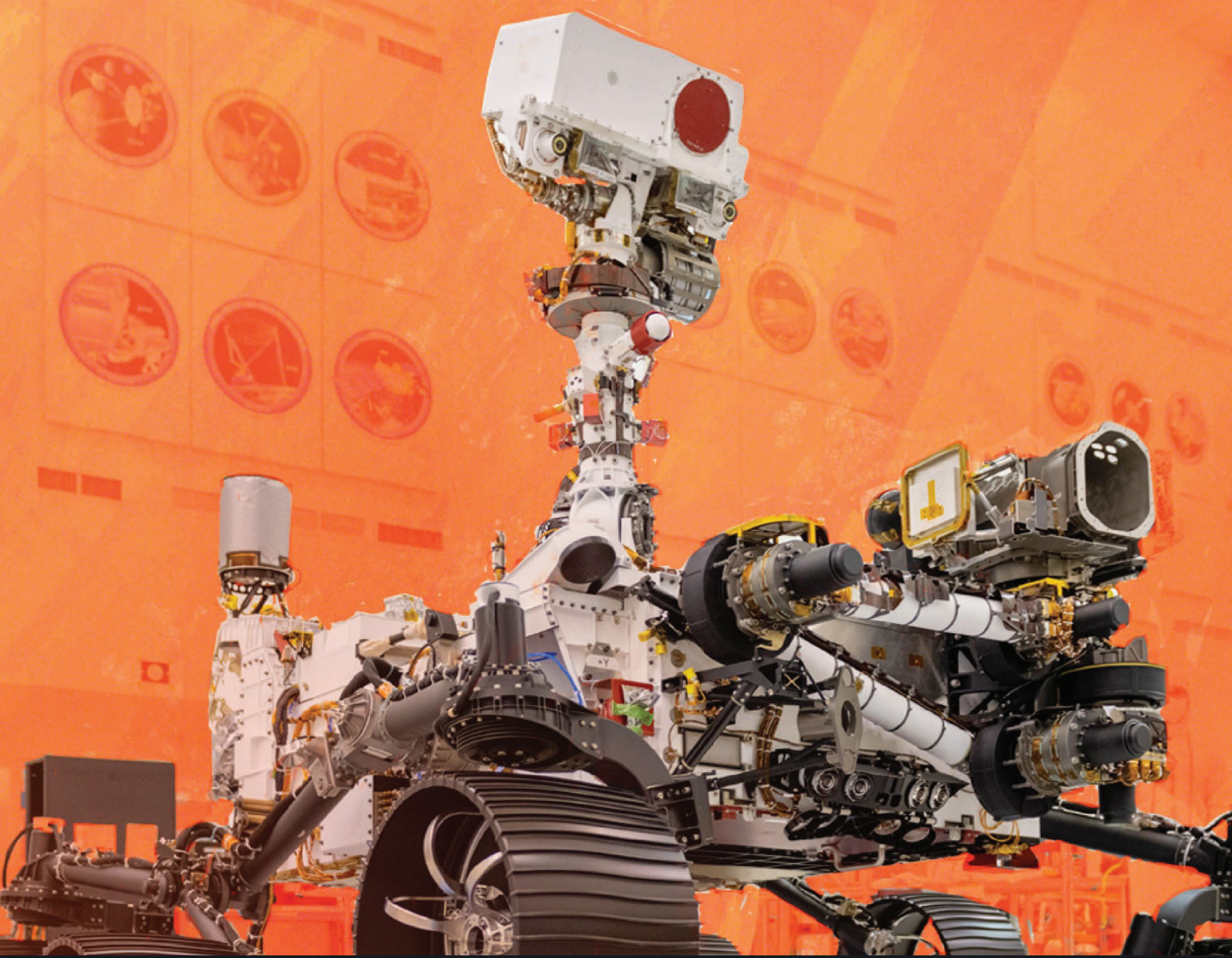
National Aeronautics and Space Administration



Mars 2020 Perseverance Launch Press Kit

JUNE 2020

www.nasa.gov

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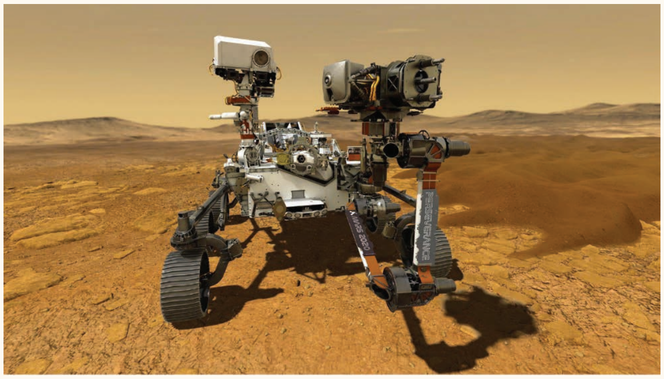
Introduction

NASA's next mission to Mars — the Mars 2020 Perseverance mission — is targeted to launch from Cape Canaveral Air Force Station no earlier than July 20, 2020. It will land in Jezero Crater on the Red Planet on Feb. 18, 2021. Perseverance is the most sophisticated rover NASA has ever sent to Mars, with a name that embodies NASA's passion for taking on and overcoming challenges. It will search for signs of ancient microbial life, characterize the planet's geology and climate, collect carefully selected and documented rock and sediment samples for possible return to Earth, and pave the way for human exploration beyond the Moon.

Perseverance will also ferry a separate technology experiment to the surface of Mars — a helicopter named Ingenuity, the first aircraft to fly in a controlled way on another planet.

Seven Things to Know About the Mars 2020 Perseverance Mission

The Perseverance rover, built at NASA's Jet Propulsion Laboratory in Southern California, is loaded with scientific instruments, advanced computational capabilities for landing and other new systems. With a chassis about 10 feet (3 meters) long, Perseverance is also the largest, heaviest robotic Mars rover NASA has built. What drives its ambitious mission and what will it do at the Red Planet? Here are seven things you should know about Perseverance:

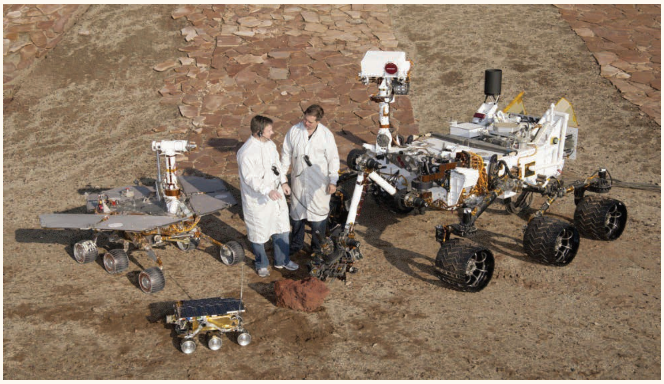


1. The Perseverance rover embodies the NASA — and the American — spirit of overcoming challenges.

Getting the spacecraft to the launch pad this summer has required an extended effort. Concept studies and early technology work started a decade ago — years before the project was formally announced in

December 2012. Landing on another planet, searching for signs of ancient life, collecting samples and proving new technologies will also be tough. These challenges epitomize why NASA chose the name Perseverance from among the 28,000 essays submitted during the "Name the Rover" contest. The months leading up to the launch in particular have required creative problem solving and teamwork during the coronavirus pandemic.

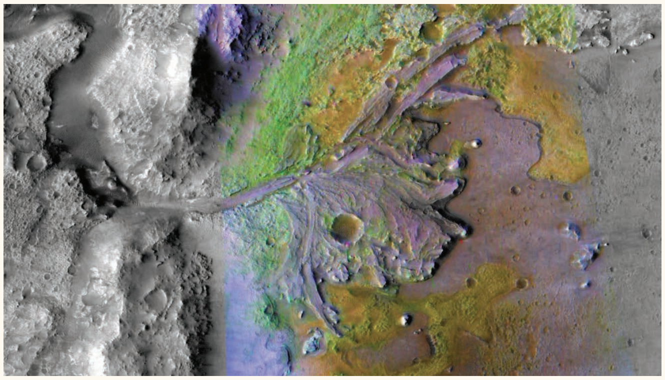
As Alex Mather of Lake Braddock Secondary School in Burke, Virginia, wrote in his winning essay, "We are a species of explorers, and we will meet many setbacks on the way to Mars. However, we can persevere. We, not as a nation but as humans, will not give up."



2. Perseverance builds on the lessons of other Mars rovers.

NASA's first rover on Mars was modest: Sojourner, the size of a microwave oven, demonstrated in 1997 that a robot could rove on the Red Planet. NASA's next Mars rovers, Spirit and Opportunity, were each the size of a golf cart. After landing in 2004, they discovered evidence that the planet once hosted running water before becoming a frozen desert. The car-sized Curiosity rover landed in 2012. Curiosity discovered that its landing site, Gale Crater, hosted a lake billions of years ago and an environment 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 potential signs of past microbial life, or biosignatures on Mars?

