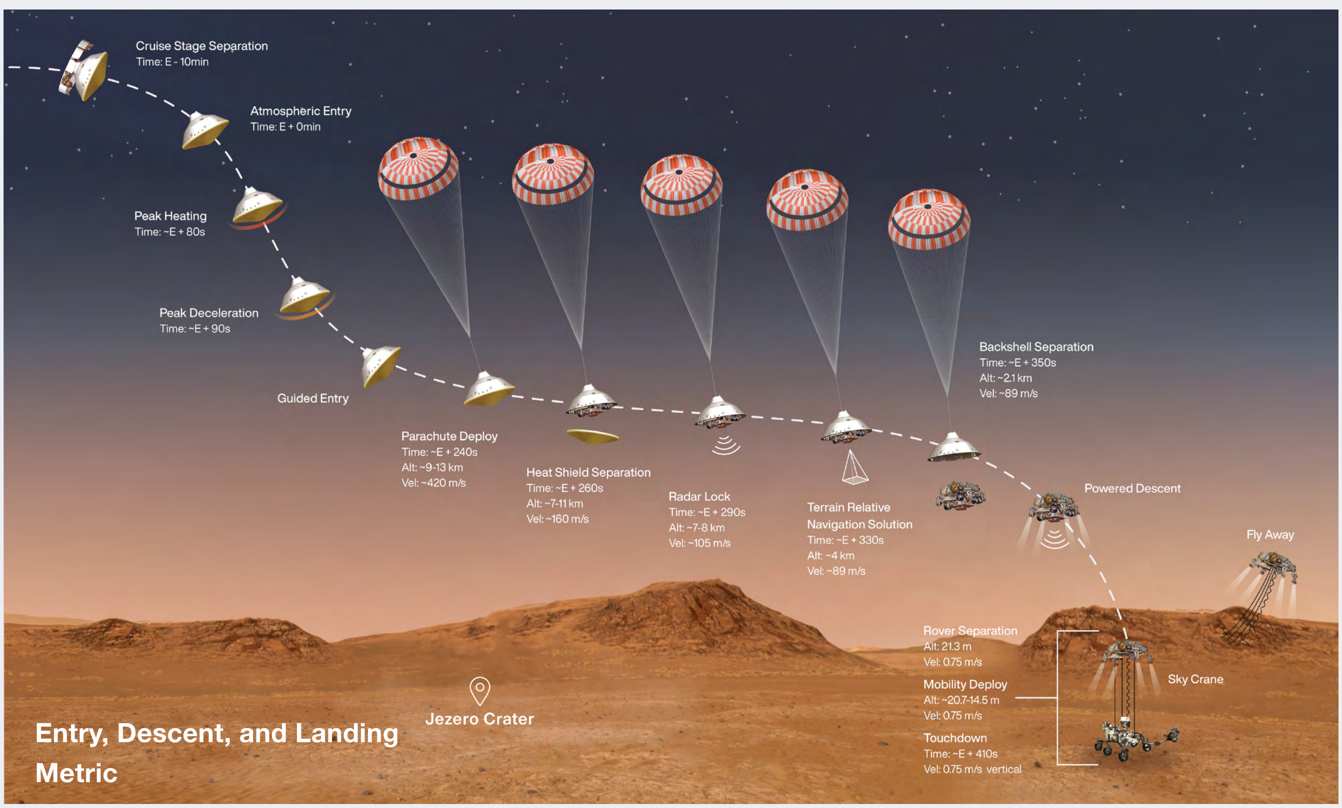


Image credit: NASA/JPL-Caltech

Key EDL Milestones

If all goes as planned, engineers expect to receive notice of Perseverance's completion of these milestones at the times below. Landing time may vary by plus or minus one minute because of a variety of factors in the dynamic environment of a Mars landing, such as uncertainties about the Red Planet's atmosphere. Because of the distances the signals have to travel from Mars to Earth, these events take place on the actual spacecraft at Mars (known as spacecraft event time) 11 minutes and 22 seconds earlier than what is noted here.

Milestone	EST	PST
Cruise stage separation	3:38 p.m.	12:38 p.m.
Atmospheric entry	3:48 p.m.	12:48 p.m.
Peak heating	3:49 p.m.	12:49 p.m.
Parachute deployment	3:52 p.m.	12:52 p.m.
Heat shield separation	3:52 p.m. *(20 seconds after parachute deployment)*	12:52 p.m. *(20 seconds after parachute deployment)*
Back shell separation	3:54 p.m.	12:54 p.m.
Rover touchdown	3:55 p.m.	12:55 p.m.

Atmospheric Entry

At about 3:38 p.m. EST (12:38 p.m. PST) – 10 minutes before entering the Martian atmosphere – the Mars 2020 spacecraft will shed the cruise stage that helped fly Perseverance and Ingenuity to Mars. The spacecraft will manipulate its descent into Mars' atmosphere using a technique called guided entry to reduce the size of the targeted ellipse-shaped landing area on Mars while compensating for variations in the density of the Martian atmosphere and drag on the vehicle. During guided entry, small thrusters on the back of the aeroshell will adjust the angle and direction of lift, enabling the spacecraft to control how far downrange it is flying.

Peak heating occurs about 75 seconds after atmospheric entry, when the temperature at the external surface of the heat shield will reach about 2,370 degrees Fahrenheit (about 1,300 degrees Celsius). About three minutes later, Perseverance's parachute is expected to deploy with the help of a new technique called Range Trigger.

New EDL Technologies

During EDL, Range Trigger will autonomously update the deployment time for the parachute based on navigation position. It will calculate the spacecraft's distance to the landing target and open the parachute at the ideal time for the spacecraft to hit its mark. The result: a smaller, more precise landing ellipse, or target landing area. The landing ellipse for Perseverance is 10 times smaller in area than the Curiosity rover's in 2012 and almost 300 times smaller than that of the first Mars rover, Sojourner, in 1997.

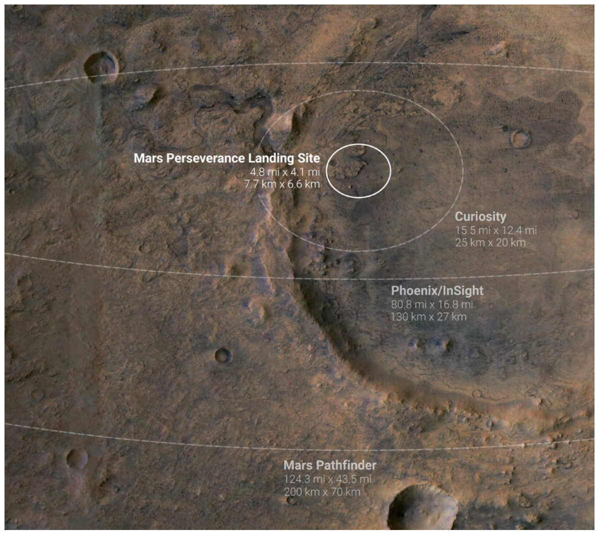


Image credit: NASA/JPL-Caltech

The parachute, which is 70.5 feet (21.5 meters) in diameter, deploys about 240 seconds after entry, at an altitude of about 7 miles (11 kilometers) and a velocity of about 940 mph (1,512 kph). Twenty seconds after parachute deployment, the heat shield separates and drops away, revealing a radar and cameras that feed into the other new landing technology, called Terrain-Relative Navigation. Terrain-Relative Navigation is a kind of autopilot that can quickly figure out the spacecraft's location over the Martian surface and select the best reachable safe landing target.

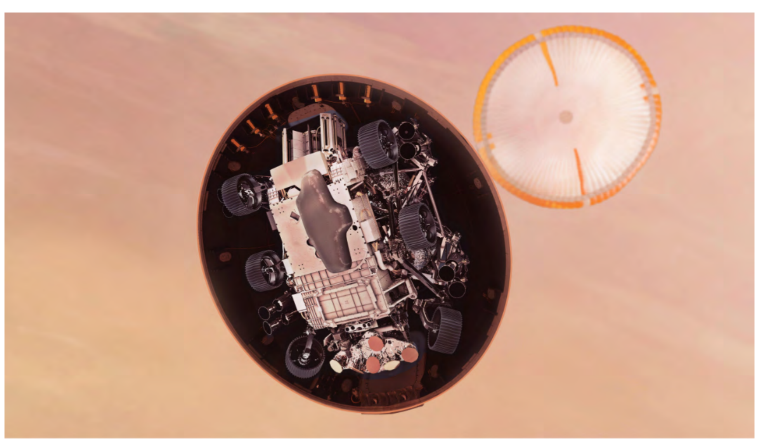


Image credit: NASA/JPL-Caltech

Previous Mars missions have relied on radar to help the spacecraft determine how far they are from the ground and how fast they are going during landing. Perseverance has data from a radar and something new called the Lander Vision System. The radar actively pings the ground from the time the heat shield comes off (about 4 to 5 miles, or 7 to 8 kilometers, above the surface) all the way to touchdown. The Lander Vision System, part of the Terrain-Relative Navigation technology, operates when the spacecraft is between about 2.6 to 1.4 miles, or 4.2 to 2.2 kilometers, above the ground. Terrain-Relative Navigation can change the rover's touchdown point by up to 2,000 feet (600 meters).

The Lander Vision System's job is to determine the rover's position, handling different possible terrain conditions, within an accuracy of about 130 feet (40 meters) in less than 10 seconds. It has a downward-facing camera that takes image after image of the ground rushing up to meet the rover and an onboard computer (the Vision Compute Element) that processes the images and spits out locations. After the camera turns on, the Lander Vision System uses an initial 5 seconds to take three images and process them to calculate a rough position relative to the Martian surface. Then, using that initial location solution, it takes additional images and processes them every second, deriving locations on a finer scale. The Vision Compute Element sends a stream of these location calculations to the main rover brain (the Rover Compute Element). (More detail about these computers is in the Spacecraft section of this press kit.) Around the same time the rover separates from the back shell (and its parachute), the Rover Compute Element uses the last accurate location calculation from the Lander Vision System to pick the safest reachable landing site, thereby completing Terrain-Relative Navigation activities.

At the time the powered descent vehicle – the combination of the descent stage and the rover – separates from the back shell it is about 1.3 miles (2.1 kilometers) above the surface.

Image credit: NASA/JPL-Caltech

The eight throttleable retrorockets on the descent stage, called Mars landing engines, not only help the spacecraft fly to a safe landing site, but also help slow the spacecraft. When the powered descent phase begins, the spacecraft is traveling at about 190 mph (306 kph) 6,900 feet (2,100 meters) above the ground. It slows to 1.7 mph (2.7 kph) by the time it's about 66 feet (20 meters) above the surface.

When the descent stage determines it is 65 feet (20 meters) over the landing area designated by Terrain-Relative Navigation, it initiates the sky crane maneuver: Nylon cords spool out to lower the rover 25 feet (7.6 meters) below the descent stage. When the spacecraft senses the rover has touched down in Jezero Crater, pyrotechnically fired blades sever the cords, and the descent stage flies a safe distance away before impacting the Martian surface.

Confirmation of Landing Milestones

NASA's Mars Reconnaissance Orbiter (MRO) will be flying overhead during Perseverance's landing on Mars. If the communications relay system from Mars to Earth works as expected, MRO will receive telemetry (detailed engineering data) from the lander and then relay it to NASA's Deep Space Network (DSN) antennas on Earth. This will allow mission controllers to confirm the spacecraft has touched down at around 3:55 p.m. EST (12:55 p.m. PST). MRO has been newly configured to send telemetry to Earth throughout the landing timeline in 5-second packets, with about a 16-second latency. (For more on this special relay system, called "pseudo bent pipe," read the Telecommunications section of this press kit.) The DSN's antenna complex near Madrid, Spain, will be lead during entry, descent, and landing, with the complex in Goldstone, California, providing support.

Perseverance will also be sending tones (simpler signals without detailed engineering data) in the X-band frequency and an ultrahigh frequency (UHF) dial-tone-like carrier signal directly back to Earth. The tones will enable the engineers to determine that the rover has completed some key milestones, and the carrier signal will enable engineers to determine that the spacecraft is still functioning. The X-band tones will be received by DSN antennas. The UHF carrier signal is expected to be received directly from the rover by the Green Bank Observatory in West Virginia and the Effelsberg Observatory in Germany.

Because the rover is landing at a time of day when the landing site (Jezero Crater) doesn't have a direct line of sight back to Earth, both of these direct-to-Earth transmissions are expected to end a little after back shell separation, about one minute before touchdown.

NASA engineers always have backup plans, so they have scheduled MRO to replay the detailed engineering data 10 and 15 minutes after landing for additional chances to study the information. NASA's Mars Atmosphere and Volatile EvolutioN (MAVEN) orbiter will also be flying by when Perseverance is landing and receiving the same detailed engineering data as MRO. Unlike MRO, MAVEN is not configured to be able to receive data from Mars and transmit it to Earth immediately, however. What's more, it captures the data in a form that requires additional processing when they reach Earth. As a result, mission controllers expect the MAVEN data to be readable on Earth for the first time about 10 hours after landing.

Surface Phase

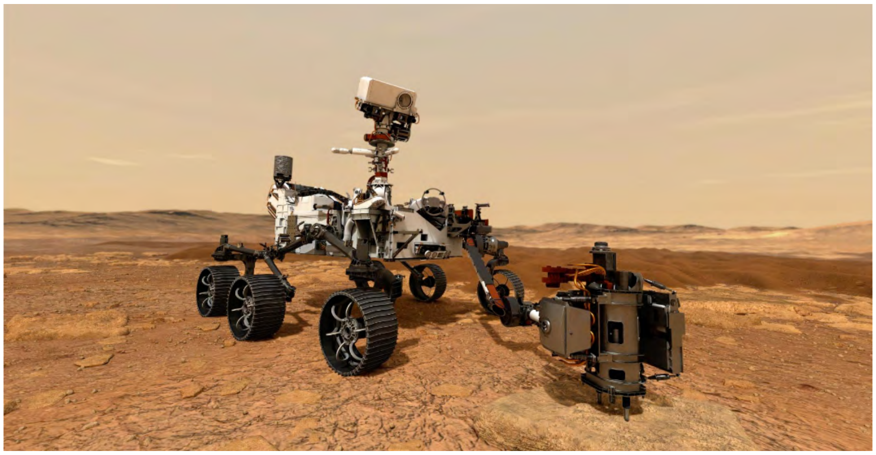


Image credit: NASA/JPL-Caltech

The rover is expected to touch down in the Martian afternoon – at 3:53 p.m. local mean solar time. Soon after, the rover's computer switches from entry, descent, and landing mode to surface mode. This initiates a series of autonomous activities for the first Martian day on the surface of the Red Planet.

First Images

One of Perseverance's first activities in surface mode is to take a pair of pictures with the engineering cameras – known as the Hazard Cameras, or Hazcams – on the front and rear of the rover. Hazcams have clear covers over their lenses to protect them from dust that gets kicked up during landing. The first two images – front and rear Hazcam images – will be taken through these dust covers within minutes after landing. The reduced-resolution version of these images, known as "thumbnails," are expected to become available the same day. Depending on the terrain where Perseverance lands, MRO, the rover's communications relay, may move below the horizon from the rover's point of view shortly after landing, limiting communications with that satellite.