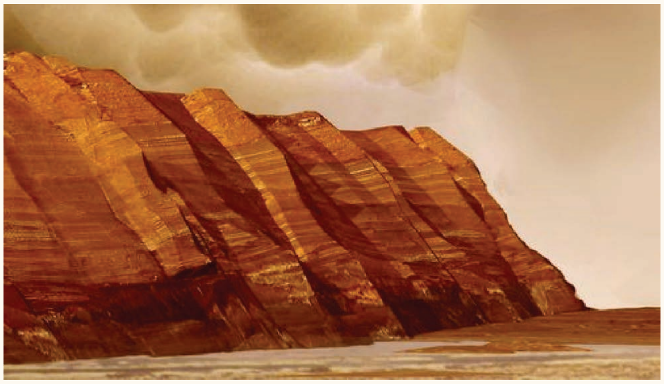
This demanding science goal requires a new suite of cutting-edge instruments to tackle the question from many angles. The Scanning Habitable Environments with Raman & Luminescence for Organics & Chemicals (SHERLOC) instrument, which can detect organic matter, and the Planetary Instrument for X-ray Lithochemistry (PIXL), which measures the composition of rocks and soil, will allow Perseverance to map organic matter, chemical composition and texture together at a higher level of detail than any Mars rover has done before. These instruments — two of the seven total onboard — will play a particularly important role in Perseverance's search for potential signs of life.



3. The rover will be landing in a place with high potential for finding signs of past microbial life.

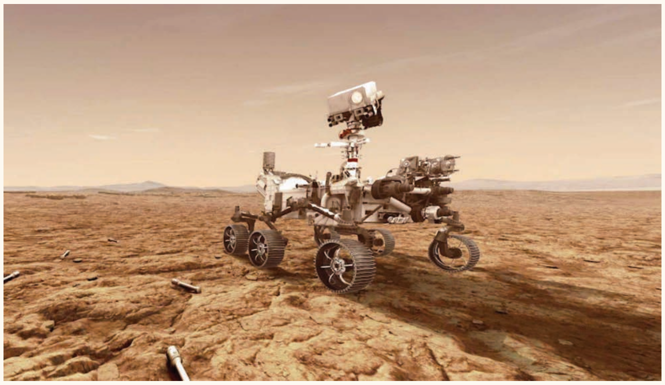
Jezero Crater on Mars is a 28-mile-wide (45-kilometer-wide) crater on the western edge of Isidis Planitia, a giant impact basin just north of the Martian equator. The crater was a possible oasis in its distant past.

Between 3 billion and 4 billion years ago, a river there flowed into a body of water the size of Lake Tahoe, depositing sediments packed with carbonite minerals and clay. The Perseverance science team believes this ancient river delta could have collected and preserved organic molecules and other potential signs of microbial life.



4. Perseverance will also be collecting important data about Mars' geology and climate.

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 — which formed from the same primordial stuff — ended up so different.



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

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.

A Mars sample return campaign is being planned by NASA and the European Space Agency because here on Earth we can investigate the samples with instruments too large and complex to send to Mars. Examining those samples on Earth will provide far more information about them than even the most sophisticated rover could provide.

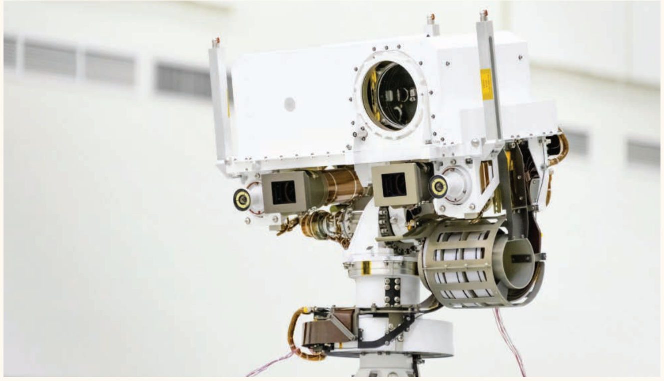
6. Perseverance carries instruments and technology that will pave the way for future human missions to the Moon and Mars.

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

Engineers have also given Perseverance more self-driving smarts than any other rover, allowing it to cover more ground in a day's operations without having to wait for engineers on Earth to send up instructions. Calculated over the length of the mission, this fast pace can translate into more science. This fast-traverse capability (courtesy of upgraded sensors, computers and algorithms) will make exploration of the Moon, Mars and other celestial bodies more efficient for other spacecraft.

Perseverance also carries a technology demonstration — a proof-of-concept experiment — called MOXIE (Mars Oxygen In-Situ Resource Utilization Experiment). 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.

The Mars Environmental Dynamics Analyzer (MEDA) instrument suite will also be key for future human exploration, providing information about the current weather and climate, as well as the nature of the dust on the surface. The Mars Science Laboratory Entry, Descent and Landing Instrumentation 2 (MEDLI2) package, a next-generation version of what flew on the Mars Science Laboratory mission that delivered the Curiosity rover, will help human exploration, too, providing data about the entry and descent of the spacecraft through the atmosphere.



7. You will get to ride along.

The Mars 2020 Perseverance mission carries more cameras than any interplanetary mission in history. The Perseverance rover itself has 19 cameras that will deliver images of the landscape in breathtaking detail. The other parts of the spacecraft involved in entry, descent and landing carry four additional cameras, potentially allowing engineers to put together a high-definition view of the landing process after the rover safely touches down on Mars. As with previous Mars missions, the Mars 2020 Perseverance mission plans to make raw and processed images available on the mission's website.

In this spirit of bringing the public along, the Perseverance rover carries an anodized plate with the words "Explore as one" in Morse code and three silicon chips with the names of approximately 10.9 million people who signed up to ride along on Perseverance's journey to Mars.

You can also follow Perseverance's adventure on social media **@NASAPersevere** and **@NASAMars.**

Six Things to Know About Ingenuity

Ingenuity, NASA's Mars Helicopter, may weigh only about 4 pounds (1.8 kilograms), but it has some outsized ambitions. As the Wright Brothers were the first to achieve powered, controlled flight on our world with their Flyer, Ingenuity's team at JPL expects its helicopter to be the first flyer on another world. Here are six things you should know about the first helicopter going to another planet:

1. Ingenuity is an experimental flight test.

Ingenuity is what is known as a technology demonstration — a project that seeks to test a new capability for the first time, with limited scope. Previous groundbreaking technology demonstrations include the Mars Pathfinder rover Sojourner and the Mars Cube One (MarCO) CubeSats that flew by Mars.

Ingenuity features four specially made carbon-fiber blades arranged into two 4-foot-long (1.2-meter-long) counter-rotating rotors that spin at around 2,400 rpm — about eight times as fast as a standard helicopter on Earth — plus innovative solar cells, battery, avionics, sensors, telecommunications, and other designs and algorithms. But many of its other components are commercial, off-the-shelf parts from the world of smart phones, including two cameras, an inertial measurement unit (measuring movement), an altimeter (measuring altitude), an inclinometer (measuring tilt angles) and computer processors. The helicopter does not carry science instruments and is a separate experiment from the Mars 2020 Perseverance mission.

2. Ingenuity will be the first aircraft to attempt controlled flight on another planet.

Mars has beyond bone-chilling temperatures, with nights as cold as minus 130 degrees Fahrenheit (minus 90 degrees Celsius) at Jezero Crater. These temperatures will push the original design limits of the off-the-shelf parts used in Ingenuity. Tests on Earth at the predicted temperatures indicate they should work as designed, but the team is looking forward to the real test at Mars. One of Ingenuity's first objectives when it gets to the Red Planet is just to survive the frigid Martian night for the first time.

Mars has a rarefied atmosphere — just 1% of the density of our atmosphere on Earth. Because the Mars atmosphere is so much less dense, Ingenuity is designed to be light, with rotor blades that are much larger and spin much faster than what would be required for a helicopter of Ingenuity's mass on Earth. And Mars gives the helicopter a little help: The gravity at Mars is only about one-third that of Earth's. That means slightly more mass can be lifted at a given spin rate.

There is also the challenge of communication. Delays are an inherent part of communicating with spacecraft across interplanetary distances, which means the helicopter's flight controllers at JPL won't be able to control the helicopter with a joystick.

Therefore, Ingenuity has to fly autonomously. The command to fly will be sent to Ingenuity well in advance, and the engineering data from the flight will be returned to Earth after the flight takes place. Ingenuity will communicate through the rover, which will then communicate with an orbiter that in turn communicates with Earth.

3. Ingenuity has already demonstrated feats of engineering.

It took humankind a lot of trial and error to figure out how to fly a plane or helicopter on Earth. In careful steps over five years, engineers on the Ingenuity team were able to demonstrate it was possible to build something that was lightweight enough and could generate enough lift in Mars' thin atmosphere to take off from the ground.

Using a special space simulation chamber at JPL, they first showed that a helicopter could lift off in Mars' thin atmosphere in 2014 and then in 2016 that it could fly in a controlled way. They proved a helicopter could be built to survive in Mars' environment and operate as designed in January 2018, by flying a helicopter test model in the chamber with the full functionality that would be required for Mars. In February 2019, the team completed test flights with the actual helicopter that will ride with Perseverance to the Red Planet, demonstrating its capabilities in Mars-like conditions.

Taking off from the surface of Mars and hovering will confirm these previous tests and give practical insight into operating a helicopter on Mars.

4. Ingenuity is a fitting name for a robot that has required creativity from its engineering team.

Vaneeza Rupani of Northport, Alabama, originally submitted the name Ingenuity for the Mars 2020 rover, but NASA officials recognized the submission as a fitting name for the helicopter, given how much creative thinking the team employed to get their mission off the ground.

"The ingenuity and brilliance of people working hard to overcome the challenges of interplanetary travel are what allow us all to experience the wonders of space exploration," Rupani wrote. "Ingenuity is what allows people to accomplish amazing things."

Rupani's essay also unknowingly gave a nod to the rover and the helicopter working together to accomplish great feats in space exploration: Landing people on the Moon and sending rovers to Mars, she wrote, "are not just the product of pure determination; they are a combination of human perseverance and ingenuity."

5. The Ingenuity team counts success one step at a time.

Given all the firsts Ingenuity is trying to accomplish, the team has a long list of milestones they need to pass before the helicopter can take off and land in the spring of 2021. The team will celebrate if they meet each one. The milestones include:

- Surviving launch from Cape Canaveral, the cruise to Mars and landing on the Red Planet
- Safely deploying to the surface from the belly pan of the Perseverance rover
- Autonomously keeping warm through the intensely cold Martian nights
- Autonomously charging itself with its solar panel

And then, if Ingenuity succeeds in its first flight, the helicopter team will attempt up to four other test flights within a 30-Martian-day (31-Earth-day) window.

6. If Ingenuity succeeds, future Mars exploration could include an ambitious aerial dimension.

Ingenuity is intended to demonstrate technologies needed for flying in the Martian atmosphere. If successful, these technologies could enable other advanced robotic flying vehicles that might be included in future robotic and human missions to Mars. Among the possible uses of a future helicopter on Mars: offering a unique viewpoint not provided by our current orbiters high overhead or by rovers and landers on the ground; high-definition images and reconnaissance for robots or humans; and access to terrain that is difficult for rovers to reach. A future helicopter could even help carry light but vital payloads from one site to another.

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SuperCam

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

NASA Jet Propulsion Laboratory, Pasadena, Calif.

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MEDLI2

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Technology Demonstration

Ingenuity Mars Helicopter (Technology Demonstration)

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agle@jpl.nasa.gov

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

Mission news, updates and feature stories about the Ingenuity Mars Helicopter will be available at: nasa.gov/mars and by filtering for helicopter stories on NASA's Mars news webpage.

Video and Images

A Mars 2020 Perseverance mission media reel is available at the **NASA Image and Video Library:** go.nasa.gov/perseverance-b-roll

Two Ingenuity Mars Helicopter media reels are available on the NASA Image and Video Library: **animations** go.nasa.gov/mars-helicopter-animations and **b-roll** go.nasa.gov/mars-helicopter-b-roll.

Additional footage related to the Perseverance rover and Ingenuity Mars Helicopter is available on the **JPL Raw YouTube channel** youtube.com/user/JPLraw.

Additional images related to Perseverance are available at the NASA Image and Video Library, **the mission website's gallery:** mars.nasa.gov/mars2020/multimedia/images/ and Planetary Photojournal

The **NASA image use policy** is available here:
nasa.gov/multimedia/guidelines
The **JPL image use policy** is available here:
jpl.nasa.gov/imagepolicy

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 launch page:** mars.nasa.gov/mars2020/timeline/launch/. More information on NASA TV and streaming channels can be found below in the "How to Watch" section.

Briefings and Availabilities

A news conference presenting an overview of the mission will take place at NASA Headquarters in Washington on **June 17, 2020, at 2 p.m. EDT (11 a.m. PDT)**.

For a **July 20** launch attempt, a **pre-launch news conference** open to accredited news media is scheduled at **1 p.m. EDT (10 a.m. PDT)** on **July 17** at the Kennedy Space Center, Florida.

Additional briefings at KSC and media availabilities are expected in the days before launch.

A post-launch news conference at KSC may begin approximately three hours after launch.

All news briefings will be broadcast and streamed.

Live Launch Feed

A live video feed of key launch activities and commentary from the mission control room at Cape Canaveral Air Force Station will be broadcast.The first launch opportunity is targeted to begin at **9:15 a.m. EDT (6:15 a.m. PDT)** on **July 20** and lasts for two hours.

On **July 21**, the launch opportunity begins at **9:25 a.m. EDT (6:25 a.m. PDT)** and lasts for two hours.

On-Site Media Logistics

News media representatives who would like to cover the Mars 2020 Perseverance mission and Ingenuity Mars Helicopter launch and pre-launch media briefings in person at Kennedy Space Center must be accredited through KSC. All accreditation requests should be submitted online at media.ksc.nasa.gov For questions about accreditation, journalists may call the KSC newsroom at **321-867-2468** or contact the credentialing team at KSC-Media-Accreditat@mail.nasa.gov.

Due to the ongoing coronavirus (COVID-19) pandemic, NASA will be credentialing a limited number of media to cover the launch at KSC. International media already based in the U.S. had to have applied by **4 p.m. EDT (1 p.m. PDT) June 9. U.S.** journalists need to apply for credentials by **4 p.m. EDT (1 p.m. PDT), June 28**.

Interviews with mission team members in the Cape Canaveral area around the time of launch may be arranged by calling the KSC newsroom at **321-867-2468**.

Public Viewing Locations

NASA recommends viewing the launch virtually. Subject to local restrictions on public gatherings, there may be viewing sites in the Cape Canaveral area that are open to the public. More information is available on the mission website's **"Watch in Person" section:** mars.nasa.gov/mars2020/timeline/launch/watch-in-person.

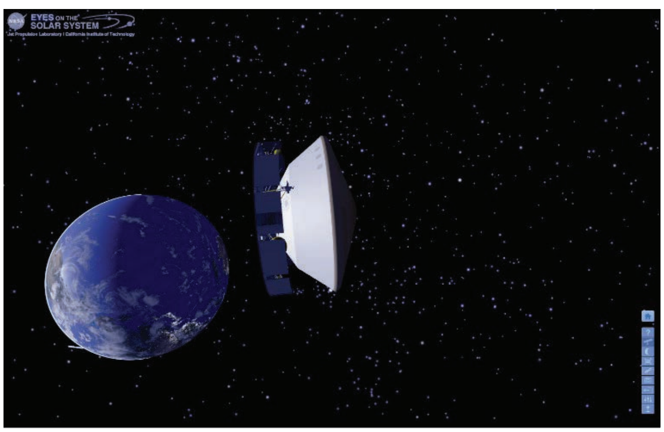
How to Watch (Live and On Demand)

News briefings and launch commentary will be streamed on **NASA TV**, NASA.gov/live and YouTube.com/NASAJPL/live. (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:** mars.nasa.gov/mars2020/timeline/launch/watch-online/ 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 nasa.gov/ntv.

Audio Only

Audio only of launch coverage will be carried on the NASA "V" circuits, which may be accessed by dialing **321-867-1220, -1240, -1260** or **-7135**. On launch day, "mission audio," the launch conductor's countdown activities without NASA TV launch commentary, will be carried on **321-867-7135**.



Eyes on the Solar System

Shortly after launch, the public can begin following the path of Mars 2020 Perseverance to Mars in real-time through **NASA's Eyes on the Solar System** at go.nasa.gov/3e3JObn.

You can also follow the spacecraft live with **NASA's Solar System Interactive:** solarsystem.nasa.gov/solar-system/our-solar-system/overview.

Additional Resources on the Web

Online and PDF versions of this press kit are available online at go.nasa.gov/perseverance-launch-press-kit.

Additional detailed information about the Perseverance rover is available on the **mission's website:** mars.nasa.gov/mars2020.

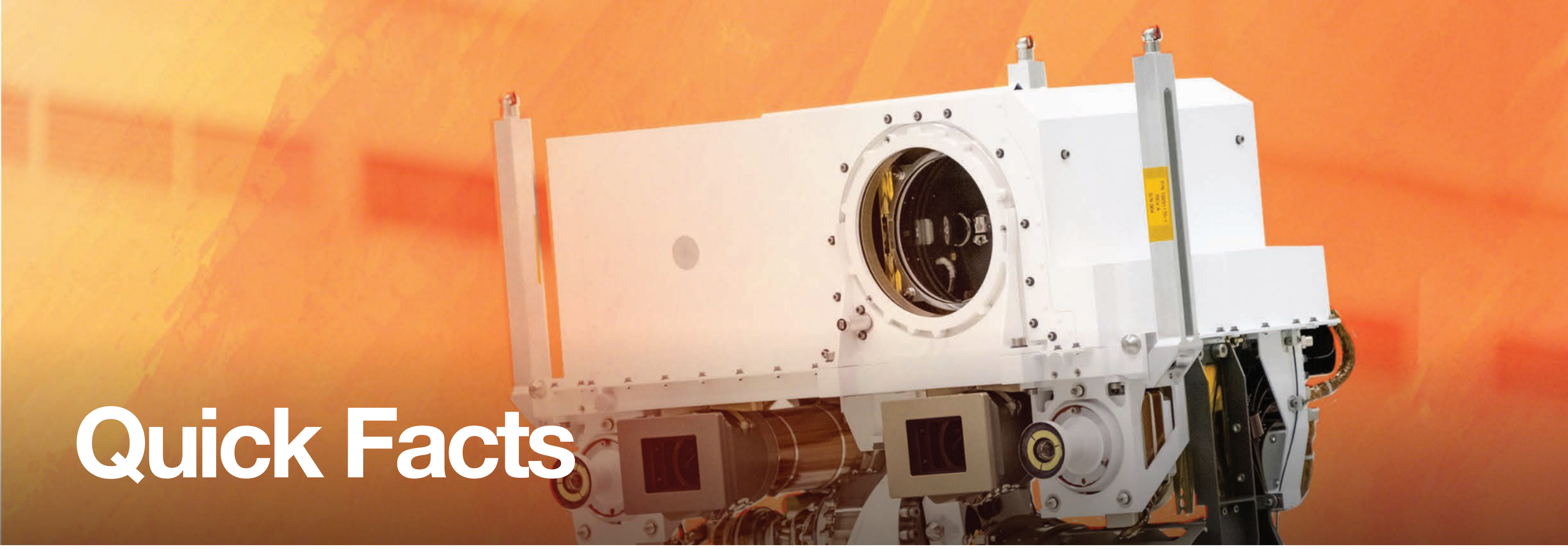
Social Media

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

@NASAPersevere, @NASAJPL, @NASAMars, @NASA

@NASAPersevere, @NASAJPL, @NASAMars, @NASA

@NASAJPL, @NASA



Quick Facts

Mission Names

Mars 2020
The overall name of the mission and spacecraft that include the rover

Rover
Perseverance, submitted by Alex Mather, 13, of Lake Braddock Secondary School in Burke, Virginia