A low-resolution thumbnail image taken by the Perseverance engineering model's front Hazcam during a practice landing session.
Image credit: NASA/JPL-Caltech

A low-resolution thumbnail image transmitted by the Perseverance engineering model's rear Hazcam during a practice landing session.
Image credit: NASA/JPL-Caltech

Later on landing day, quarter-resolution versions and stereo images from the Hazcams with the covers open will become available. By the following morning, a high-resolution image of the wheels from the Hazcams and one image from a camera looking down at the rover from the descent stage are expected to be available.

Over the next couple days and through the weekend, Perseverance will take additional pictures of the landing site and rover hardware, including from the Navigation Cameras (Navcams) and Mastcam-Z on the remote sensing mast (the rover's "head"). The rover is also expected to be transmitting additional images from the EDL cameras and microphone, allowing the public to see and hear what it was like to land on Mars.

More information about the cameras is in the Spacecraft section.

Checkout

Perseverance's first Martian day on the surface of the Red Planet is known as Sol 0.

A sol is a Martian day, which is 24 hours, 39 minutes, 35.244 seconds. (Perseverance team members tend to refer to sols rather than Earth days during operations since the rover will be working during the Martian day and "sleeping" during the Martian night.) The prime mission for the Perseverance rover is one Martian year on the surface. One Martian year is 687 Earth days, or 669 sols.

Perseverance's first images are part of a planned 90-sol initial checkout period. The mission team will perform tests of all the rover's parts and science instruments to ensure everything – including the team – is ready for surface operations. For about 90 sols, the operations team will be working on Mars time, which means they will be setting their clocks to the Martian 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.

Working on Mars time also means that team members will move their start times 40 minutes later each day. Eventually, team members will be waking up in the middle of the night to start their shifts. Because living on Mars time makes daily life on Earth much more challenging, the team does this only for a limited period.
The first part of the checkout period is called the commissioning phase. During this period, the rover unpacks its instruments, upgrades its software, and goes for a test drive.

Here's what to expect in the first 30 sols after landing:

- Images of the rover's wheels just after touching down (first with dust covers on, then with covers off).
- Deployment of mast and high-gain antenna.
- Images of the landing site and the rover's deck.
- Update of rover flight software.
- Health checks performed on all instruments.
- Short, approximately 16-foot (5-meter) drive test.
- Unstowing of the robotic arm and "calisthenics," testing its movement.

- Jettisoning of the belly pan beneath the rover, which protects the sampling system and internal robotic arm during landing.
- PIXL and SHERLOC instrument images of their calibration targets.
- Deployment of the sample-tube-handling robotic arm inside the rover's body and system checkouts.checkouts

The commissioning phase is expected to end about 30 sols after landing, depending on how well the activities go. Milestones after that include:

- Driving to the helicopter flight zone.
- Jettisoning of the debris shield, which protects the Ingenuity helicopter during landing.

Helicopter Flight Testing

Image credit: NASA/JPL-Caltech

After mission controllers have determined that rover systems are functioning as desired, Perseverance will find a flat area to serve as a helipad for the Ingenuity Mars Helicopter technology demonstration. In the first months after landing, if all goes well, the rover will deploy Ingenuity in the center of this area and drive a safe distance (about 330 feet, or 100 meters) away from it. The helicopter's team will then have up to 30 sols to perform a series of flight tests on Mars, the first time powered, controlled flight has been attempted on another planet.

The rover will act as a communications relay between Ingenuity, Mars orbiters, and mission controllers on Earth. Perseverance's MEDA instrument will provide meteorological information (including data on airborne dust), while its Mastcam-Z and Navigation Cameras will collect still images of Ingenuity – and possibly a video or two. The rover's two microphones (one located on the SuperCam instrument; the other, on its chassis) will attempt to pick up the sounds of the flight operations.

During the Helicopter Deployment Phase and the subsequent 30-sol technology demonstration window, there will likely be segments of time where no direct support of helicopter operations is required of the rover. During these periods, the Mars 2020 mission team will pursue science opportunities with its other instruments.

Find more information in the Ingenuity Mars Helicopter press kit: http://go.nasa.gov/ingenuity-press-kit.

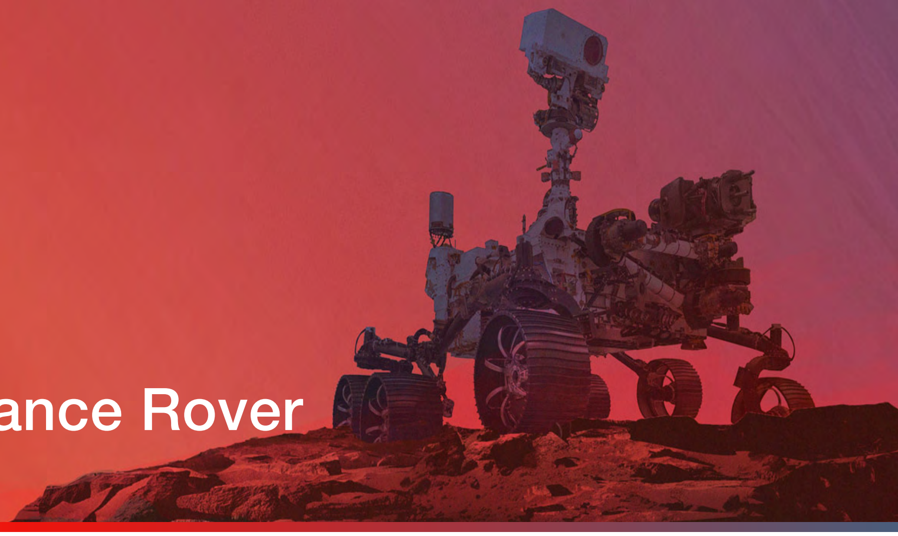
Surface Operations

At the end of these experimental helicopter flights, Perseverance will begin its surface operations phase, when the team will carry out its ambitious science mission: searching for signs of ancient microbial life, characterizing the climate and geology of Mars, and collecting carefully selected and documented samples for future return to Earth. Find more about Perseverance's science objectives in the Science section of this press kit.

Exploration of the Martian surface is led by the rover's science team. To maximize the science being conducted in the time available, the mission team plans a science strategy in advance while building in the flexibility to respond to new discoveries as scientists study the data. The science team has a variety of tools at its disposal, starting with data from NASA's Mars orbiters. The science team has studied Jezero Crater extensively for years with these tools, mapping out key places, called campaign locations, they want to study with Perseverance. Campaign locations include individual outcrops, or rover stops. As data comes in with finer and finer resolution from the rover's science instruments, the science team will make progressively more detailed decisions about what data to collect, what samples to cache, and where to go next.

Perseverance is expected to cover more ground than any previous Mars rover. Much of its driving operations will be automated, streamlining the process for navigating around rocks and sand traps. Perseverance is designed to drive on average about 650 feet (200 meters) per Martian day. To put that into perspective, the longest drive in a single Martian day was 702 feet (214 meters), a record set by NASA's Opportunity rover. Perseverance is designed to regularly drive at nearly the current planetwide record drive distance in a day.

More information about the rover's driving capabilities is available in this story.



Perseverance Rover

Perseverance will be the fifth rover NASA has sent to Mars. Each of these rovers has carried cameras and other instruments to study the Martian surface. As opposed to stationary landers, like InSight and Phoenix, rovers can drive into craters, up slopes, and along sand dunes, allowing scientists and engineers to more fully explore the planet. All of NASA's Mars rovers have been built at the agency's Jet Propulsion Laboratory.

For an interactive 3D experience of the rover, visit:
http://mars.nasa.gov/mars2020/spacecraft/rover/
Image credit: NASA/JPL-Caltech

Heavier and More Capable

The car-size Perseverance rover is about 10 feet long (not including the robotic arm arm), 9 feet wide, and 7 feet tall (about 3 meters long, 2.7 meters wide, and 2.2 meters tall). It weighs about 2,260 pounds (1,025 kilograms) on Earth.

The Perseverance rover and other major Mars 2020 mission hardware (such as the cruise stage, descent stage, back shell, and heat shield) build upon the success of NASA's Curiosity rover (part of the Mars Science Laboratory mission) and include many heritage components. So how much bigger and heavier is Perseverance than Curiosity? Perseverance's chassis is about 5 inches (3 centimeters) longer, and the rover is about 278 pounds (126 kilograms) heavier than Curiosity.

Image credit: NASA/JPL-Caltech

Curiosity is equipped with a robotic arm that extends 7 feet (2 meters) and wields a rotating 65-pound (30-kilogram) turret – a kind of robotic "hand" equipped with a scientific camera, chemical analyzers, and rock drill. Like Curiosity, Perseverance's robotic arm is equipped with a rotating turret, which includes a rock drill, science instruments, and a camera. But while Perseverance's arm is 7 feet (2 meters), just like Curiosity's, its turret weighs more – 99 pounds (45 kilograms) – because it carries larger instruments and a larger drill, which will cut intact rock cores. Those cores will then be placed in sample tubes via a complex storage system. (Curiosity, on the other hand, pulverizes rock for its instruments to study.)

Image credit: NASA/JPL-Caltech

Perseverance also has a six-wheel rocker-bogie design derived from earlier NASA Mars rovers that helps to maintain a relatively constant weight on each of the rover's wheels and minimizes tilt. The wheels on Perseverance are slightly narrower and taller than Curiosity's. But the wheels of both rovers are machined out of a rigid, lightweight aluminum alloy and lined with grousers – raised treads specially designed for the Martian desert. Curiosity's have a pointed chevron pattern for climbing rocks, a design that made them more vulnerable to wheel damage. Perseverance's grousers are nearly straight with a gentle curve, and each wheel has twice the number of treads as Curiosity's (48 versus 24). The wheel skin is also twice as thick as Curiosity's. During testing, the mobility team found this improved both damage tolerance and wheel performance over rocks and sand.

Just like Curiosity, Perseverance has two main computers, or "brains": One is active at any given time, while the other serves as a backup. Both use radiation-hardened RAD750 computers, and together, they're referred to as Rover Compute Element A and B.

Another RAD750 serves as a third "brain," on Perseverance. Called the Vision Compute Element, it is equipped with a special card for analyzing images. This card has a Virtex-5 field programmable gate array (FPGA) and is the driving force behind Terrain-Relative Navigation and the Lander Vision System, which analyzes images of the landing site during descent and compares them to an onboard map to determine the rover's position relative to the ground.

After landing, the Vision Compute Element is reprogrammed to analyze images of the Martian terrain so that the rover can autonomously navigate around obstacles more efficiently.

For more on the distinctions between Curiosity and Perseverance, read the feature story Two Rovers to Roll on Mars Again.

Find more on the rover's science instruments in the Science section of this press kit.

Sample Caching System

The Perseverance rover's Sample Caching System is made of three robotic components that will work in concert to collect samples of rock and regolith (broken rock and dust), seal them in sample tubes, and deposit those tubes on the surface of Mars for retrieval by a future mission.

Robotic Arm

The first robot involved with the Sample Caching System is the 7-foot-long (2-meter-long) robotic arm with its drill and instrument-laden turret. Bolted to the front of the rover's chassis, the five-jointed arm can be manipulated so that the turret is placed in close proximity to interesting geologic features on the surface. The turret contains the coring tool: a rotary-percussive device designed to acquire rock core and regolith samples. A small tank of pressurized nitrogen can be used to blow dust and other particles off targets prior to analysis by two science instruments also located on the turret: the ultraviolet Raman spectrometer SHERLOC and the X-ray fluorescence spectrometer PIXL.

If the Perseverance science team determines rock or regolith is worthy of sampling, it will command the arm to place either a coring or regolith bit, with a sample tube inside, into the coring tool and then place the drill bit against the target. When coring, the drill – using either rotary mode (where a hole is produced using a drill bit under constant pressure) or percussive mode (where the rotary motion is supplemented with swift hammerlike blows to propel the drill bit forward) – obtains a cylindrical sample about 0.5 inches (13 millimeters) in diameter and 2.4 inches (60 millimeters) long in a sample tube in the center of the bit. This chalk-size sample amounts to an average of 0.35-0.53 ounces (10-15 grams) of Martian material. A similar process is used with the regolith bit to collect regolith samples.

Adaptive Caching Assembly

The adaptive caching assembly consists of the sample handling arm, sample tube assemblies, tube seals, and processing stations for a variety of activities. When the bit carousel transfers a filled sample tube to the adaptive caching assembly, the 1.6-foot-long (0.5-meter-long) sample handling arm then moves the tube to the processing stations. The stations measure the volume and take an image of the sample, install, and activate a tube seal, and place the tube in storage. Later, when the rover reaches a suitable location, the sample handling arm retrieves the sealed tubes and drops them to the surface of Mars for retrieval by a future mission. Perseverance may also be able to store them internally and transport them to a future return mission's lander.

In addition to these functions, the Sample Caching System must also maintain unprecedented biological cleanliness to protect the sample from possible Earth-based contamination. The combination of these two factors makes it the most complex integrated robotic subsystem ever built for Mars.

This video shows how the Sample Caching System works

Seeing and Hearing Mars

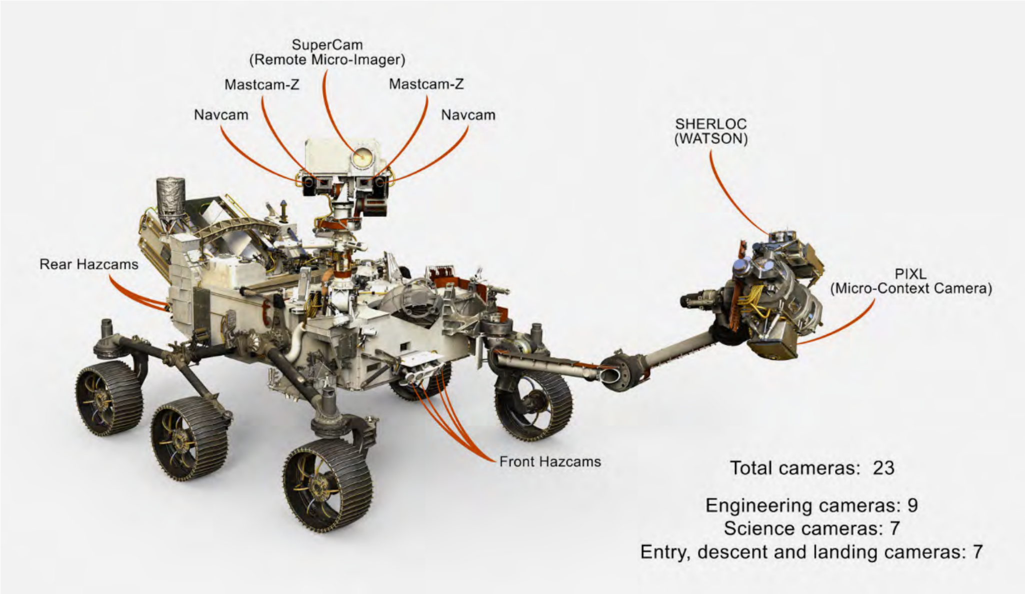


Image credit: NASA/JPL-Caltech

The Mars 2020 mission carries more cameras to Mars than any interplanetary mission in history, with 23 spread throughout the components of the Mars 2020 spacecraft. The Perseverance rover itself has 19 cameras that will deliver images of the landscape in breathtaking detail. Those include nine cameras for engineering; seven for science; and three for entry, descent, and landing (EDL).