Helicopter (a separate experiment)
Ingenuity, submitted by Vaneeza Rupani, 17, of Tuscaloosa County High School in Northport, Alabama

Spacecraft

Total mass at launch (including rocket; rover; entry, descent and landing system; fueled cruise stage; and helicopter)

About 1.17 million pounds (531,000 kilograms)

Mars 2020 Perseverance mission major components

Perseverance rover, cruise stage (to fly to Mars), aeroshell (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)

Perseverance Rover

Mass: About 2,260 pounds (1,025 kilograms), including a robotic arm with a 99-pound (45-kilogram) turret at the end

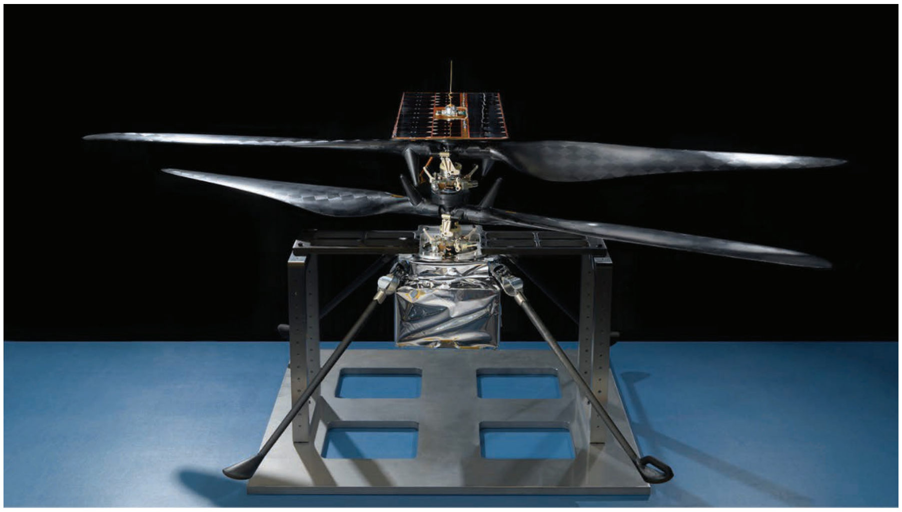
Dimensions: About 10 feet long (not including the arm), 9 feet wide and 7 feet tall (about 3 meters long, 2.7 meters wide and 2.2 meters tall), with a robotic arm that is about 7 feet (2.1 meters) long

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: 1 bit carousel with 9 drill bits for sample acquisition and surface analysis, 1 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 natural decay of plutonium-238 to generate a steady flow of about 110 watts of electricity. Two lithium-ion rechargeable batteries are available to meet peak demands of rover activities when the demand temporarily exceeds the MMRTG's electrical output levels.

Microphones: 1 on SuperCam and 1 on the side of the rover for public engagement and later entry, descent and landing analysis



Ingenuity Mars

Mass: about 4.0 pounds (1.8 kilograms)

Height: 1.6 feet (0.49 meters)

Rotor system: Two pairs of counter-rotating blades, spanning 4 feet (1.2 meters) in diameter, spinning at about 2,400 rpm

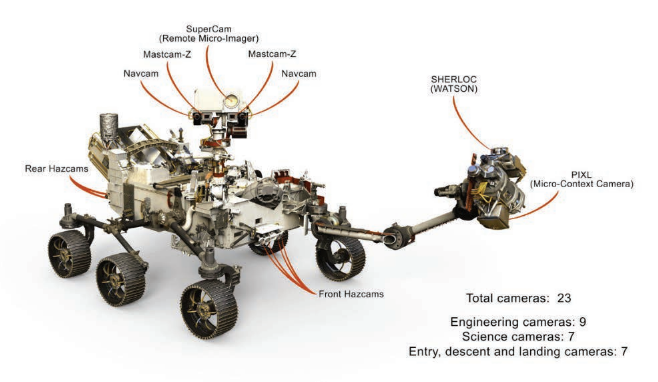
Fuselage (body) dimensions: 0.446 feet by 0.64 feet by 0.535 feet (13.6 centimeters by 19.5 centimeters by 16.3 centimeters); four legs, each about 1.26 feet (0.384 meters) long, giving the helicopter about 0.427 feet (0.13 meters) of clearance above the ground

Power: Solar panel that charges lithium-ion batteries, providing enough energy for one 90-second flight per Martian day (about 350 watts of average power during flight)

Cameras

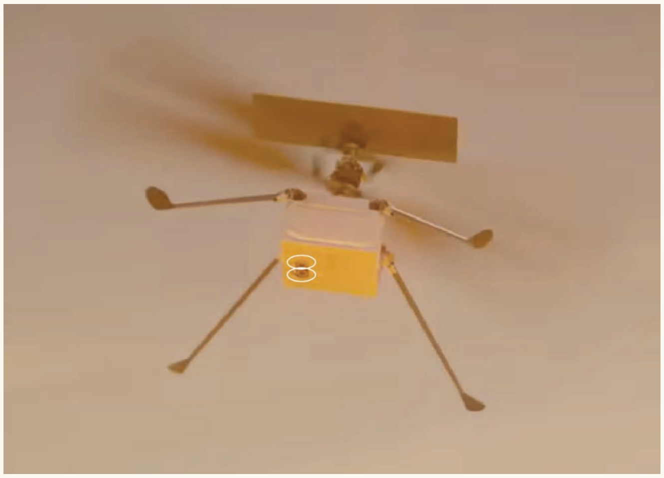
The Mars 2020 Perseverance mission is ferrying 25 cameras to the Red Planet — the most ever flown in the history of deep-space exploration.

19 cameras total on the rover: 9 for engineering (color); 3 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 for Mastcam-Z (color with zoom); 1 for SuperCam (color); 2 for SHERLOC (color); 1 for PIXL (black-and-white with some color capabilities); and 1 for MEDA (black-and-white)



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

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



Cameras circled in white.

2 cameras on Ingenuity: 1 color with an oblique view for terrain images and 1 black-and-white for navigation

Launch

Targeted Launch Period: July 20 to Aug. 11, 2020

Targeted Launch windows: 9:15 a.m.-11:15 a.m. EDT (6:15 a.m.-8:15 a.m. PDT) on July 20, with additional times listed on the mission's launch page

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

Launch vehicle: Atlas V 541 from United Launch Alliance

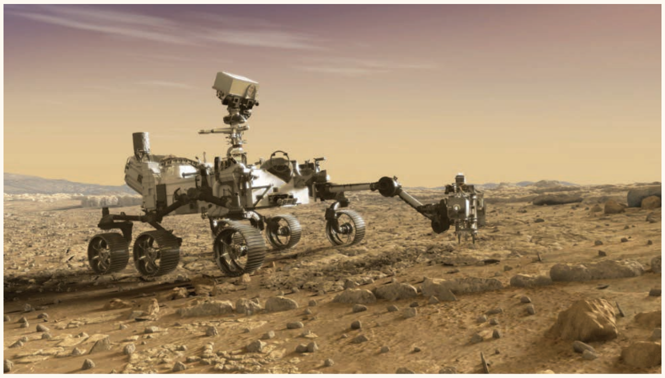
Earth-Mars distance on July 20, 2020: 65 million miles (105 million kilometers)

Spacecraft's distance traveled, Earth to Mars (July 20 launch): 309 million miles (497 million kilometers)

Surface Mission

Time of Mars landing: Feb. 18, 2021, shortly after 3:30 p.m. EST (12:30 p.m. PST), to be made more precise depending on the launch date and time. If launch is July 20, 2020, the time of day at the landing site will be 3:46 p.m. local mean solar time

Landing site: Jezero Crater, about 18 degrees latitude, 77 degrees longitude



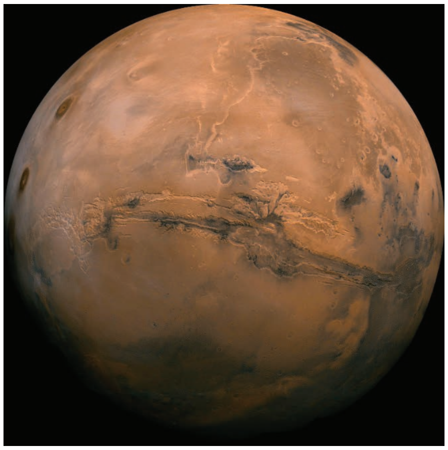
One-way light time (the time it takes radio signals to travel): Mars to Earth, on Feb. 18, 2021: about 10.5 minutes