Cameras for EDL are also installed on the aeroshell and descent stage. Find more information about the two cameras on the Ingenuity Mars Helicopter in the Ingenuity press kit.

Mars 2020 Cameras and Their Capabilities

Camera Type	Number	Color or BW	Resolution	Location
Engineering Cameras	**9**	**Color**	**20 megapixel**	**Various locations on the rover**
Navigation Cameras (Navcams)	2	Color	20 megapixel	Rover mast
Hazard Avoidance Cameras (Hazcams, fisheye)	6	Color	20 megapixel	4 on front of rover, 2 on rear
Sample Caching System Camera (CacheCam)	1	Color	20 megapixel	In Sample Caching System

Camera Type	Number	Color or BW	Resolution	Location
EDL Camera Suite	**7**	**6 color, 1 black-and-white**	**1.3 or 3.1 megapixels**	**On back shell, descent stage, and rover**
Parachute Uplook Cameras (PUC)	3	Color	1.3 megapixel	Back shell
Descent Stage Downlook Camera (DDC)	1	Color	3.1 megapixel	Descent stage
Rover Uplook Camera (RUC)	1	Color	1.3 megapixel	Rover deck
Rover Downlook Camera (RDC)	1	Color	1.3 megapixel	Front left corner beneath rover
Lander Vision System Camera (LCAM)	1	Black-and-white	1.3 megapixel	Front right corner beneath rover

Camera Type	Number	Color or BW	Resolution	Location
Science Cameras	**7**	**2 color, 1 black-and-white, 1 black-and-white with some color capability**	**.43 to 4 megapixels**	**Various locations on rover**
Mastcam-Z (ZCAM) instrument suite	2	Color	2 megapixels	Left and right side of rover mast
SuperCam Remote Micro-Imager (RMI)	1	Color	4 megapixels	Rover mast
SHERLOC camera suite	2 (WATSON and Autofocus and Context Imager)	Color (WATSON) and black-and-white (ACI)	2 megapixels	Rover turret
PIXL Micro Context Camera (MCC)	1	Black-and-white, with some color capability	.43 megapixel	Rover turret
MEDA SkyCam (fisheye)	1	Black-and-white	About 1 megapixel	Rover deck

The six color, off-the-shelf cameras that capture Perseverance's EDL are for public engagement and for engineers to reconstruct what happened during the landing.

Of those six, three are on the bell-shaped back shell, looking up to capture the parachute opening. One on the descent stage looks down at the rover and surface below. One on the rover looks up at descent stage operations, and the other on the rover looks down at the Martian surface.

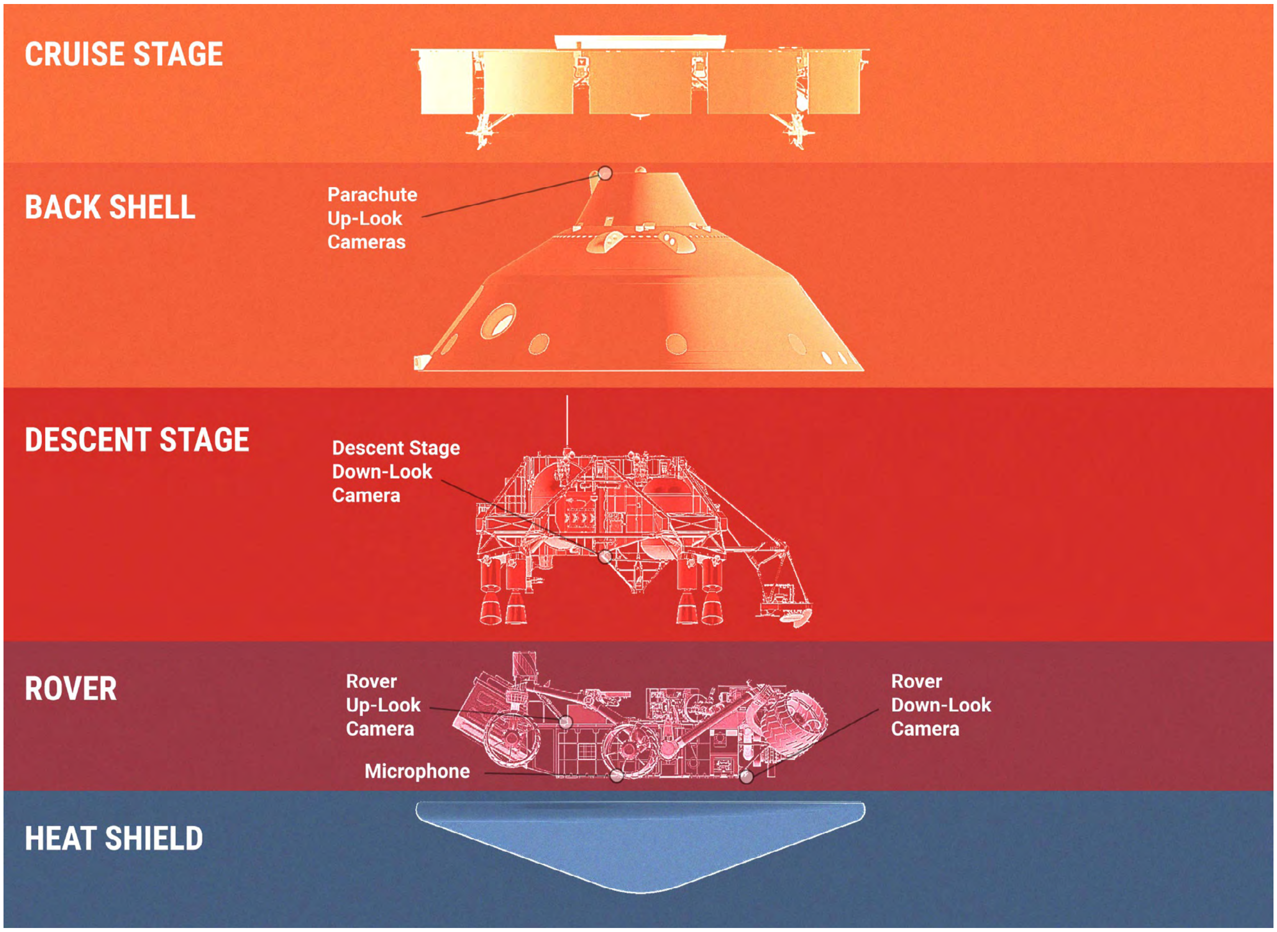


Image credit: NASA/JPL-Caltech

One black-and-white camera dedicated to Terrain-Relative Navigation as part of the Lander Vision System plays a key role in the landing itself. (Find more details about its role in the [Entry, Descent, and Landing section]() of this press kit.)

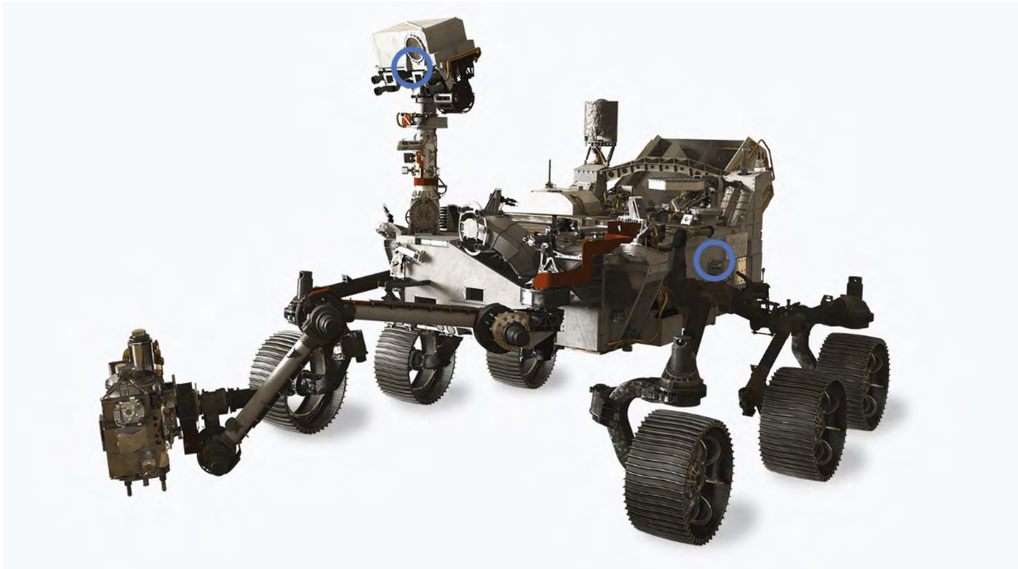


Image credit: NASA/JPL-Caltech

The Perseverance rover also has two microphones: one to record the sounds of a Mars landing for the first time, and one that is part of the SuperCam science instrument.

The EDL microphone is a commercial, off-the-shelf part on an aft-side panel. It is intended for public engagement and later EDL analysis, but there is no guarantee what exactly it will record. Wind and engine sounds could overwhelm the microphone. But the rover's team is hoping to capture some of the following:

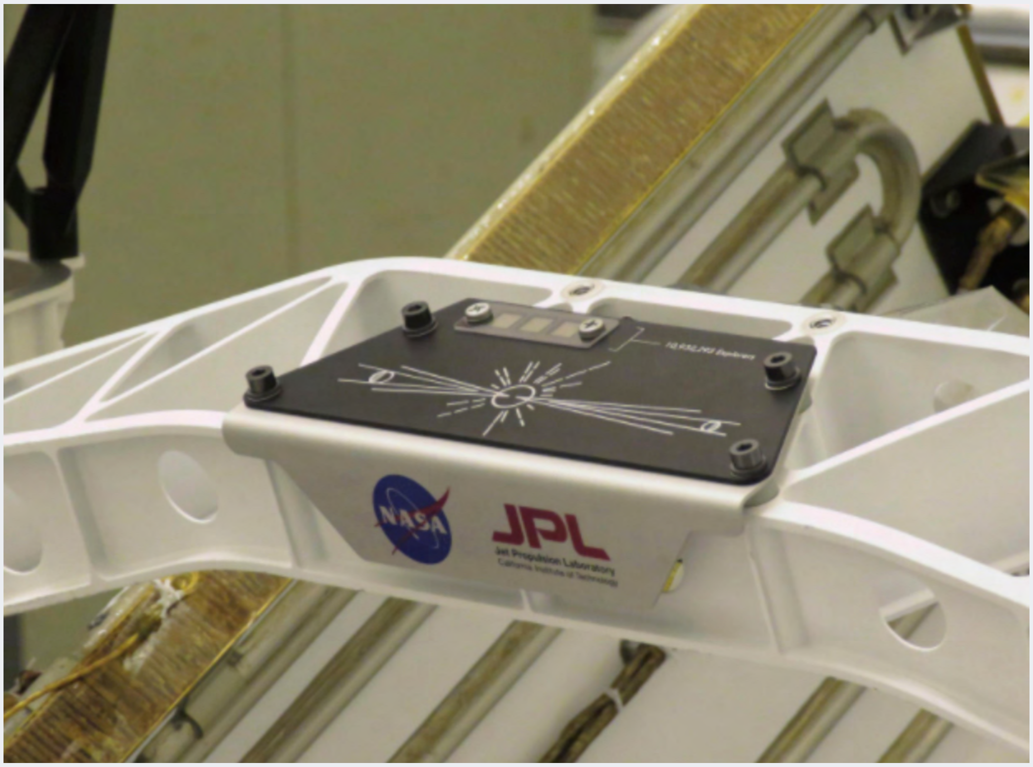
- Parachute mortar firing
- Heat shield separation bolts firing
- Wind noise
- Landing-thruster noise
- The rover touching down on the Martian surface
- Ambient Mars noise
- The faint sound of the descent stage impacting the surface after delivering Perseverance to the surface and flying away

Depending on how the microphone works after landing, it may be used to occasionally record sounds on the Martian surface.

Separately, a microphone on the SuperCam instrument on the remote sensing mast will record the sound of the instrument's laser zaps against the Martian surface. The sounds will help scientists understand the property of the rocks SuperCam is examining, including their hardness. SuperCam's microphone can also can also listen to the wind.

Your Name Is on Its Way to Mars

Another special feature on the rover can be found on the aft crossbeam: a plate that contains three silicon chips stenciled with the names of approximately 10.9 million people from around the world who participated in the "Send Your Name to Mars" online campaign from May to September 2019. The fingernail-size chips also contain the essays of 155 finalists in NASA's "Name the Rover" essay contest.



This placard commemorating NASA's "Send Your Name to Mars" campaign was installed on the Perseverance Mars rover on Mar. 16, 2020, at NASA's Kennedy Space Center in Florida. | *Image credit: NASA/JPL-Caltech*

The chips share space on the plate with a laser-etched graphic depicting Earth (the circle on the left in the image above) and Mars (the circle on the right) joined by the star that gives light to both and a Morse code message in the Sun's rays: "Explore as one."

The rover also features some additional elements – from practical to playful – that are part of a tradition of "festooning" that harks back to the early space age.

Getting to Mars

Cruise Stage

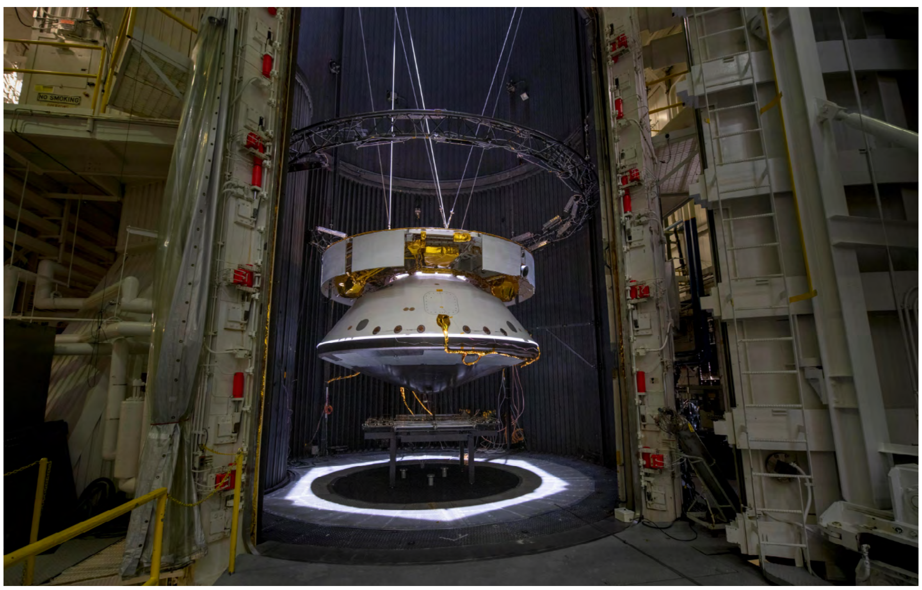


Image credit: NASA/JPL-Caltech

Perseverance is traveling to Mars in an almost identical way to NASA's Curiosity rover, which landed in 2012. Three major components of the flight system will deliver the new rover safely to the surface of the Red Planet: the cruise stage, aeroshell, and descent stage.

After separating from the rocket, the ring-shaped cruise stage flies the aeroshell, and Perseverance within it, through interplanetary space to Mars. To remain stable throughout cruise, the combined spacecraft spins at about 2 rpm during the journey. The cruise stage features eight thrusters that receive commands to fire at specific times during the six-and-a-half-month journey to help shape the spacecraft's trajectory to Mars (these are called trajectory correction maneuvers).

The cruise stage also has solar arrays that provide power in addition to the rover's main power source, the Multi-Mission Radioisotope Thermoelectric Generator. And it is equipped with an assortment of antennas for communicating with Earth. Find more information in the Telecommunications section of this press kit.

Aeroshell

Image credit: LMS

This capsule protects the rover and descent stage as they plummet through the Martian atmosphere toward the surface of the Red Planet. Built by Lockheed Martin Space in Denver, the aeroshell has two parts: the bell-shaped back shell and, at its base, a heat shield. The heat shield is covered with tiles of a material called phenolic impregnated carbon ablator (PICA) that was invented at NASA's Ames Research Center in California's Silicon Valley. Engineers estimate the spacecraft could be exposed to temperatures as high as about 2,370 degrees Fahrenheit (about 1,300 degrees Celsius) from the friction generated as it descends through the Martian atmosphere. The job of the heat shield is to carry most of this heat away from the Perseverance rover.

The back shell contains several components critical to landing the rover: weights that alter the spacecraft's center of mass so it can fly correctly, a parachute, and antennas both for communicating directly with Earth and for communicating with orbiters at Mars that can relay messages to Earth. In addition, the back shell and heat shield have a sensor suite known as the Mars Entry, Descent, and Landing Instrumentation 2 (MEDLI2). Since the back shell will also get hot – though not as hot as the heat shield – it, too, sports a protective covering, in this case made of a material known as SLA-561V.

Atmospheric friction will slow the entry vehicle to about 540 mph (865 kph) by the time it is about 7 miles (11 kilometers) in altitude above Mars. At around this point, the spacecraft will use a technique called Range Trigger, to determine whether it is in an optimal position relative to the landing target. If it is, the spacecraft will command the deployment of the parachute, which inherits its design from the Mars Viking missions of the 1970's but is scaled up to 70.5 feet (21.5 meters) in diameter and strengthened to accommodate Perseverance's greater mass.

As the parachute inflation slows Perseverance further, the heat shield will be jettisoned so that a radar and a new, specially developed Terrain-Relative Navigation system can help guide the rover to a safe landing in Jezero Crater.

The back shell with the parachute will separate from what is known as the powered descent vehicle (which includes the rover and the descent stage, a rocket-powered structure that helps the spacecraft land) about 60 seconds before touchdown.

The aeroshell also features the MEDLI2 sensor suite to collect data during EDL. More on this suite can be found in the Experimental Technologies section.

Descent Stage

Image credit: NASA/JPL-Caltech

Think of the descent stage as a kind of jetpack with eight engines that safely lowers the spacecraft to the ground. The descent stage slows down until it's hovering over the surface, then slowly winches Perseverance down with nylon cords as part of the sky crane maneuver.

When the rover is safely on the ground, pyrotechnically activated blades will cut the cords connecting it to the descent stage. The descent stage flies off to make its own uncontrolled landing on the surface a safe distance away from Perseverance.

Power

Image credit: NASA/JPL-Caltech

The Perseverance rover requires electrical power to operate. The dependable flow of electricity for the rover comes from a power system known as a Multi-Mission Radioisotope Thermoelectric Generator (MMRTG), provided to NASA by the U.S. Department of Energy (DOE).

What Is an MMRTG?

Perseverance's power system works essentially like a nuclear battery. The MMRTG converts heat from the natural radioactive decay of plutonium-238 into a steady flow of electricity. The power system will reliably produce about 110 watts (similar to a light bulb) at the start of Perseverance's mission, declining a few percent each year in a very predictable way. The MMRTG doesn't just power the rover; excess heat is collected in a fluid loop system. The warm fluid is routed around the vehicle to keep its sensitive electronics warm during the cold Martian nights.

The MMRTG also charges two lithium-ion batteries, which are used during daily operations and when the demand temporarily exceeds the usual electrical output levels. Perseverance's power demand can reach 900 watts during science activities.

The MMRTG, located at the aft of the rover, weighs about 99 pounds (45 kilograms) altogether. It contains 10.6 pounds (4.8 kilograms) of plutonium dioxide as its heat source.

The two batteries weigh a total of 58.4 pounds (26.5 kilograms) and each has a capacity of about 43 amp-hours.

More details on the MMRTG can be found on the mission's electrical power page and NASA's radioisotope power systems website.

Why Does This Mission Use an MMRTG?

The Perseverance rover needs to operate extremely efficiently to accomplish its prime mission. An MMRTG allows the rover to work free of limitations associated with solar panels, such as the daily and seasonal variations of sunlight on Mars and the accumulation of fine Martian dust.

The advantages of MMRTG power give Perseverance greater mobility over a range of lighting conditions at different latitudes and surface locations. It also provides engineers with valuable flexibility in operating the rover (e.g., communications, mobility, or science throughout the day and night).

Overall, the MMRTG enables the Perseverance team to maximize the operational capabilities of the rover and its science instruments.

How Reliable Is an MMRTG?

Perseverance's power system is identical to the one that the Curiosity rover has been using successfully since its launch in 2011.

The MMRTG is expected to operate for at least 14 years, significantly beyond Perseverance's prime mission duration (at least one Mars year, or about two Earth years).

NASA has used similar radioisotope thermoelectric generators (RTGs) successfully for five decades, including on the Apollo missions to the Moon and the Viking missions to Mars. They have also been used on spacecraft that flew to the outer planets and Pluto, such as during the Pioneer, Voyager, Ulysses, Galileo, Cassini, and New Horizons missions.

Mission:
Spacecraft › Telecommunications

Telecommunications: How Perseverance Talks to Earth

Cruise

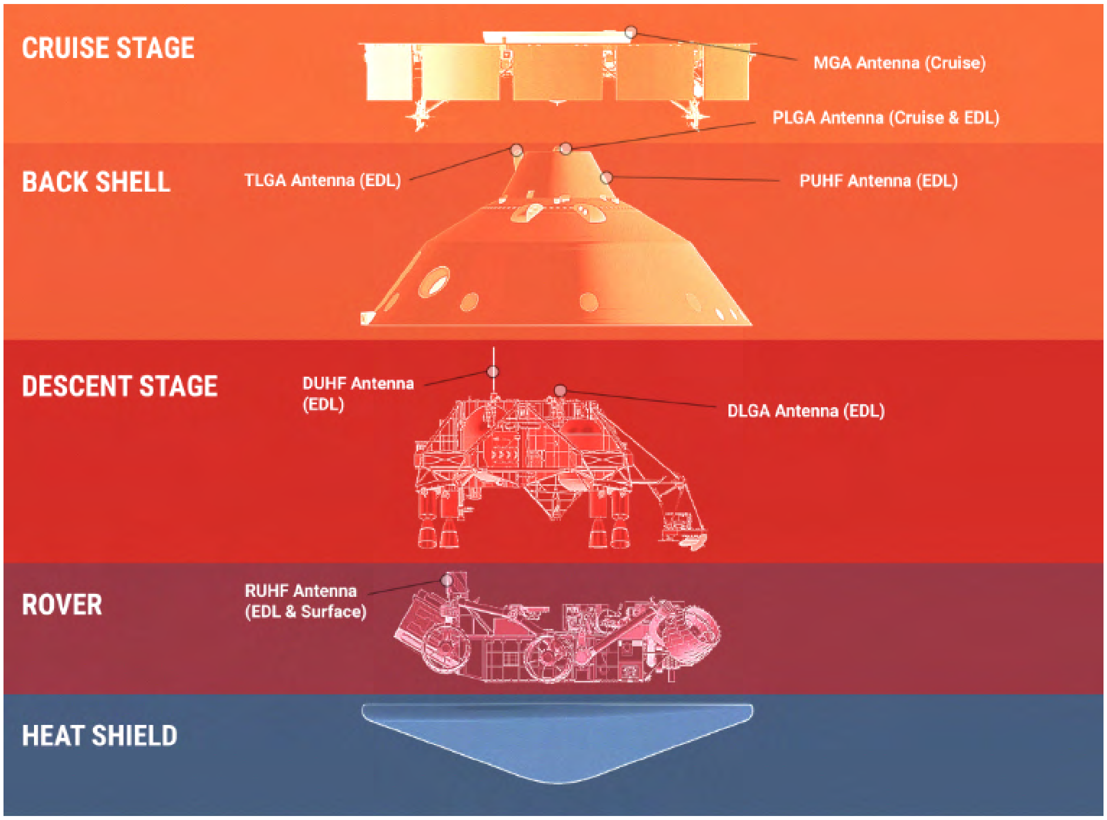


Image credit: NASA/JPL-Caltech

For the first two months of the journey to Mars, the Mars 2020 spacecraft communicates using a low-gain antenna on the aeroshell's parachute cone, which is exposed through the center of the cruise stage.

As the spacecraft gets farther from Earth, a stronger, medium-gain antenna located on the cruise stage takes over. This antenna provides higher data rates but requires more accurate pointing toward Deep Space Network dishes on Earth.

Landing

During landing, the spacecraft switches between several antennas. Some use ultrahigh frequency (UHF) transmission, communicating with orbiting spacecraft, like the Mars Reconnaissance Orbiter (MRO), which then relay the information back to Earth. Other antennas use more powerful X-band transmissions, talking directly to Earth with simple tones that provide basic, but limited, spacecraft health and status.

X-band

EDL communications begin with the same low-gain antenna – located on the aeroshell's parachute cone – used at the start of the cruise phase. As the spacecraft performs banking maneuvers during its guided entry into the Martian atmosphere, it shifts to a tilted low-gain antenna on the spacecraft's back shell. After separation from the back shell, a low-gain antenna on the powered descent stage takes over. NASA's Deep Space Network sites located in Goldstone, California, and Madrid, Spain, will be listening for these X-band signals until Perseverance loses its direct line of sight back to Earth.

UHF

A UHF antenna mounted on the back shell starts transmitting during cruise stage separation. It continues transmitting until the back shell separates from the powered descent stage, at which point a UHF antenna on the descent stage will take over. For the rover's final descent to the surface, it will use its cylindrical UHF low-gain antenna. Green Bank Observatory in Green Bank, West Virginia, and the Effelsberg Observatory in Germany will be listening for a dial-tone-like UHF signal called a carrier signal until Perseverance loses its direct line of sight back to Earth.

Perseverance will also use the UHF antennas to communicate detailed information during landing by transmitting data to MRO and the Mars Atmosphere Volatile EvolutioN (MAVEN) spacecraft. MRO is expected to relay EDL data to Earth in near-real-time, while MAVEN is expected to return its data within hours after landing.

MRO launched more than 15 years ago without this near-real-time relay capability. Real-time relay is often referred to as a "bent pipe" transmission. In the past year, a near-real-time relay capability, called "pseudo-bent pipe," has been added to the veteran orbiter so it can send telemetry (detailed engineering data) to Earth throughout landing in 5-second packets, with about a 16-second latency. This required updates to MRO's software as well as to ground data systems on Earth. These updates, combined with special maneuvers to point the spacecraft's antenna to Deep Space Network dishes, ensure consistent data flow from Mars to Earth. Along with the near-real-time transmission, the data is recorded by MRO for later playback, which is scheduled to be transmitted to Earth several minutes after landing.

MAVEN will provide a recording of this landing data in a less processed file format. MAVEN is scheduled to transmit its data several hours after touchdown and its data also takes more time to process once it is on the ground. More detail on the transmission time table is available in the Confirmation of Landing Milestones section.

Surface

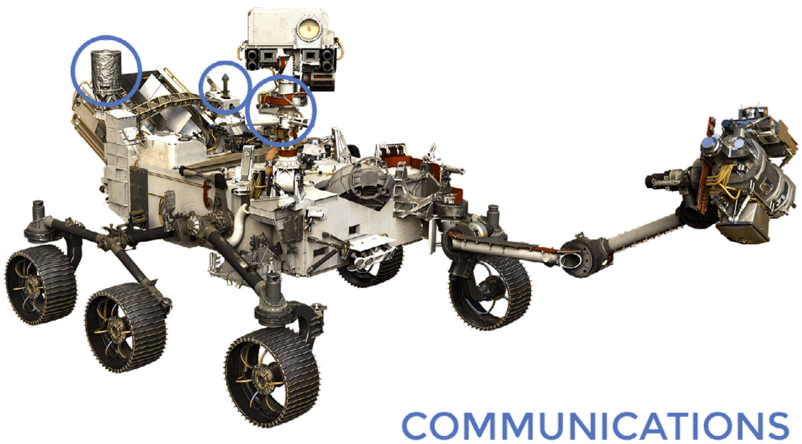


Image credit: NASA/JPL-Caltech

Once Perseverance is wheels-down on Mars, it will begin communicating using antennas on its deck. Communication will resume through the cylindrical, paint-can-shaped UHF low-gain antenna at the back of the rover. During surface operations, 99.9% of science data is communicated through this antenna to passing orbiters, including MAVEN and MRO, as well as ESA's (European Space Agency's) Trace Gas Orbiter.

Commands sent from Earth will routinely be received by Perseverance's X-band high-gain antenna, the rotatable hexagonal paddle toward the back of the rover. While the antenna is also capable of transmitting data back to Earth, it is limited.

If the views and distance to the Earth are favorable, Perseverance can also use an X-band low-gain antenna (a chess-piece-shaped antenna behind the high-gain antenna).

Biological Cleanliness

The Mars 2020 mission has two primary motivations for keeping the spacecraft biologically clean. The first, called "planetary protection," is to avoid harmful contamination of Mars, which could confound future searches for life. The second, referred to as "returned sample science cleanliness," is to limit Earth-based contamination in the samples that the mission will collect for science purposes.

Planetary Protection

Image credit: NASA/JPL-Caltech

The United States has obligations under the international 1967 Outer Space Treaty to explore space in a manner that avoids the harmful contamination of celestial bodies while also not adversely affecting Earth's environment with the return of any extraterrestrial matter. To help meet these obligations, NASA's Planetary Protection Office draws up cleanliness standards known as planetary protection requirements. Flight hardware for the Mars 2020 Perseverance mission and the Ingenuity Mars Helicopter have been designed and built to meet requirements limiting the amount of Earth-sourced biological material they carry to Mars.

NASA's primary strategy for limiting Earth-based contamination of Mars is to be sure that all hardware going to the planet is biologically clean.

Engineers assemble spacecraft in "clean rooms," where powerful air filters limit dust particles and where surfaces are frequently treated with strong cleaning solutions to kill and remove living microbes. Mission hardware is cleaned using techniques that have proven effective on many previous missions without damaging the spacecraft. These include wiping down the hardware with special sterile cloths and alcohol wipes, and heating durable parts to high temperatures (230 to 392 degrees Fahrenheit, or 110 to 200 degrees Celsius). The Mars 2020 Perseverance mission also used innovative new cleaning methods, such as employing hydrogen peroxide vapor to clean some spacecraft parts that couldn't be treated with other methods.

At launch, the entire payload going to Mars (the Perseverance rover, Ingenuity Mars Helicopter, cruise stage, aeroshell, and descent stage) carried fewer than 500,000 bacterial spores (dormant forms of bacteria). This is a tiny number as far as spores go and wouldn't even cover a typical smartphone camera lens. Of this number, the parts of the Mars 2020 spacecraft intended to land on Mars – including the rover, the parachute, and the descent stage – had no more than 300,000 spores in total. The rover itself was allowed to have just 41,000 spores, spread out over the vehicle's entire surface area.