Perseverance mission duration: At least one Mars year (about 687 Earth days)

Number of samples able to be collected: At least 30

Ingenuity flight test duration: Up to 30 Martian days (about 31 Earth days)

Mars



Size: About half the size of Earth, but twice the size 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 (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

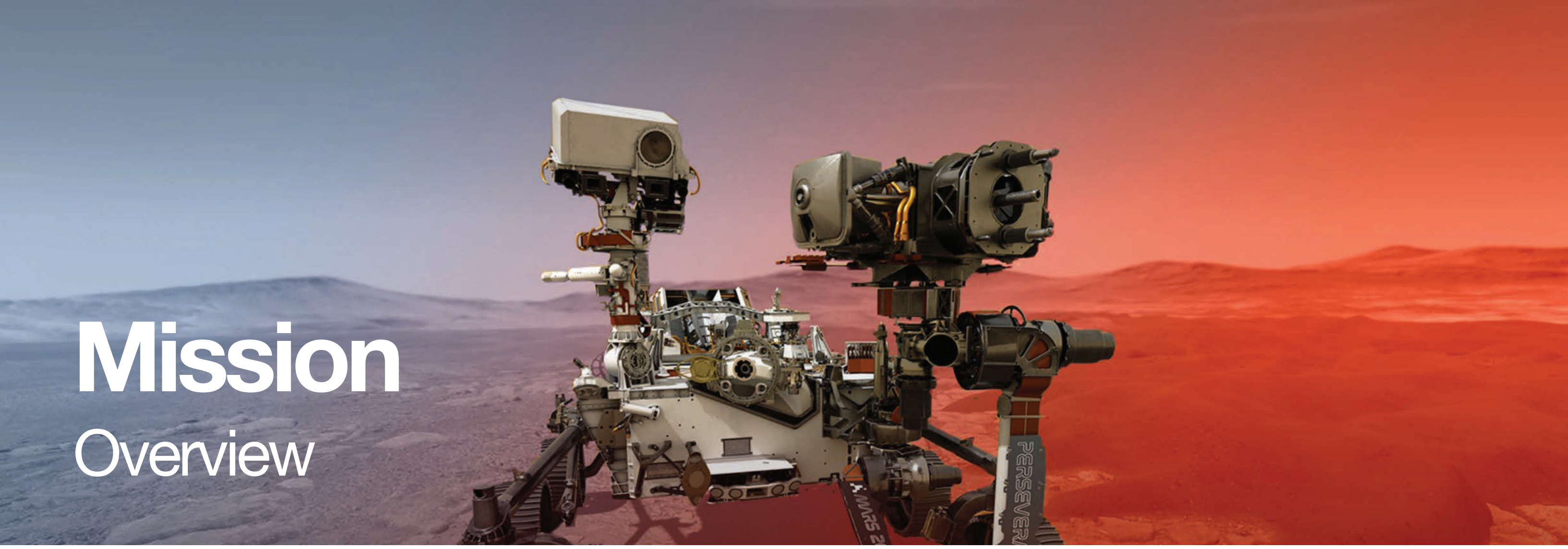
Temperature: Surface temperature averages minus 64 Fahrenheit (minus 53 Celsius); varies from minus 199 Fahrenheit (minus 128 Celsius) during polar night to 80 Fahrenheit (27 Celsius) at equator during midday at closest point in orbit to Sun

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 tis prime mission is approximately $300 million.

NASA has invested about $80 million to build the Ingenuity Mars Helicopter and about $5 million to operate the helicopter.

Mission
Overview



Overview

The Mars 2020 mission spacecraft that includes the Perseverance rover will launch to the Red Planet in July or August 2020 from Cape Canaveral, Florida. With the help of celestial mechanics, the spacecraft will arrive at Mars about seven months later. The date Perseverance lands on Mars — Feb. 18, 2021 — remains the same regardless of the launch date.

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 at least one Mars year (about 687 Earth days), Perseverance's exploration of Jezero Crater will address high-priority science goals for Mars exploration, including key questions about the potential for life on Mars. The rover's astrobiology mission will search for signs of ancient microbial life, characterize the planet's climate and geology and collect samples for future return to Earth. Perseverance will also gather knowledge about, and demonstrate the viability of, technologies that address the challenges of future human expeditions to Mars.

The Ingenuity Mars Helicopter, a technology demonstration, will also ride along to Mars, attached to the belly of the Perseverance rover. More information about its mission is in the **Experimental Technologies** section.

Launch Activities

Why This Launch Period?

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 (on the order of several months). 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 a launch period within the range of possible dates was scheduling the landing to occur when NASA orbiters at Mars are passing over the landing site. Such scheduling aims to allow 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 landing so that engineers know what is happening at each stage.

Launch Period and Window

The launch period is the range of days when a launch is possible to achieve the designated mission goal — in this case, successfully landing at Mars' Jezero Crater. The launch period for Perseverance to do that is targeted to begin **July 20** and extend to **Aug. 11, 2020**.

The launch window is the time period on a given day during which the rocket must be launched to achieve its designated mission goal. The targeted launch window for Perseverance extends from **9:15 to 11:15 a.m. EDT (6:15 to 8:15 a.m. PDT)** on **July 20** — the first day of the launch period. On the last day of the launch period, **Aug. 11**, the window extends from **8:55 a.m. to 9:25 a.m. EDT (5:55 a.m. to 6:25 a.m. PDT)**.

The window of time for each day of the launch period can be found on the mission website's launch page.

Launch

A two-stage United Launch Alliance (ULA) Atlas V 541 launch vehicle will lift the Mars 2020 spacecraft from Launch Complex 41 at Cape Canaveral Air Force Station, Florida. The numbers "541" in the launch vehicle's designation signify a 5-meter (17-foot) short payload fairing, four solid-rocket boosters, and a one-engine Centaur upper stage. It stands at 197 feet (60 meters) tall.

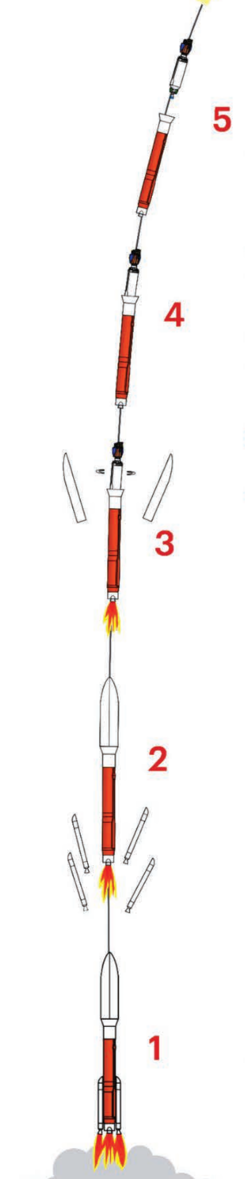
This will be the 11th Mars launch on an Atlas rocket, and the fifth by the Atlas V following NASA's Mars Reconnaissance Orbiter in 2005, Curiosity rover in 2011, MAVEN orbiter in 2013 and InSight lander in 2018.

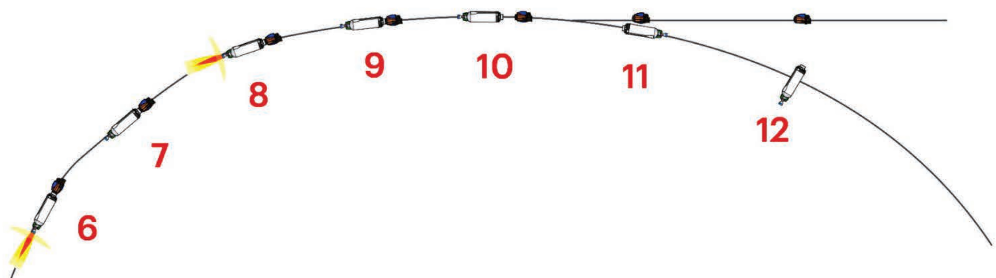
The spacecraft will ride into the sky inside a protective payload fairing atop the Atlas' Centaur stage. Approximately 50 to 60 minutes after launch (depending on when liftoff actually occurs), the Mars 2020 spacecraft will separate from the launch vehicle and complete the rest of its journey to Mars on its own.

The spacecraft will start communicating with the ground between 70 and 90 minutes after launch (again depending on when liftoff occurs). The variability in communication time is due to how long the spacecraft is in the Earth's shadow for each launch opportunity. The Earth's shadow blocks light from reaching the spacecraft's solar panels, which charge batteries that power the communications radio. Mission controllers don't want to turn on the radio while the spacecraft is in shadow because this would draw down the batteries when they can't recharge.