Another way to avoid transporting unwanted Earth materials to Mars is to keep hardware that does not meet cleanliness standards from going to Mars accidentally. Because only some portions of the Atlas V rocket ferrying the Mars 2020 Perseverance spacecraft into space could be cleaned as thoroughly as the spacecraft, the rocket was initially pointed along a trajectory that did not intercept Mars. After the spacecraft separated from the launch vehicle's upper stage, Perseverance was redirected toward landing on Mars. This technique, known as "trajectory biasing," was intended to ensure that the launch vehicle has less than a 1 in 10,000 chance of accidentally encountering Mars for 50 years after launch.

Avoiding Sensitive Areas

Places on Mars where Earth organisms would be likely to replicate, or that could have a high potential for the existence of Martian life forms, are known as "special regions." These include regions on Mars that could have water ice or liquid water in some form within 16 feet (5 meters) of the surface.

A key goal of Perseverance's mission is to seek signs of ancient microbial life, not current, or extant, life. The rover does not need to visit a special region, and its landing site – Jezero Crater – is not considered one.

Returned Sample Science

Because one of the mission's key goals is to search for signs of ancient microbial life on Mars, scientists want to be confident that any signs of ancient life they might observe in samples returned to Earth are from Mars, not Earth. Perseverance's Sample Caching System is therefore the cleanest set of components humankind has ever launched into space.

Because samples collected by the Perseverance rover are intended to be brought back to Earth for scientific analysis, the project must adhere to additional cleanliness standards beyond what's required of missions solely intended to explore the surface of Mars.

The elements of the Perseverance rover involved in sample collection are handled with extra care. They have been assembled in aseptic spaces (a clean room within a clean room), which provide the increased level of stringency for cleanliness that some sample collection hardware must meet. These parts are also thoroughly sterilized, exceeding the cleanliness standards of tools that doctors use in surgery.

The critical components of the Sample Caching System were integrated only shortly before launch at Kennedy Space Center in Florida. The sample caching elements are enclosed behind a door on the rover's belly that will unseal and detach only after landing. An additional barrier behind this door will limit the flow of unwanted material into the parts that will touch the samples and should remain clean.

Mission teams also identified and kept track of any known materials that remained on the spacecraft after thorough cleaning. This helps maintain a list of what's known to be on board before the sample tubes left Earth, which can be compared with future measurements of the samples. Perseverance's sampling system also carries "witness" tubes that record the state of the environment within the sampling system, including any terrestrial contamination that may have been on the rover before it left Earth and remains on board after touchdown on Mars.

This approach should result in the most pristine, well-documented planetary samples ever obtained that are ready for imaging and analysis on Earth, where scientific specialists from around the world can apply the full breadth of terrestrial laboratory capabilities.

For more information, read this fact sheet on Perseverance's biological cleanliness.

Experimental Technologies

Several brand new or next-generation technologies are riding aboard the Mars 2020 spacecraft. Two of these (MOXIE and the Ingenuity Mars Helicopter) are officially designated technology demonstrations – experiments that seek to prove a first-of-their-kind capability, with limited scope. Previous examples of these groundbreaking experimental technologies include the Mars Pathfinder mission and its rover (Sojourner), the Mars Cube One (MarCO) CubeSats that flew by Mars, and the NASA-sponsored rocket planes and lifting body vehicles that paved the way for the space shuttle. The success of these technology demonstrations is not connected to the overall success of the Perseverance rover and the Mars 2020 mission.

MOXIE (Mars Oxygen ISRU Experiment)

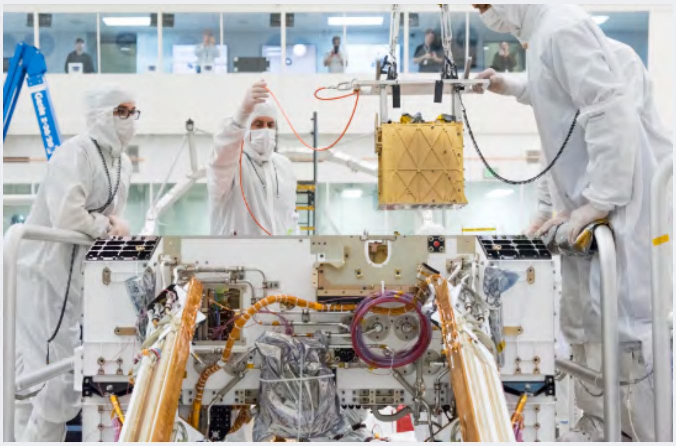


Image credit: NASA/JPL-Caltech

Located inside the body of the Perseverance rover, MOXIE will test technology that converts carbon dioxide in the Martian atmosphere into oxygen. The "I" in MOXIE stands for "in-situ resource utilization," or ISRU – the concept of using resources found where a spacecraft lands rather than bringing those resources from Earth.

More information about MOXIE is available in the Payload Instruments section of this press kit.

MEDLI2 (Mars Entry, Descent, and Landing Instrumentation 2)

Image credit: LMS

Based on an instrument flown on NASA's Mars Science Laboratory (MSL) mission, which landed the Curiosity rover in 2012, MEDLI2 is a next-generation sensor suite that collects temperature, pressure, and heating measurements on the heat shield and back shell during entry, descent, and landing. Data collected by MEDLI2 will help engineers validate their models for designing future systems (both robotic and crewed) for entry, descent, and landing systems.

MEDLI2 is a Game Changing Development project led by NASA's Space Technology Mission Directorate, with support from the Human Exploration and Operations Mission Directorate and Science Mission Directorate. The project is managed at NASA Langley Research Center in Hampton, Virginia, and implemented in partnership with NASA's Ames Research Center in California's Silicon Valley and NASA's Jet Propulsion Laboratory in Southern California.

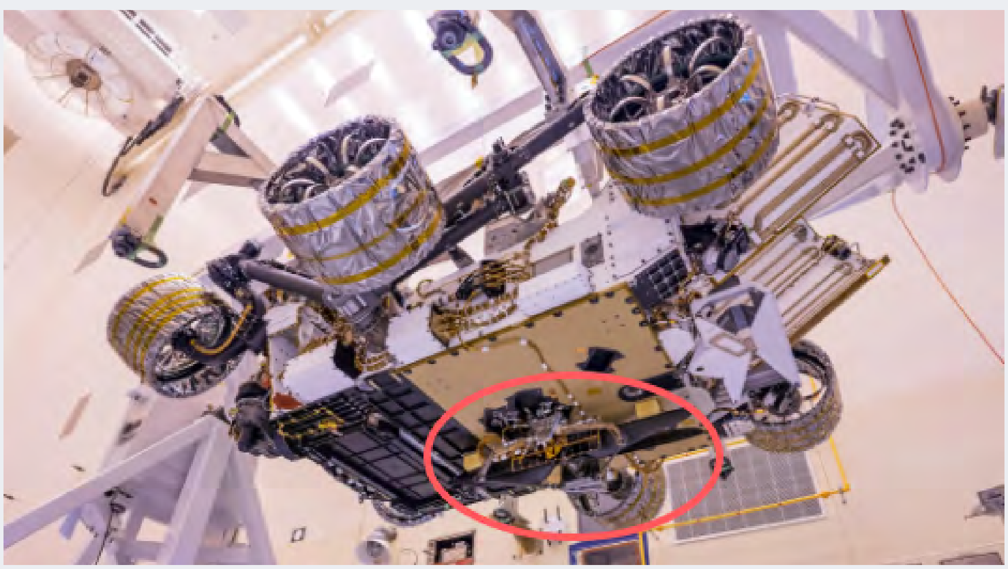
Find more information about MEDLI2 in this story.

Ingenuity Mars Helicopter

Image credit: NASA/JPL-Caltech

Weighing just about 4 pounds (1.8 kilograms), the Ingenuity Mars Helicopter is a small, autonomous rotorcraft designed to test – for the first time – powered, controlled flight in the thin Martian atmosphere. This lightweight helicopter does not carry any science instruments.

Ingenuity's performance during its experimental test flights will help NASA make decisions about small helicopters for future Mars missions, where they could perform in a support role as robotic scouts, surveying terrain from above, or as full standalone science craft carrying instrument payloads. Taking to the air would give scientists a new perspective of a region's geology and allow them to peer into areas too steep or slippery to send a rover. In the distant future, they might even help astronauts explore Mars.



The Mars Helicopter Delivery System holds the Ingenuity Mars Helicopter to the underside of Perseverance | *Image credit: NASA/JPL-Caltech*

The Mars Helicopter Delivery System – designed collaboratively by Lockheed Martin Space and JPL's Mars 2020 and helicopter teams – attaches the helicopter to the belly of the rover for the journey to the Red Planet. This system protects Ingenuity from debris during landing and will deploy the helicopter onto the Martian surface in the months after landing.

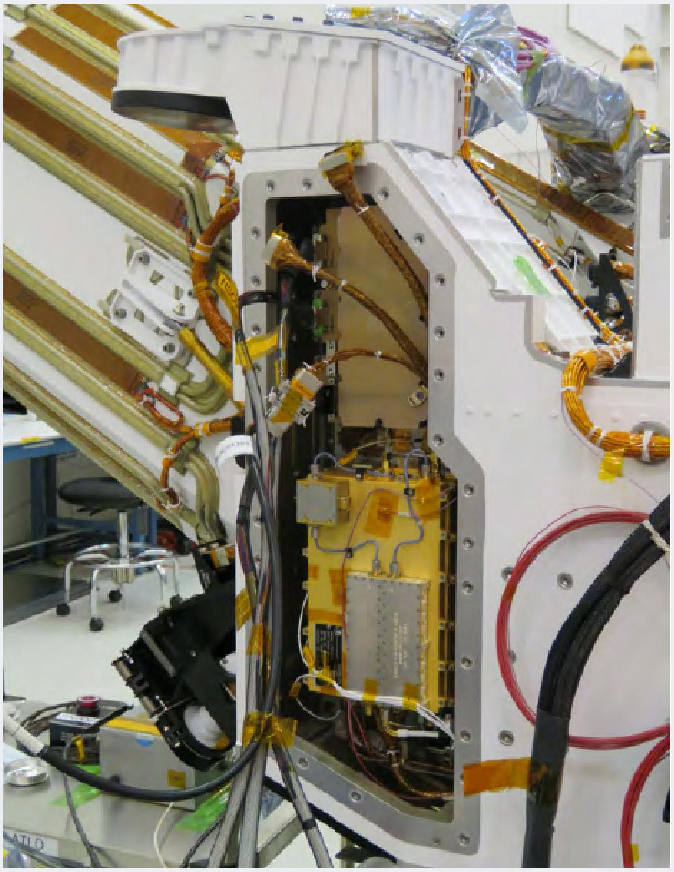


Image credit: NASA/JPL-Caltech

Also installed in Perseverance is the Mars Helicopter Base Station. This station carries computers that monitor and regulate helicopter systems while it is attached to the rover and the communications gear that – once the helicopter deploys to the surface – stores and routes communications between Ingenuity, Perseverance, and Earth.

For more on Ingenuity, read the Ingenuity press kit.

Mission: Science

Why This Mission

Image credit: NASA/JPL-Caltech

Billions of years ago, Earth and Mars were more similar than they are today. Both had liquid water at the surface; both had magnetic fields to protect their surface from the Sun's radiation. Life developed on Earth at that time, so could it also have developed on Mars?

NASA has sent rovers, landers, and orbiters to the Red Planet to investigate that key astrobiological question. Scientists can study rocks and sediment on the Martian surface to learn what environments once existed, whether and for how long liquid water was once present, and what the climate was like in the past. This record can reveal when and where Mars had the ideal conditions for life.

But Perseverance is different: It's the first Mars rover designed to collect samples that will one day be returned to Earth. Despite the immense technical capabilities of the rover's science instruments, there are far more powerful laboratories and science tools on our planet than we could hope to send to Mars. As with the Moon samples returned by the Apollo missions, Mars samples would benefit future generations of scientists who will study them using advanced technology, some of which hasn't been invented yet.

The Mars 2020 mission also looks ahead to the day when astronauts travel to Mars. It carries technologies that could help land humans or equipment on the planet and even help produce rocket propellant and breathable oxygen. These efforts, detailed below, will feed into NASA's plans for sending humans to Mars, with the Artemis program returning astronauts to the Moon as the first step.

Science Goals

Perseverance will contribute to the overarching goals of NASA's Mars Exploration Program:

GOAL 1

Determine whether life ever existed

GOAL 2

Characterize the climate

GOAL 3

Characterize the geology

GOAL 4

Prepare for human exploration

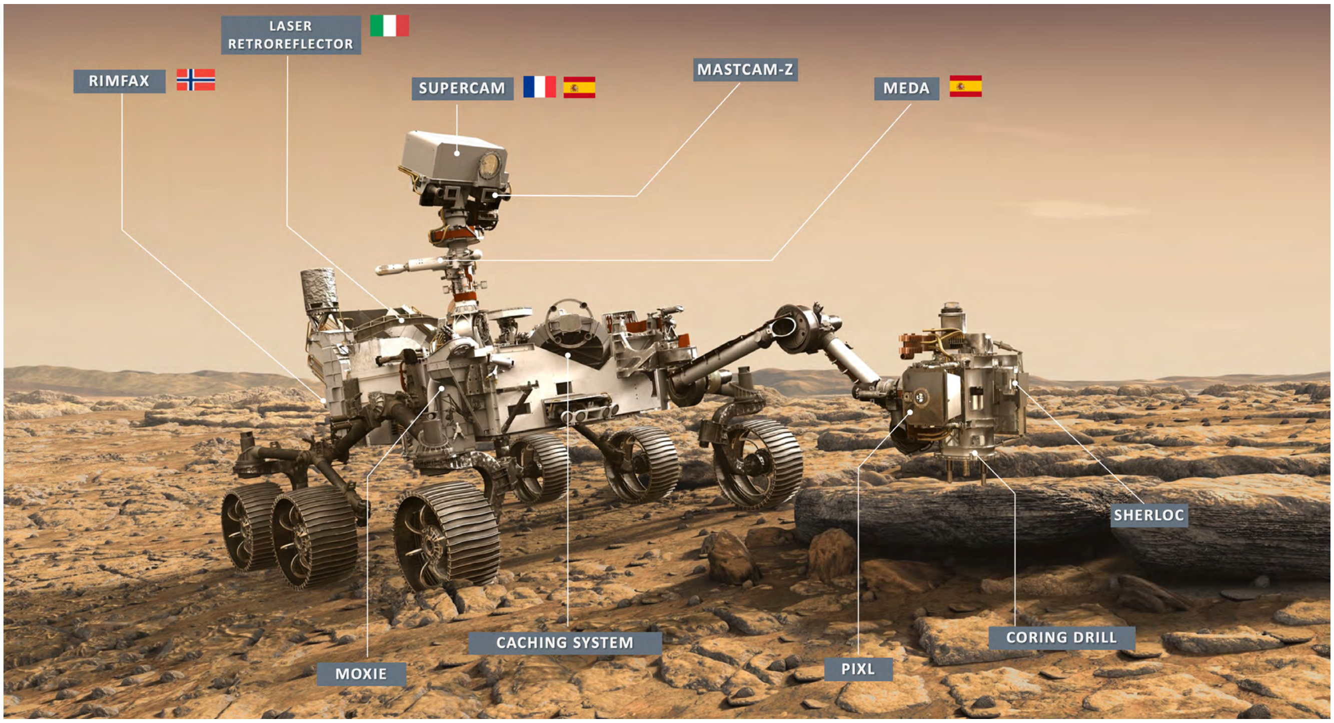
To reach the first three goals, NASA has determined the following more specific science objectives for Perseverance:

- Understand the geology of the field site explored by the Perseverance rover.
- Determine whether Perseverance's landing site, Jezero Crater, could have supported microbial life in the distant past, and search for evidence that such ancient life may have left behind.
- Select and collect samples representing the geologic diversity of the Perseverance field site, focusing on materials with the highest potential to preserve signs of life and planetary evolution. Keep these samples pristine, isolating them from Earth-sourced contaminants.

NASA has also tasked the Mars 2020 team with a mission objective to prepare for future human exploration by conducting the following investigations:

- With the MOXIE experiment, demonstrate a technology that converts carbon dioxide in the Martian atmosphere into oxygen. In the future, oxygen generated this way could be used by astronauts for rocket propellant and for breathing. More on MOXIE below.
- With data from the MEDA instrument, study how atmospheric dust could affect future technology, including human life support systems.
- Study how Mars weather could affect human explorers. More on MEDA below.
- With MEDLI2, use sensors in the rover's heat shield and back shell to better understand entry into the Martian atmosphere. This can help spacecraft engineers design safe landings for future astronauts traveling to Mars. More information on MEDLI2 is here.

Payload Instruments



Several instruments on Perseverance involve international partners | *Image credit: NASA/JPL-Caltech*

Perseverance's science instruments are state-of-the-art tools for acquiring information about Martian geology, atmosphere, environmental conditions, and potential signs of life (biosignatures) from the past. The mission's science supports the field of astrobiology, which aims to understand the origin, evolution, and distribution of life in the universe.

Perseverance has seven primary payload instruments.

Mastcam-Z

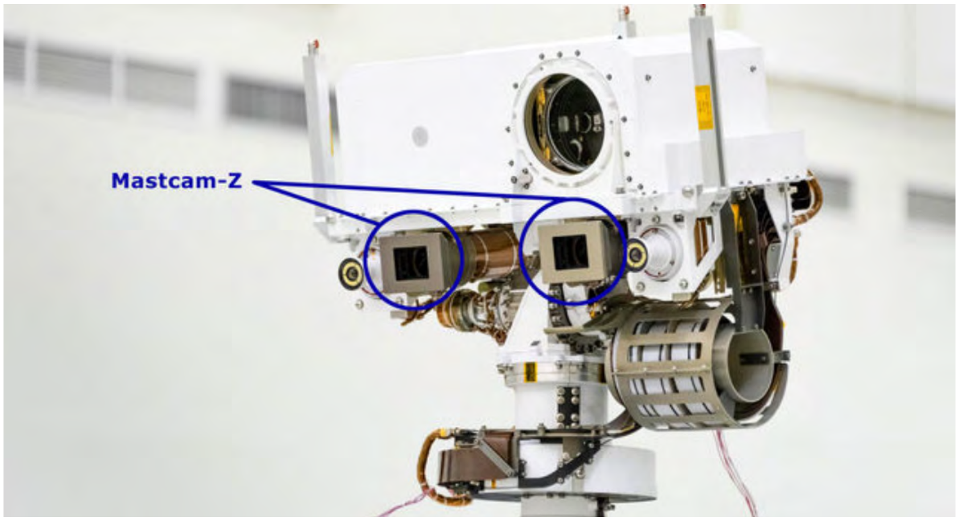


Image credit: NASA/JPL-Caltech

Principal Investigator:

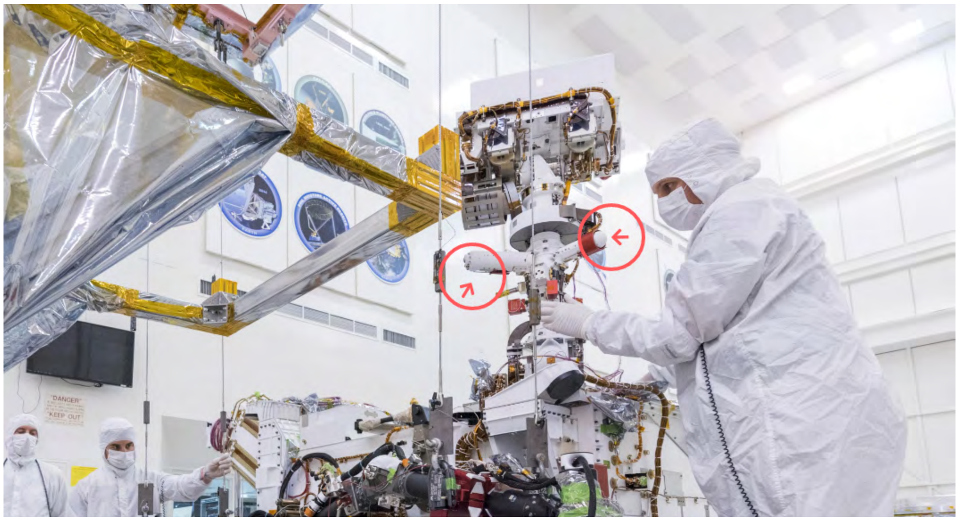
Jim Bell, Arizona State University, Tempe

Mastcam-Z is a pair of next-generation science cameras on Perseverance's remote sensing mast, or "head." This pair of zoomable cameras can be used to shoot video and to create high-resolution, color stereo/3D panoramas of the Martian landscape in multiple spectra of light. These images also help rover operators drive and position the rover's arm instruments. Analysis of the landing site's geology viewed in Mastcam-Z images will help scientists determine the history of the landing site region.

Mastcam-Z

- Serves as Perseverance's primary scientific "eyes."
- At maximum zoom, can see a feature as small as a house fly from as far away as the length of a soccer field.
- Can build 360-degree color and stereo panoramas for science and rover driving.

MEDA (Mars Environmental Dynamics Analyzer)



MEDA wind sensors on Perseverance's mast.
Image credit: NASA/JPL-Caltech

Principal Investigator:

Jose Rodriguez-Manfredi, Centro de Astrobiología, at the Instituto Nacional de Técnica Aeroespacial, Madrid, Spain

MEDA is a set of sensors distributed over Perseverance's mast and body that measures wind speed and direction, air pressure, relative humidity, ambient temperature, and solar radiation. Solar radiation affects the surface environment and is important to understand more fully before sending humans to Mars. A skyward-facing camera, SkyCam measures how tiny airborne particles, or aerosols, such as dust and ice can affect sunlight reaching the surface.

This set of sensors was built by an international team led by Spain's Centro de Astrobiología.

MEDA

- Measures how Martian weather changes within one day and across the seasons.
- Helps scientists understand how dust responds to environmental changes and when its properties change, or if it influences engineering systems and the interpretation of other instruments' observations.
- Through SkyCam, studies types and abundances of clouds.

MOXIE (Mars Oxygen ISRU Experiment)

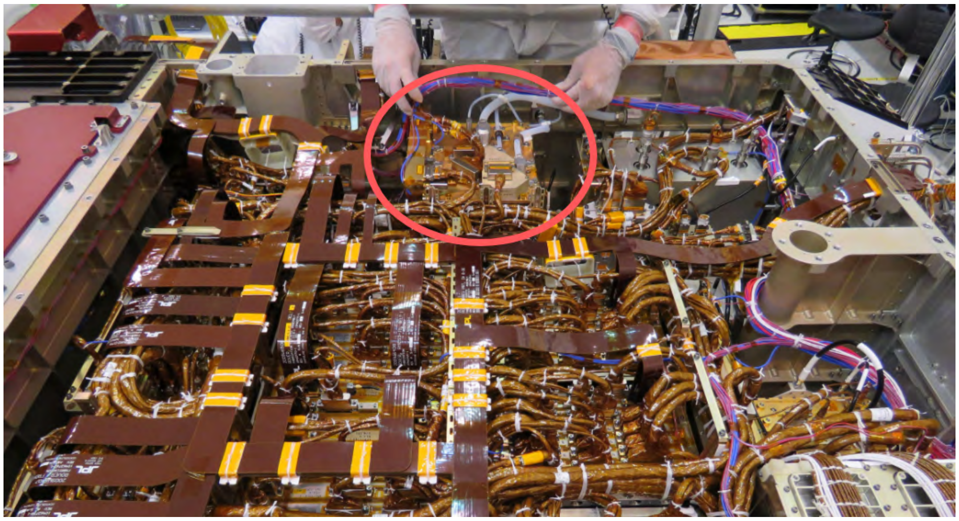


Image credit: NASA/JPL-Caltech

Principal Investigator:

Michael Hecht, Massachusetts Institute of Technology, Cambridge

MOXIE is a technology demonstration that will show whether such technology could be used to help launch rockets off the surface of Mars in the future. (The "I" in MOXIE stands for "in-situ resource utilization," or ISRU – the concept of using resources found where a spacecraft lands rather than bringing those resources from Earth.) MOXIE converts carbon dioxide in the Martian atmosphere into oxygen, which is required in massive quantities in order to launch rockets. To burn enough rocket fuel to launch themselves back to Earth, future astronauts will require tens of metric tons of liquid oxygen. The MOXIE experiment aboard Perseverance is about the size of a car battery and can produce enough oxygen to sustain a small dog. A system that produces breathing oxygen for human missions would need to be about 200 times larger.

This set of sensors was built by an international team led by Spain's Centro de Astrobiología.

MOXIE

- Weighs about 38 pounds (17 kilograms).
- Is designed to produce 0.022 pounds of oxygen per hour (10 grams of oxygen per hour).

PIXL (Planetary Instrument for X-ray Lithochemistry)

Image credit: NASA/JPL-Caltech

Principal Investigator:

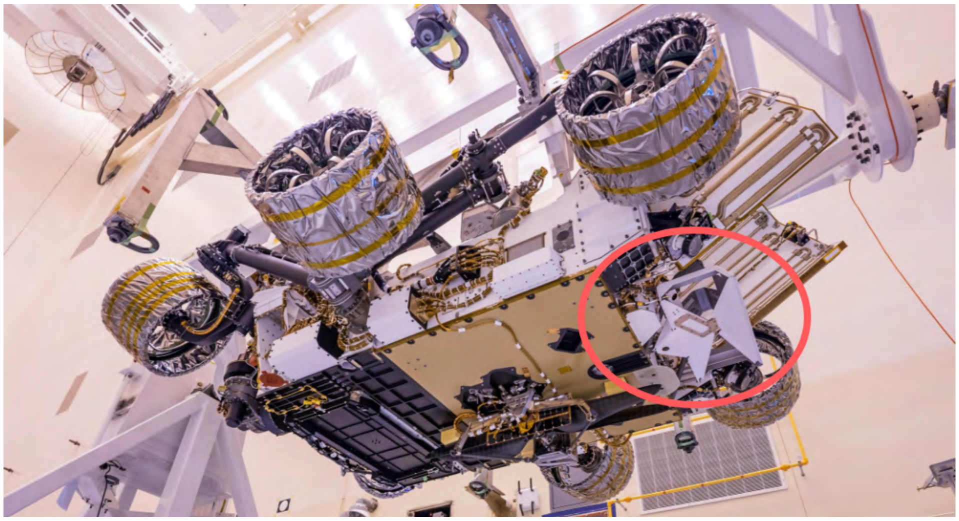
Abigail Allwood, NASA's Jet Propulsion Laboratory, Southern California

Located on the end of Perseverance's robotic arm, PIXL aims a tiny but powerful X-ray beam at rocks. This produces a different "glow," or fluorescence, depending on the rock's elemental chemistry. PIXL creates postage stamp-size "maps," revealing how and where these chemicals are positioned relative to each other as well as to a rock's textures and structures. That information can help scientists determine how these features formed, including whether they were biological in nature.

PIXL

- Can detect over 20 chemical elements.
- Takes just 10 seconds to perform a highly accurate analysis of a single point as small as a grain of sand.
- Uses a hexapod, a device that features six mechanical legs connecting PIXL to the robotic arm and that is guided by artificial intelligence to get the most accurate aim.

RIMFAX (Radar Imager for Mars' Subsurface Experiment)



The white box with cutouts on the right side of the rover's underside is part of the RIMFAX instrument.
Image credit: NASA/JPL-Caltech

Principal Investigator:

Svein-Erik Hamran, University of Oslo, Norway

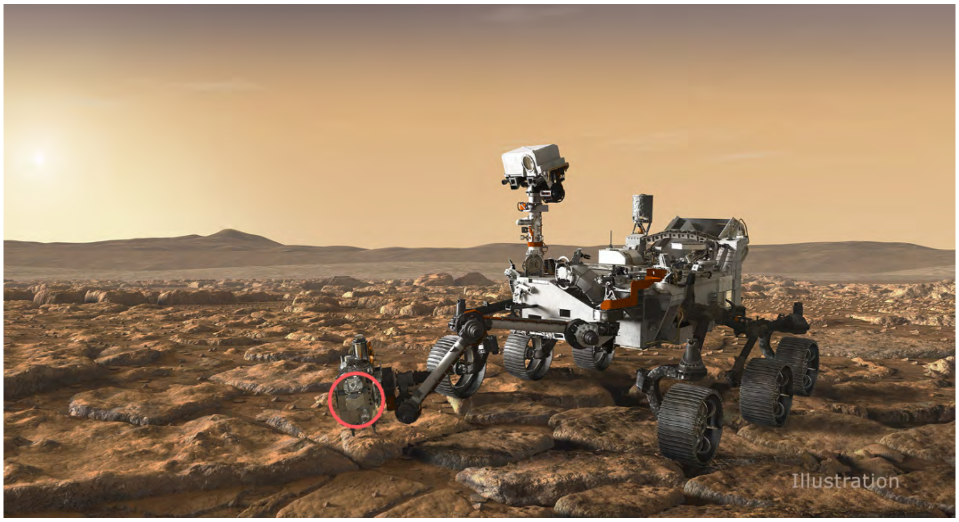
RIMFAX is the first ground-penetrating radar to be carried by a rover or lander to Mars. Such radar systems have been used by orbiting spacecraft, but bringing them to the surface offers much higher-resolution data. RIMFAX determines how different layers of the Martian surface formed over time.

The Norwegian Defense Research Establishment (FFI) in Kjeller, Norway, provided the instrument.

RIMFAX

- Is based on the design of ground-penetrating radar used to study rock and ice at Earth's poles.
- Takes its name from "Hrímfaxi," the horse in Norse mythology that faithfully brings the night.
- Helps pave way for future generations of RIMFAX that could detect water ice deposits for use by astronauts. (Jezero Crater, however, is too warm to harbor subsurface water ice.)