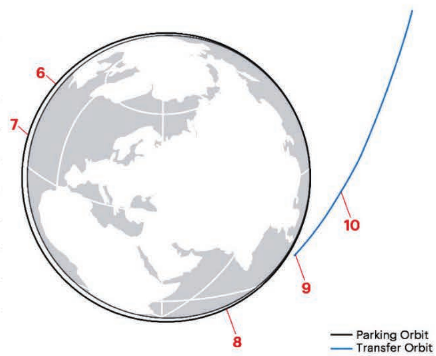
United Launch Alliance hoists its Atlas V first stage onto the mobile launch platform at Launch Complex 41, Cape Canaveral Air Force Station, about a month and a half before Perseverance is set to launch. Image Credit: ULA

FLIGHT PROFILE

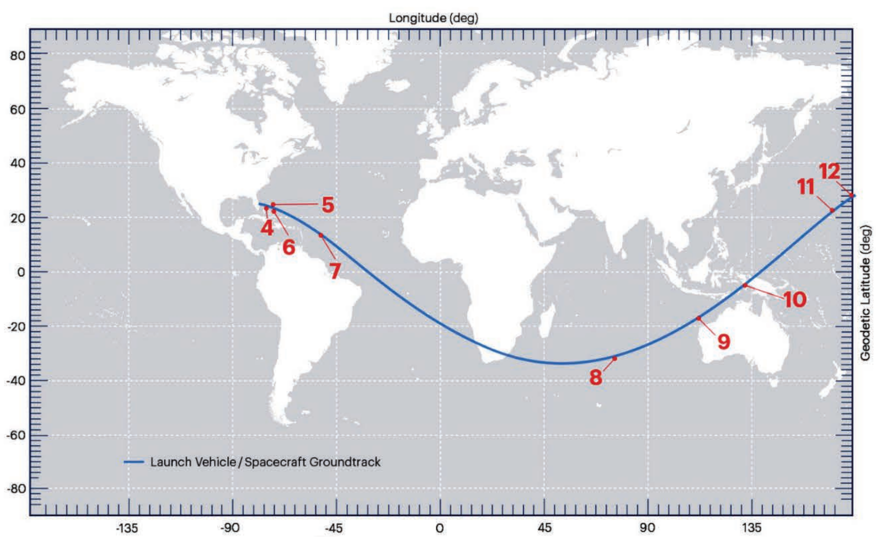




	Event	Time (hr:min:sec)
1	Liftoff (Thrust to Weight > 1)	00:00:01.1
2	SRB Jettison	00:01:49.5
3	PLF Jettison	00:03:27.9
4	Atlas Booster Engine Cutoff (BECO)	00:04:21.9
5	Atlas Centaur Separation	00:04:27.9
6	Main Engine Start (MES1)	00:04:37.9
7	Main Engine Cutoff (MECO1)	00:11:39.1
8	Main Engine Start (MES2)	00:45:21.1
9	Main Engine Cutoff (MECO2)	00:52:59.1
10	Mars 2020 Separation	00:57:42.1
11	Start Blowdown	01:24:02.1
12	End of Mission	01:57:22.1



Mars 2020 Orbit at Separation
C3: 14.49 (km^2/s^2) | Declination (J2000): 35.32 (deg)
Right Ascension (J2000): 13.93 (deg)



All Values Approximate

Key activities for the launch vehicle. Note that event times are dependent on the launch date and time. Image Credit: ULA

Interplanetary Cruise

If Perseverance launches on the first day of its targeted launch period (July 20), it will take 213 days to travel about 309 million miles (497 million kilometers) from Earth to Mars. This is the cruise phase of the mission. (The cruise phase will be shorter if the spacecraft launches later.) The final 45 days of the cruise phase make up the approach subphase.

The cruise phase begins when the spacecraft separates from the launch vehicle. During cruise, the Perseverance rover and its descent stage are protected inside a capsule known as an aeroshell; the aeroshell is attached to the disk-shaped, solar-powered cruise stage. For more information about the cruise stage, aeroshell and descent stage, go to the **Spacecraft section** of this press kit.

During cruise, engineers perform a series of events designed to check the spacecraft subsystems and instruments. They also execute the first three “trajectory correction maneuvers” during this phase. For these feats of navigation, mission team members estimate where the spacecraft is and design a maneuver that fires the cruise stage thrusters to alter the path of the spacecraft to arrive at a particular location at Mars.

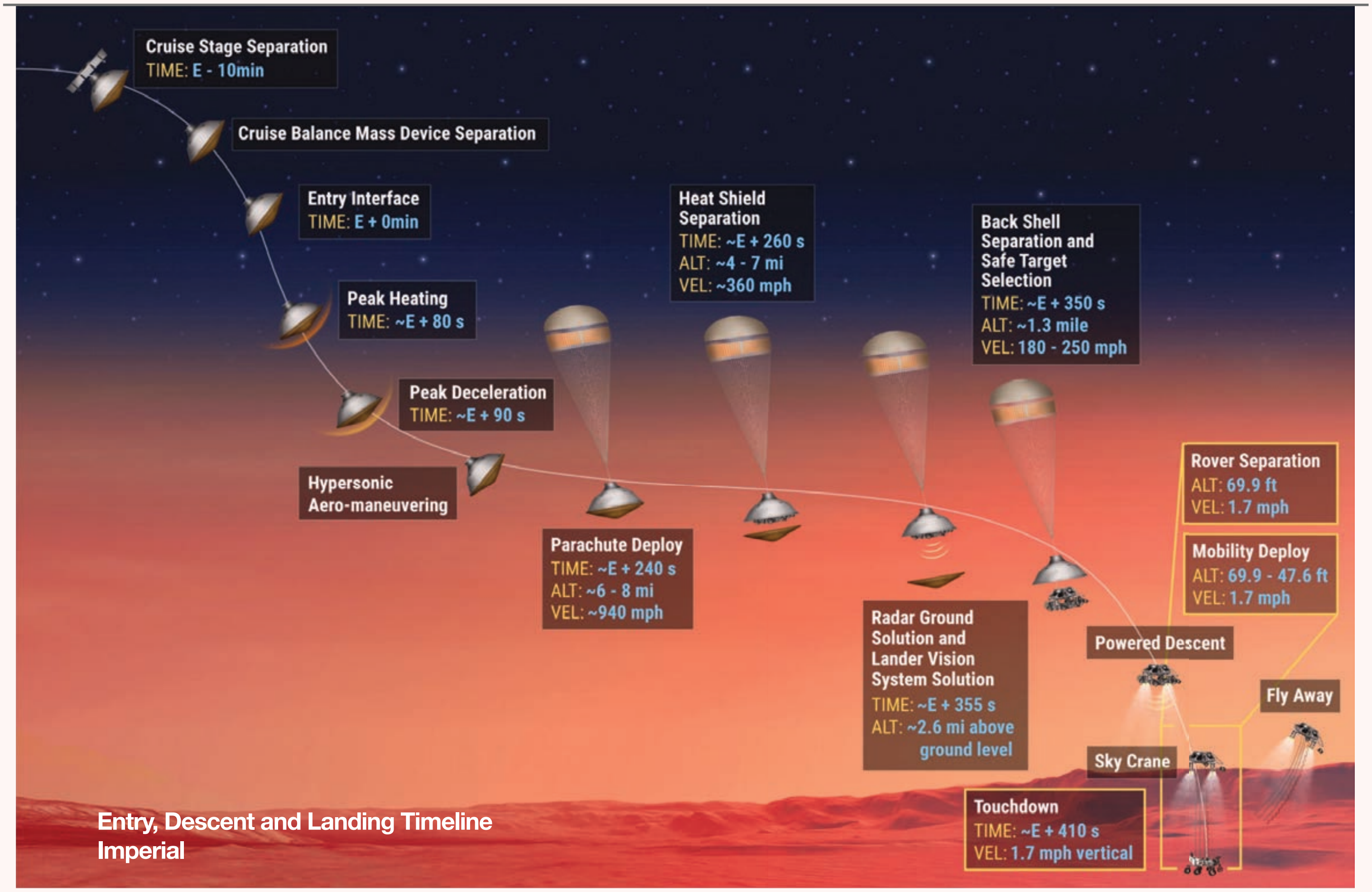
Because some portions of the rocket are not cleaned as thoroughly as the spacecraft, the rocket is initially pointed along a trajectory that does not intercept Mars in order to avoid transporting unwanted Earth materials to the Red Planet accidentally. (More information on this technique, called “trajectory biasing,” is in the **Biological Cleanliness section** of this press kit.) Another way of making sure the mission avoids transporting unwanted Earth materials to Mars is to ensure that hardware that does not meet cleanliness standards does not go to Mars accidentally. The maneuvers after separation from the Centaur stage will point the spacecraft more directly at Mars and target the area where it is supposed to enter the atmosphere.