SHERLOC (Scanning Habitable Environments with Raman & Luminescence for Organics & Chemicals)



The SHERLOC instrument is circled in black in this illustration of the Perseverance rover.
Image credit: NASA/JPL-Caltech

Principal Investigator:

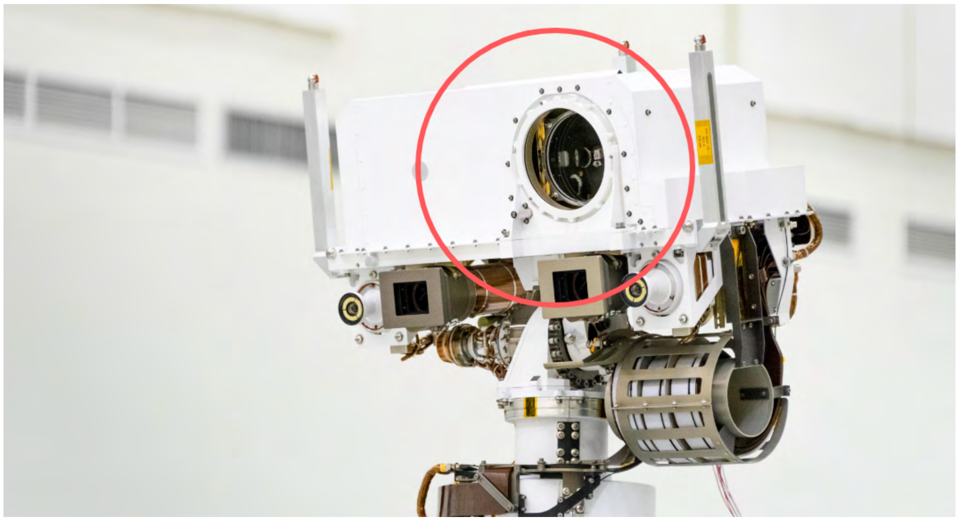
Luther Beegle, JPL

SHERLOC is located near PIXL on Perseverance's robotic arm. As PIXL looks for elemental chemistry, SHERLOC looks for organic molecules and minerals. While the presence of organic molecules helps scientists determine which samples to collect for future return to Earth, the presence of different minerals helps explain how a sample was formed. SHERLOC flashes an ultraviolet laser over surface material, which emits a subtly different glow depending on which organic compounds and minerals are present. SHERLOC also has a camera for taking microscopic images of rock grains and surface textures.

SHERLOC

- Features a camera called WATSON (Wide Angle Topographic Sensor for Operations and eNgineering).
- Has a calibration target that includes five spacesuit materials and a sample of a Martian meteorite.

SuperCam



SuperCam's laser looks like an eye on Perseverance's mast.
Image credit: NASA/JPL-Caltech

Principal Investigator:

Roger Wiens, Los Alamos National Laboratory, New Mexico

This next-generation version of Curiosity's ChemCam instrument is located on Perseverance's mast. Like its predecessor, SuperCam uses a pulsed laser to study the chemistry of rocks and sediment. It also uses three new techniques to probe the mineral content of its targets and the hardness of the rocks. One of these techniques heats small amounts of the target to around 18,000 degrees Fahrenheit (10,000 degrees Celsius), creating a bright "spark." SuperCam can then determine the chemical makeup of these rocks from the plasma generated by the laser zaps.

SuperCam is a collaboration between Los Alamos National Laboratory and France's Institut de Recherche en Astrophysique et Planétologie (IRAP), which provided key parts of the instrument, including a special microphone. Spain built and tested the SuperCam calibration target assembly. The Spanish contributions were supported by the Spanish Ministry of Science and Innovation (MICINN), and by the University of Valladolid as well as local and regional governments.

SuperCam

- Can analyze material from up to 20 feet (7 meters) away with its laser.
- Records the sound of laser zaps up to 12 feet (4 meters) away with a microphone. The sounds will help scientists understand the property of the rocks, including their hardness.
- Can use artificial intelligence to identify and zap rock targets (in addition to the targets chosen by scientists) as the rover awaits new instructions from Earth.

Science Team Leadership

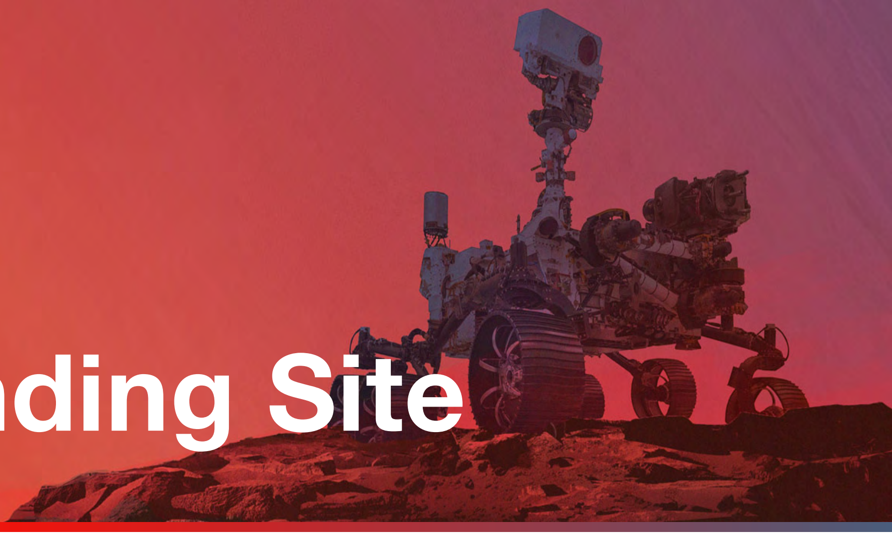
Project Scientist:

Ken Farley, Caltech, Pasadena, California

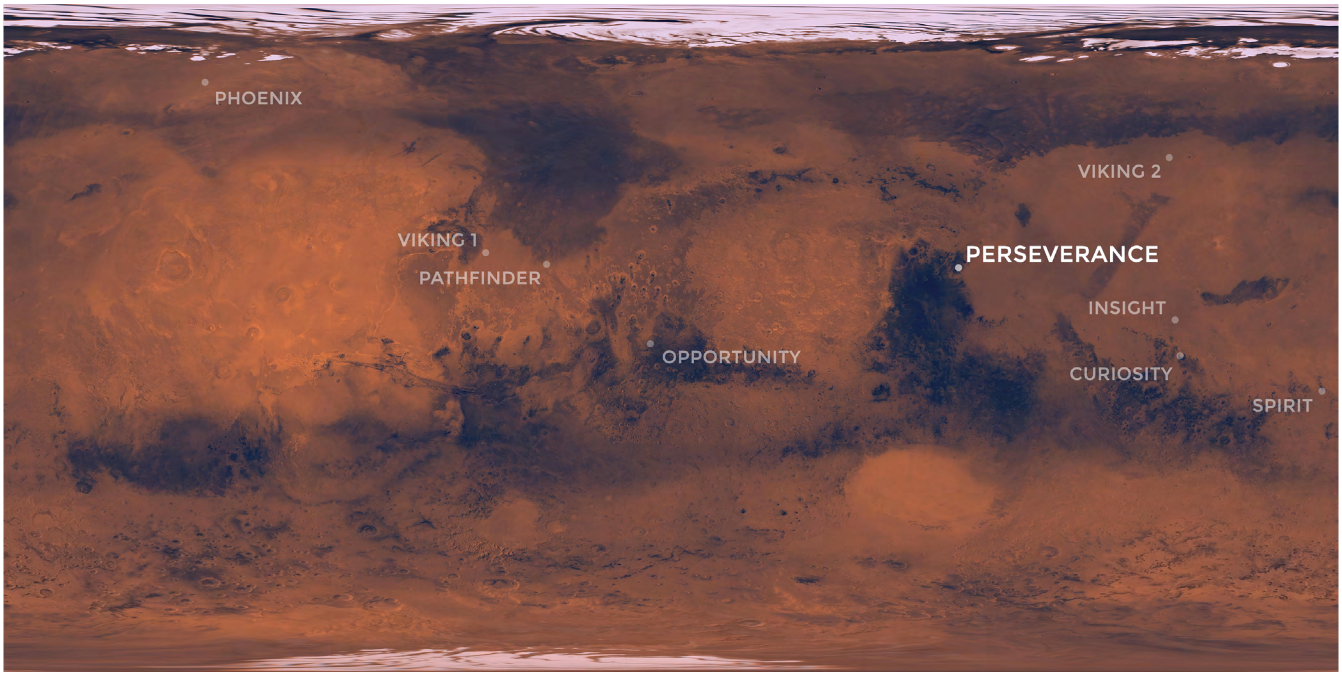
Deputy Project Scientists:

Katie Stack Morgan, JPL
Ken Williford, JPL

Mission: Landing Site



Landing Site



Location where Perseverance will land, with the locations of other successful NASA Mars landings. | *Image credit: NASA/JPL-Caltech*

Perseverance will land in Jezero Crater, located on the western edge of Isidis Planitia, a giant impact basin just north of the Martian equator at about 18 degrees north latitude, 77 degrees longitude. Perseverance's core goal is astrobiological – to seek signs of ancient microbial life – and the rover will be landing in a place with high potential for finding these signs. Western Isidis presents some of the oldest and most scientifically interesting landscapes Mars has to offer. Mission scientists believe the 28-mile-wide (45-kilometer) crater was home to a lake about 3.5 billion years ago – the word "Jezero" in several slavic languages means "lake" – as well as to an ancient river delta. Together, they could have collected and preserved ancient organic molecules and other potential signs of microbial life from the water and sediments that flowed into the crater billions of years ago.

Ilustration of a wet Jezero Crater in the ancient past.
Image credit: NASA/JPL-Caltech

Jezero Crater's ancient lake-delta system offers many promising sampling targets. Parts of Jezero may be especially rich in carbonates, minerals that, on Earth, can preserve fossilized signs of ancient life and can be associated with biological processes. And new landing technologies will allow Perseverance to touch down even closer to the most promising locations than any Mars mission before it.

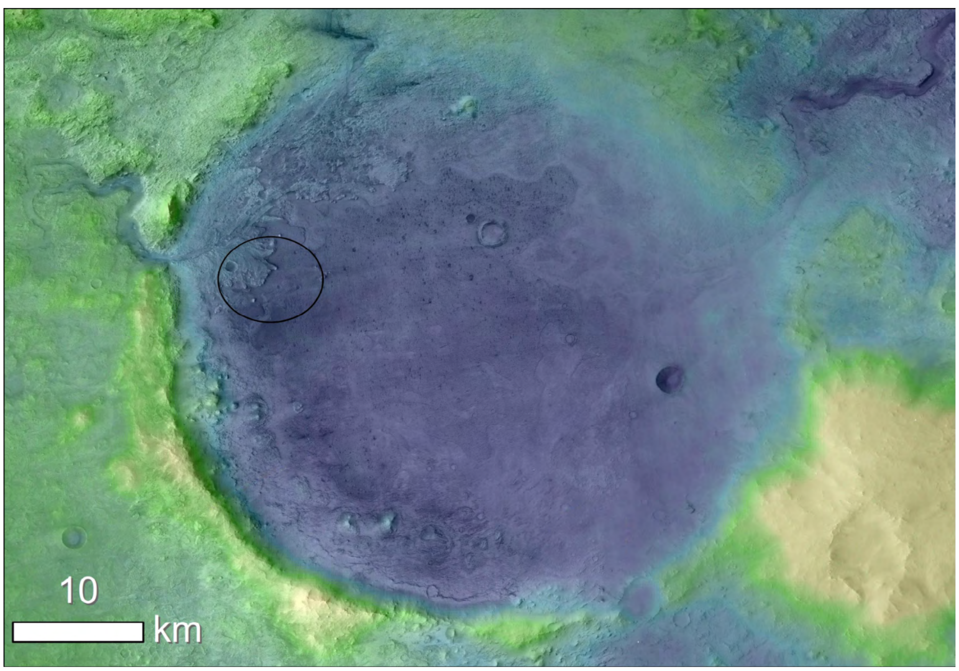
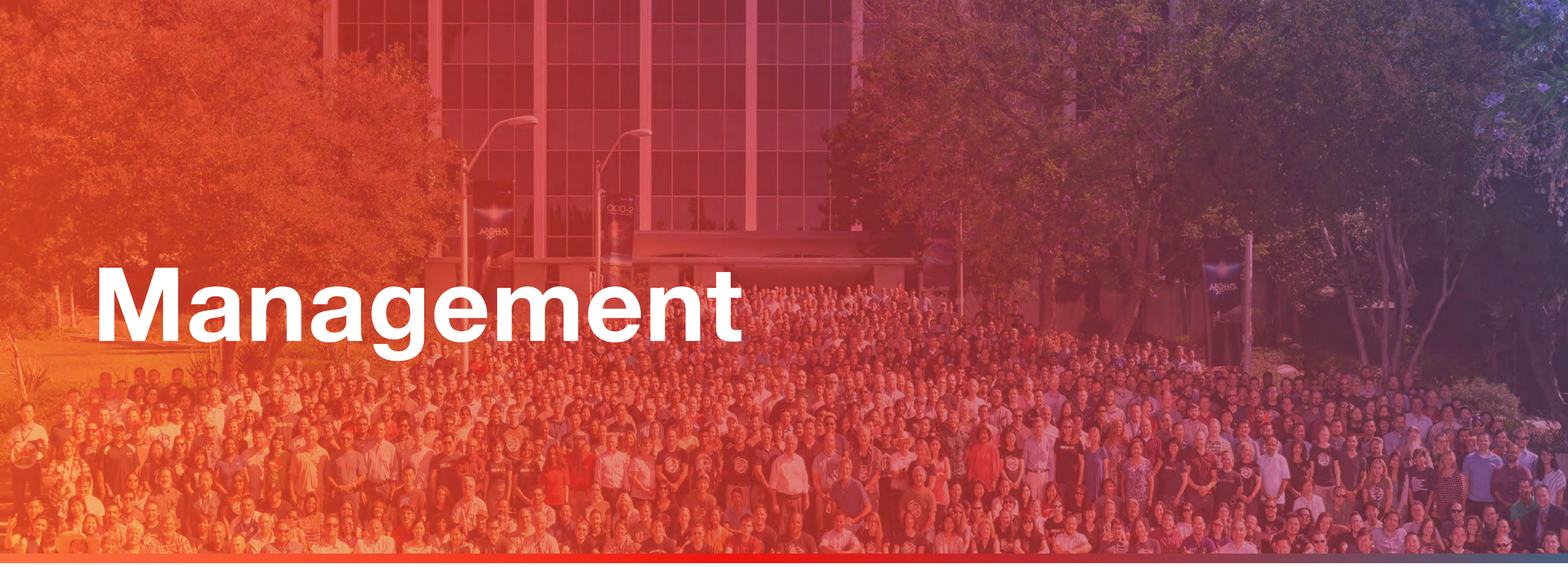


Image credit: NASA/JPL-Caltech/MSSS/JHU-APL/ESA

For more, visit the mission's landing site page.



Management

NASA Leadership

At NASA Headquarters in Washington, **Steve Jurczyk** is the agency's acting administrator. **Thomas Zurbuchen** is the associate administrator for NASA's Science Mission Directorate and **Lori Glaze** is the director of the Planetary Science Division. **Eric Ianson** is the acting director of the Mars Exploration Program and **Michael Meyer** is the chief Mars scientist at headquarters.

Mars 2020 Perseverance Mission

George Tahu is the program executive and **Mitch Schulte** is the program scientist for the Mars 2020 Perseverance mission at NASA Headquarters.

NASA's Jet Propulsion Laboratory, a division of Caltech in Pasadena, California, built and will manage operations for the Perseverance rover for NASA's Science Mission Directorate. At JPL, **John McNamee** is the Mars 2020 Perseverance project manager. **Matt Wallace** and **Jennifer Trosper** are deputy project managers. **Ken Farley** of Caltech is the project scientist. **Katie Stack Morgan** and **Ken Williford** of JPL are the deputy project scientists.