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

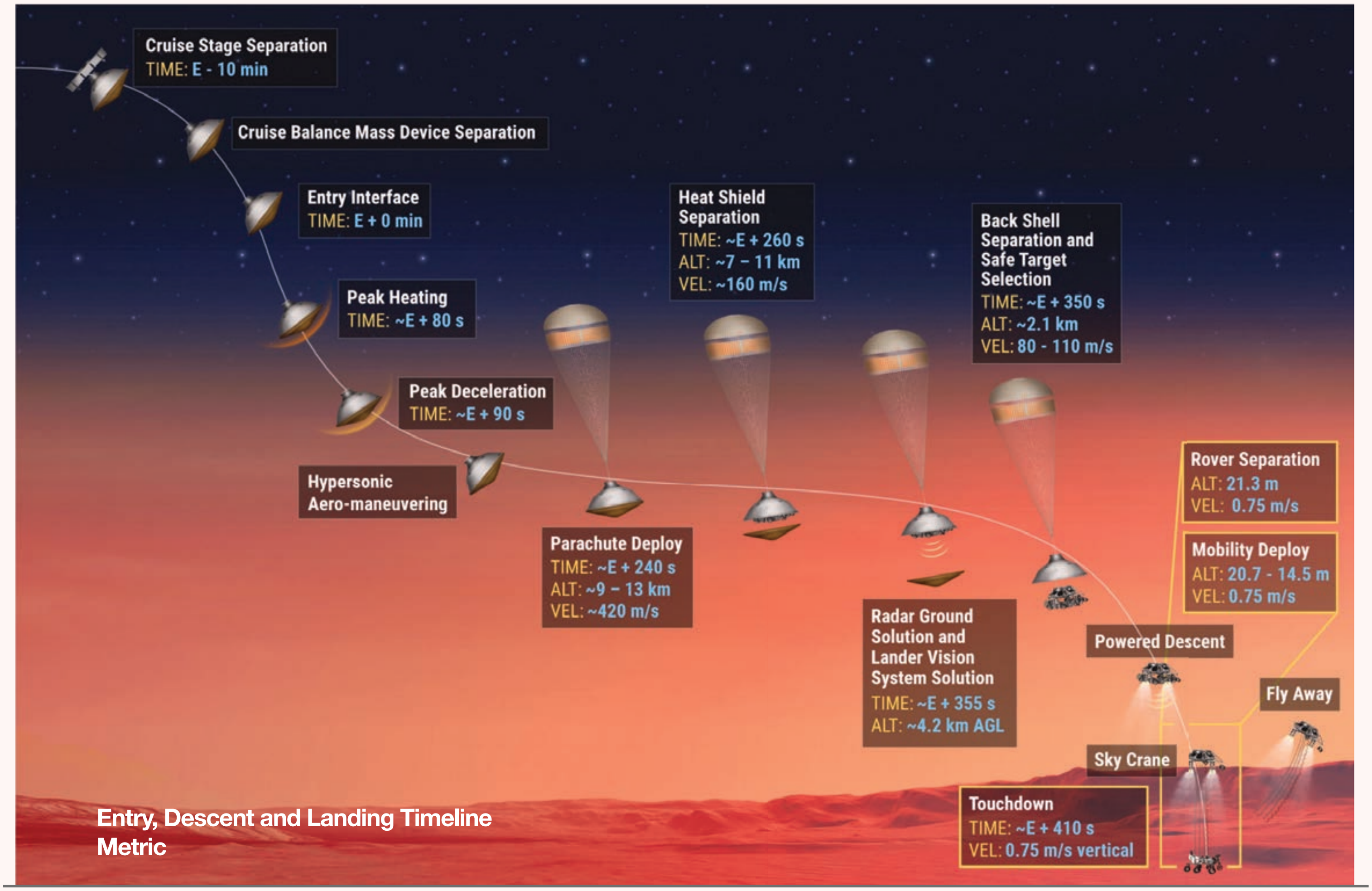
Entry, Descent and Landing

Perseverance’s entry, descent and landing will be very similar to the Curiosity rover’s in 2012, as seen in this illustration.
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.



Cruise Stage Separation
TIME: E - 10min
Cruise Balance Mass Device Separation
Entry Interface
TIME: E + 0min
Peak Heating
TIME: ~E + 80 s
Peak Deceleration
TIME: ~E + 90 s
Hypersonic Aero-maneuvering
Heat Shield Separation
TIME: ~E + 260 s
ALT: ~4 - 7 mi
VEL: ~360 mph
Parachute Deploy
TIME: ~E + 240 s
ALT: ~6 - 8 mi
VEL: ~940 mph
Back Shell Separation and Safe Target Selection
TIME: ~E + 350 s
ALT: ~1.3 mile
VEL: 180 - 250 mph
Radar Ground Solution and Lander Vision System Solution
TIME: ~E + 355 s
ALT: ~2.6 mi above ground level
Rover Separation
ALT: 69.9 ft
VEL: 1.7 mph
Mobility Deploy
ALT: 69.9 - 47.6 ft
VEL: 1.7 mph
Powered Descent
Fly Away
Sky Crane
Touchdown
TIME: ~E + 410 s
VEL: 1.7 mph vertical
Entry, Descent and Landing Timeline
Imperial



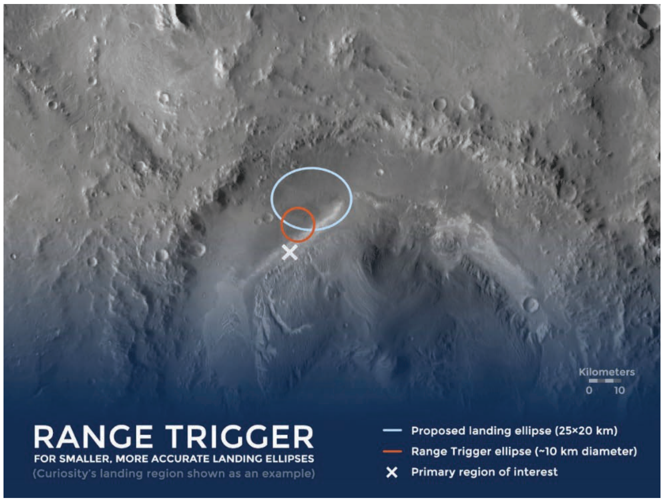
Cruise Stage Separation
TIME: E - 10 min
Cruise Balance Mass Device Separation
Entry Interface
TIME: E + 0 min
Peak Heating
TIME: ~E + 80 s
Peak Deceleration
TIME: ~E + 90 s
Hypersonic Aero-maneuvering
Heat Shield Separation
TIME: ~E + 260 s
ALT: ~7 – 11 km
VEL: ~160 m/s
Parachute Deploy
TIME: ~E + 240 s
ALT: ~9 – 13 km
VEL: ~420 m/s
Back Shell Separation and Safe Target Selection
TIME: ~E + 350 s
ALT: ~2.1 km
VEL: 80 - 110 m/s
Radar Ground Solution and Lander Vision System Solution
TIME: ~E + 355 s
ALT: ~4.2 km AGL
Rover Separation
ALT: 21.3 m
VEL: 0.75 m/s
Mobility Deploy
ALT: 20.7 - 14.5 m
VEL: 0.75 m/s
Powered Descent
Fly Away
Sky Crane
Touchdown
TIME: ~E + 410 s
VEL: 0.75 m/s vertical
Entry, Descent and Landing Timeline
Metric

Atmospheric Entry

Ten minutes before the spacecraft enters the atmosphere, it sheds the cruise stage. 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. 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).

Perseverance is headed toward NASA's biggest Martian landing challenge yet. Jezero Crater is a 28-mile-wide (45-kilometer-wide) impact basin with an intriguing ancient river delta as well as steep cliffsides, sand dunes, boulders fields and smaller impact craters. To ensure the highest probability of a safe landing, the mission added new EDL technologies known as Range Trigger and Terrain-Relative Navigation.

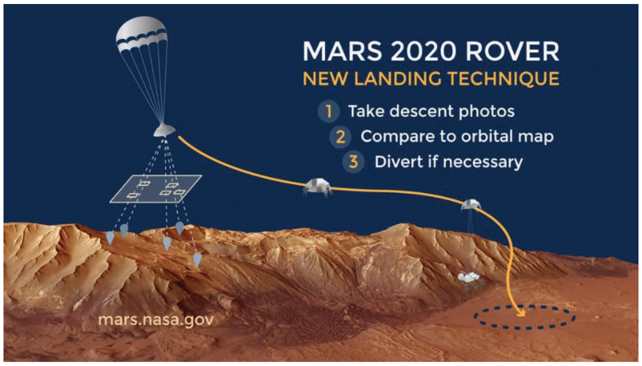


Range Trigger is a new technique the Mars 2020 mission will use to time the parachute's deployment. During EDL, it will autonomously update the deployment time for the parachute based on navigation position. The result: a smaller landing ellipse — or target landing area.

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.

The back shell, with parachute attached, separates from the descent stage and rover about 90 seconds after heat shield separation. At this point, the spacecraft is about 1.3 miles (2.1 kilometers) above the ground. All eight throttleable retrorockets on the descent stage, called Mars landing engines, begin firing for the powered descent phase. The engines' job: to slow the spacecraft, which will be traveling at about 190 mph (306 kph) when it's at 6,900 feet (2,100 meters) in altitude, to 1.7 mph (2.7 kph) by the time it's about 66 feet (20 meters) above the surface.

During the latter portion of parachute descent and the early portion of powered descent, Terrain-Relative Navigation kicks in.



Terrain-Relative Navigation is an autopilot that operates during landing and can quickly figure out the spacecraft's location over the Martian surface and select the best reachable safe landing target. During descent (after the heat shield drops away) a downward-pointing camera aboard the rover takes image after image of the ground rushing up to meet it. The camera feeds the image data into an onboard computer that determines its current position and all reachable landing points. Terrain-Relative Navigation will select the safest available landing target and command the spacecraft's descent stage to fly the Perseverance rover to that landing point. The system can change the rover's touchdown point by up to 2,000 feet (600 meters).

When the descent stage determines it is 20 meters over the Terrain-Relative Navigation's designated landing spot, 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, the connecting cords are severed and the descent stage flies away to reach a safe distance.

Surface Phase

The rover should touch down in the Martian afternoon — about 3:45 p.m. local mean solar time (with the exact time depending on the actual launch day). Soon after, the rover's computer switches from entry, descent and landing mode to surface mode. This initiates autonomous activities for the first Martian day on the surface of the Red Planet, 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 planned operational life for the Perseverance rover is one Martian year on the surface. One Martian year is 687 Earth days, or 669 sols.