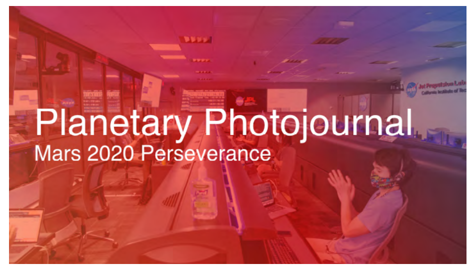
For more detail on team members, visit the Mars 2020 mission team page.

More About Mars: Gallery

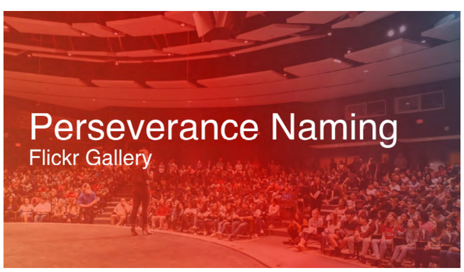
Images

NASA Images and Video Library
go.nasa.gov/perseverance-media-collection

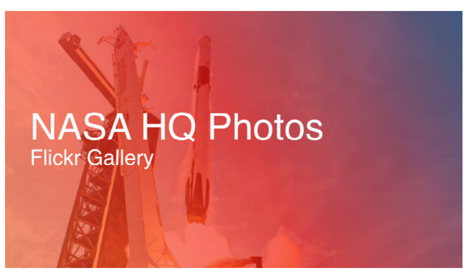
Mars 2020 Mission Website
https://go.nasa.gov/perseverance-images



Planetary Photojournal
go.nasa.gov/perseverance-media-collection



Perseverance Naming Announcement
https://bit.ly/perseverance-name

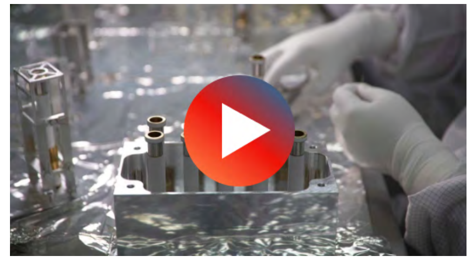


NASA Headquarters Flickr Feed
https://www.flickr.com/photos/nasahqphoto/

Web Videos

Perseverance Arrives at Mars (Mission Trailer)
http://bit.ly/perseverance-lands-trailer

Perseverance Launches
http://bit.ly/perseverance-launch-video



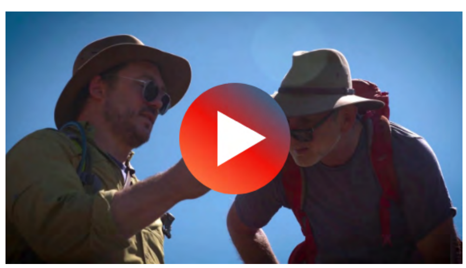
Perseverance Rover Equipped with Ultra-Clean Sample Tubes
http://bit.ly/perseverance-sample-tube

Perseverance's Test Rover on Earth
http://bit.ly/perseverance-test-rover

Perseverance: Road to Launch
https://bit.ly/perseverance-coronavirus

NASA's Latest Rover Has a Name (Recap Video)
https://bit.ly/perseverance-name-video

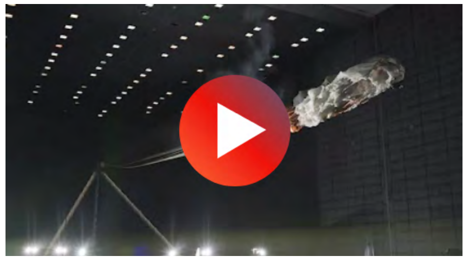
First Drive Test of NASA's Perseverance Rover
https://bit.ly/perseverance-drive



Mars Science Teams Investigate Ancient Life in Australia
https://bit.ly/mars-science-australia

Building NASA's Perseverance Rover
https://bit.ly/building-perseverance

Testing Perseverance
https://bit.ly/testing-perseverance



Preparing to Land Perseverance
http://bit.ly/perseverance-landing-prep

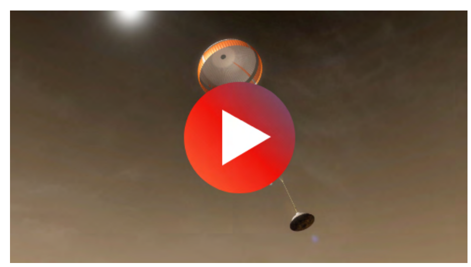
Behind the Spacecraft (Team Member Profiles)
https://bit.ly/3eaLSPz

Mars Playlist
https://bit.ly/mars-playlist

Animations and Raw Video

Perseverance B-Roll Media Reel
https://go.nasa.gov/perseverance-b-roll

NASA Announces Mars 2020 Rover Name Video File
https://go.nasa.gov/perseverance-name-video-file



Mars 2020 Perseverance Animations Media Reel
go.nasa.gov/perseverance-landing-animations

More About Mars: Historical Mars Missions

In addition to NASA's Mars 2020 Perseverance rover and the Ingenuity Mars Helicopter, humankind's other missions to Mars are listed below. Each item includes mission name, country, launch date, purpose, and results.

Marsnik 1: USSR; Oct. 10, 1960; flyby; did not reach Earth orbit

Marsnik 2: USSR; Oct. 14, 1960; flyby; did not reach Earth orbit

Sputnik 22: USSR; Oct. 24, 1962; flyby; achieved Earth orbit only

Mars 1: USSR; Nov. 1, 1962; flyby, radio failed at 65.9 million miles (106 million kilometers)

Sputnik 24: USSR; Nov. 4, 1962; flyby; achieved Earth orbit only

Mariner 3: U.S.; Nov. 5, 1964; flyby; shroud failed to jettison

Mariner 4: U.S.; Nov. 28, 1964; first successful flyby July 14, 1965; returned 21 photos

Zond 2: USSR; Nov. 30, 1964; flyby; passed Mars but radio failed, returned no planetary data

Mariner 6: U.S.; Feb. 24, 1969; flyby July 31, 1969; returned 75 photos

Mariner 7: U.S.; March 27, 1969; flyby Aug. 5, 1969; returned 126 photos

Mars 1969A: USSR; March 27, 1969; orbiter; did not reach Earth orbit

Mars 1969B: USSR; April 2, 1969; orbiter; failed during launch

Mariner 8: U.S.; May 8, 1971; orbiter; failed during launch

Kosmos 419: USSR; May 10, 1971; lander; achieved Earth orbit only

Mars 2: USSR; May 19, 1971; orbiter and lander; arrived Nov. 27, 1971; no useful data, lander burned up due to steep entry

Mars 3: USSR; May 28, 1971; orbiter and lander; arrived Dec. 3, 1971; lander operated on surface for 20 seconds before failing

Mariner 9: U.S.; May 30, 1971; orbiter; operated in orbit Nov. 13, 1971 to Oct. 27, 1972; returned 7,329 photos

Mars 4: USSR; July 21, 1973; orbiter; flew past Mars Feb. 10, 1974 and collected some data, but did not achieve Mars orbit

Mars 5: USSR; July 25, 1973; orbiter; arrived Feb. 12, 1974, lasted a few days

Mars 6: USSR; Aug. 5, 1973; flyby module and lander; arrived March 12, 1974, lander failed due to fast impact

Mars 7: USSR; Aug. 9, 1973; flyby module and lander; arrived March 9, 1974, lander missed the planet

Viking 1: U.S.; Aug. 20, 1975; orbiter and lander; entered orbit June 19, 1976, and operated until Aug. 7, 1980; landed July 20, 1976, and operated until Nov. 11, 1982

Viking 2: U.S.; Sept. 9, 1975; orbiter and lander; entered orbit Aug. 7, 1976, and operated until July 25, 1978; landed Sept. 3, 1976, and operated until April 11, 1980; combined, the Viking orbiters and landers returned more than 50,000 photos

Phobos 1: USSR; July 7, 1988; Mars orbiter and Phobos lander; lost August 1988 en route to Mars

Phobos 2: USSR; July 12, 1988; Mars orbiter and Phobos lander; lost March 1989 near Phobos

Mars Observer: U.S.; Sept. 25, 1992; orbiter; lost just before Mars arrival Aug. 21, 1993

Mars Global Surveyor: U.S.; Nov. 7, 1996; orbiter; arrived Sept. 12, 1997; mapped in high detail through January 2000, completed its third extended mission in September 2006 and last communicated Nov. 2, 2006

Mars 96: Russia; Jan. 16, 1996; orbiter, two landers, and two penetrators; launch vehicle failed

Mars Pathfinder: U.S.; Dec. 4, 1996; lander and rover; landed July 4, 1997, completed prime mission and began extended mission Aug. 3, 1997, and last communicated Sept. 27, 1997

Nozomi: Japan; July 4, 1998; orbiter; failed to enter orbit December 2003

Mars Climate Orbiter: U.S.; Dec. 11, 1998; orbiter; lost upon arrival Sept. 23, 1999

Mars Polar Lander/Deep Space 2: U.S.; Jan. 3, 1999; lander and two penetrators; lost on arrival Dec. 3, 1999

Mars Odyssey: U.S.; March 7, 2001; orbiter; entered orbit Oct. 24, 2001, completed prime mission Aug. 24, 2004, currently conducting extended mission of science collection and communication relay

Mars Express/Beagle 2: Europe; June 2, 2003; orbiter and lander; orbiter completed prime mission November 2005, currently in extended mission; lander lost on arrival Dec. 25, 2003

Mars Exploration Rover-A (Spirit): U.S.; June 10, 2003; rover; landed Jan. 4, 2004 for three-month prime mission inside Gusev Crater, completed several extended missions, last communicated March 22, 2010, mission declared complete May 25, 2011

Mars Exploration Rover-B (Opportunity): U.S.; July 7, 2003; rover; landed Jan. 25, 2004 for three-month prime mission in Meridiani Planum region, completed several extended missions, last communicated June 10, 2018, mission declared complete on Feb. 13, 2019

Mars Reconnaissance Orbiter: U.S.; Aug. 12, 2005; orbiter; entered orbit March 12, 2006, completed prime mission Sept. 26, 2010, currently conducting extended mission of science collection and communication relay

Phoenix Mars Lander: U.S.; Aug. 4, 2007; lander; landed May 25, 2008, completed prime mission and began extended mission Aug. 26, 2008, last communicated Nov. 2, 2008

Phobos-Grunt/Yinghuo 1: Russia/China; Nov. 8, 2011; Phobos lander with sample return and Mars orbiter; achieved Earth orbit only

Mars Science Laboratory (Curiosity rover): U.S.; Nov. 26, 2011; rover; landed Aug. 6, 2012, completed prime mission, currently conducting extended science mission

Mars Atmosphere and Volatile Evolution MissioN (MAVEN): U.S.; Nov. 18, 2013; orbiter; entered orbit Sept. 21, 2014; completed prime mission, currently conducting extended science mission

Mars Orbiter Mission (Mangalyaan): India; Nov. 5, 2013; orbiter; entered orbit Sept. 14, 2014, completed prime mission, currently conducting extended mission

ExoMars 2016 (Trace Gas Orbiter and Schiaparelli module): Europe; March 14, 2016; orbiter and landing-demonstration module; entered orbit Oct. 19, 2016, currently conducting prime mission; unsuccessful Mars impact of Schiaparelli module Oct. 19, 2016

InSight Lander: U.S., May 5, 2018; lander; landed Nov. 26, 2018; completed prime mission, currently conducting extended science mission

Mars Cube One: U.S.; May 5, 2018; two-CubeSat data relay for InSight Lander; flew by Mars and completed relay Nov. 26, 2018, concluded operations Feb. 2, 2020

Emirates Mars Mission (Hope probe): United Arab Emirates; July 19, 2020; orbiter; expected to enter orbit February 2021

Mars Global Remote Sensing Orbiter and Small Rover (Tianwen-1): China; July 23, 2020; orbiter and rover; expected to enter orbit February 2021 and land the rover April 2021

Future

ESA (European Space Agency) and Russia's space agency (Roscosmos) expect to launch the ExoMars 2022 mission in late September 2022 to deliver a European rover (Rosalind Franklin) and a Russian surface platform (Kazachok) to Mars June 2023.

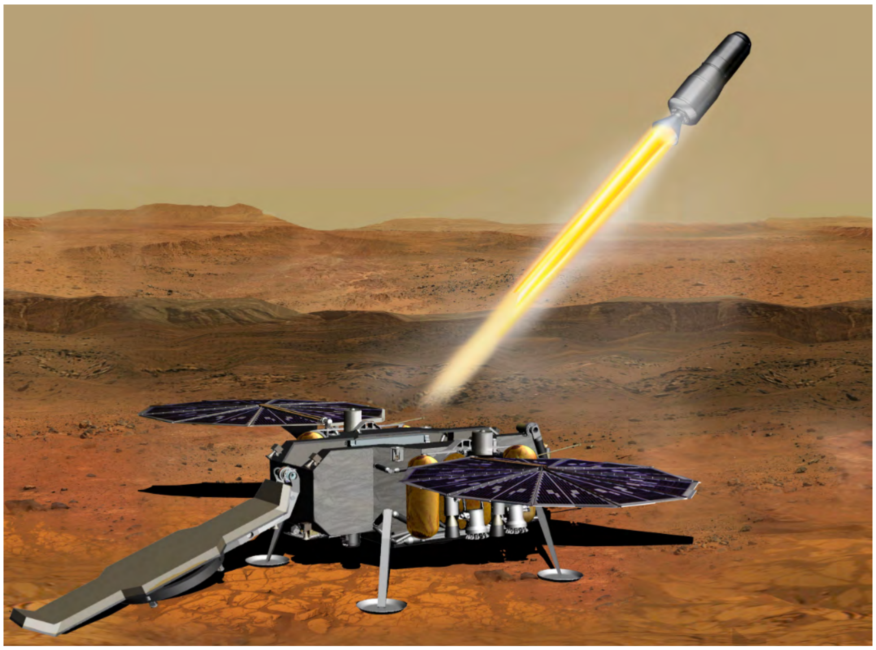


Image credit: NASA/JPL-Caltech

NASA and ESA are solidifying concepts for a Mars Sample Return campaign that begins with NASA's Perseverance rover collecting rock and other samples and storing them in sealed tubes to be left on the planet's surface for future retrieval and return to Earth.

According to the current concept, NASA and ESA expect to undertake two launches as early as 2026: a NASA lander and an ESA orbiter. Under this schedule, ESA's orbiter would arrive in orbit at Mars in 2027; subsequently NASA's lander would arrive in 2028, carrying a NASA rocket (the Mars Ascent Vehicle) and ESA's Sample Fetch Rover. The fetch rover's job is to retrieve the cached samples and deliver them to the lander for transfer to the ascent vehicle; Perseverance could also deliver samples to the lander.
The ascent vehicle will then launch a special container holding the samples into Mars orbit. The ESA orbiter will rendezvous with and capture the orbiting samples in a NASA-provided payload that will further prepare the orbiting sample container for return to Earth. The ESA orbiter will fly back to Earth and the NASA Earth Entry System will land the samples on Earth.