Initial Checkout

Perseverance's team will spend the first 90 sols performing tests of all the rover's parts and science instruments. This "checkout" period ensures everything — including the team — is ready for surface operations. For these 90 sols, the operations team will be working on Mars time, which means they will be setting their clocks to the Martian day (which is about 40 minutes longer than an Earth day). This allows them to respond quickly to any issue the rover has during its workday and 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 during the 90-sol checkout period.

The first part of the checkout period is a commissioning phase. In the first 16 sols of commissioning, Perseverance will:

- Deploy its mast and high-gain antenna
- Begin imaging the landing site
- Upgrade rover flight software
- Perform health checks on all instruments
- Perform "calisthenics," unstowing its arm and testing its movement
- Perform a short drive test
- Drop the belly pan under the rover, which protects the helicopter during landing

The entire commissioning phase ends about 30 sols after landing, depending on how well the activities go.

Initial Checkout

Around that time, Perseverance will need to find a flat area to serve as a helipad for the Ingenuity Mars Helicopter. The rover will deploy Ingenuity in the center of this area and drive a safe distance away from it. The helicopter's team will then have up to 30 sols to perform a series of flight tests on Mars as part of the **technology demonstration** of this press kit.

Surface Operations

At the end of these experimental helicopter flights, Perseverance will begin its surface operations phase, when the team carries 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. More on Perseverance's science objectives is in the **Science section** of this press kit.

There will be periods during its one-Martian-year-long mission when the rover's activities will be limited, such as the approximately 20-sol period in September 2021 when the Sun comes between Mars and Earth, interfering with transmissions between the two planets. To maximize the science being conducted in the time available, the mission team plans operations far ahead and builds in the flexibility to respond to new discoveries as scientists study the data.

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 or other instruments to study the Martian surface. As opposed to stationary landers, like InSight or Phoenix, rovers can drive into craters, up slopes and along sand dunes, allowing scientists and engineers to explore the planet. All of NASA's Mars rovers have been built at the agency's Jet Propulsion Laboratory

For an interactive 3-D experience of the rover, visit **Mars 2020 Rover:** mars.nasa.gov/mars2020/spacecraft/rover

Heavier and More Capable

The car-sized 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 2,260 pounds (1,025 kilograms) on Earth.

The Mars 2020 mission's Perseverance rover and other major 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 has about 5 inches (3 centimeters) additional chassis length and 278 additional pounds (126 kilograms) compared to Curiosity.

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 for coring. The drill will cut intact rock cores, and they'll be placed in sample tubes via a complex storage system. (Curiosity, on the other hand, pulverizes rock for its instruments to study.)

Perseverance also has a six-wheel, rocker-bogie design derived from all of NASA's Mars rovers to date that helps to maintain a relatively constant weight on each of the rover's wheels and minimizes tilt. The wheels are slightly narrower and taller than Curiosity's but are similarly machined out of a rigid, lightweight aluminum alloy. Both Curiosity and Perseverance have wheels lined with grousers — raised treads that are specially designed for the Martian desert. Curiosity's have a pointed chevron pattern for climbing rocks, a shape 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. For more on the distinctions between Curiosity and Perseverance, read the feature story Two Rovers to Roll on Mars Again.

For more on the rover's science instruments, visit the **Science section** of this press kit.

Sample Caching System

The Perseverance rover's Sampling and Caching Subsystem is three robots that will work in concert to collect rock and regolith (dust, soil, broken rock) samples, seal them in sample tubes and deposit those tubes on the surface for retrieval by a later 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 the ultraviolet Raman spectrometer SHERLOC and the X-ray fluorescence spectrometer PIXL — two science instruments also located on the turret.

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 into a sample tube in the center of the bit. This sample amounts to an average of 0.35-0.53 ounces (10-15 grams) of Martian material. The regolith bit can collect a regolith sample in a tube as well.

Bit Carousel

After the sample is collected, the robotic arm places the tube into the second robot of the Sample Caching System: the bit carousel.

Looking like a small flying saucer that is embedded in the front of the rover, the bit carousel stores empty drill bits and provides them to the corer on the turret. Once a sample has been taken by the corer, the bit carousel transfers bits containing filled sample tubes from the corer into the belly of the rover. Inside the rover, the filled tube can be handed off to the Sample Caching System's third robotic component, the adaptive caching assembly.

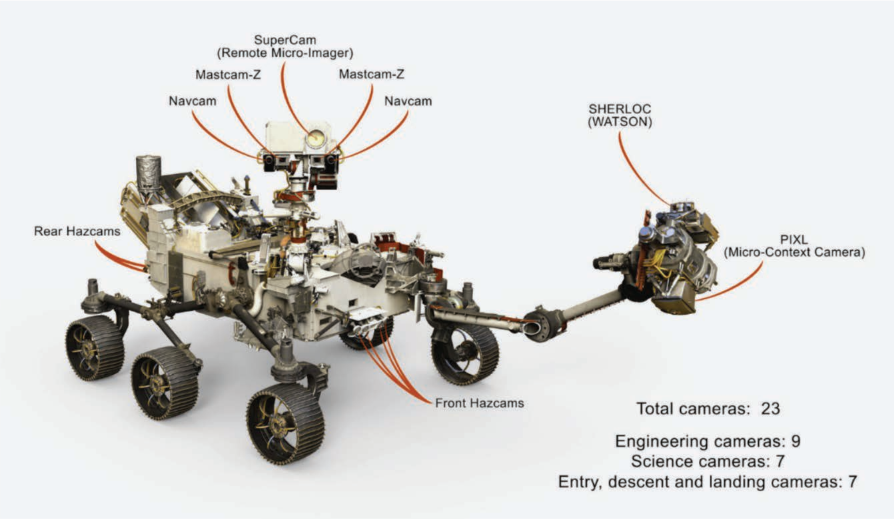
Adaptive Caching

The adaptive caching assembly consists of the sample handling arm, sample tube assemblies, tube seals and 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 a plug to restrict sample movement within the tube, 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 later mission.

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 make it the most complex integrated robotic subsystem ever built for Mars.

Watch **NASA's Perseverance Mars Rover Sample Caching System** video at:
youtu.be/MFyv8mtRPCA

Seeing and Hearing Mars



The Mars 2020 mission carries more cameras to Mars than any interplanetary mission in history. The Perseverance rover itself has 19 cameras that will deliver images of the landscape in breathtaking detail. Those include cameras for engineering (9), entry, descent and landing (3), and science (7).

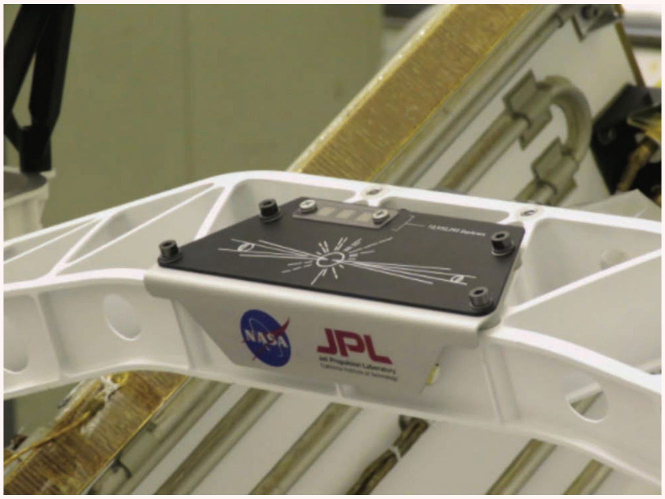
Cameras for entry, descent and landing are also installed on the **aeroshell and descent stage**. More information on the cameras on the Ingenuity Mars Helicopter can be found in the **Experimental Technologies section** of this press kit.

The Perseverance rover also has two microphones: one for later engineering analysis and public engagement, and one that is part of the **SuperCam** science instrument.

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 online "Send Your Name to Mars" campaign from May to September 2019. The fingernail-sized chips also contain the essays of 155 finalists in NASA's "Name the Rover" essay contest.

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



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

Mission

Spacecraft › Getting to Mars

Getting to Mars

Perseverance will travel 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 includes eight precise thrusters that receive commands to fire at specific times during the eight-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. More information about the latter is available in the **Telecommunications section** of this press kit.

Aeroshell

This capsule protects the rover and its descent stage through its Mars atmospheric flight until it is near the Martian surface. The aeroshell has two parts: the conical back shell and, at its base, a heat shield, both built by Lockheed Martin Space in Denver.

The heat shield is covered with tiles of a material called phenolic impregnated carbon ablator (PICA) that was invented by NASA's Ames Research

Center in California's Silicon Valley. Engineers estimate the spacecraft could be exposed to temperatures as hot 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 for altering the spacecraft's center of mass so it can fly correctly, a parachute and antennas for communicating directly with Earth and for communicating with orbiters at Mars that can relay messages to Earth. The back shell and the heat shield also have a sensor suite known as MEDLI2 (more detail below). 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 a material known as SLA-561V.

Atmospheric friction will slow the entry vehicle to about 540 mph (865 kph) and about 7 miles (11 kilometers) in altitude. At around this point in the landing sequence, the spacecraft will command deployment of the parachute. It does this once it has determined itself to be in an optimal position relative to the landing target, a technique called "Range Trigger." The parachute inherits its design from the Mars Viking missions of the 1970s but is scaled up to 70.5 feet (21.5 meters) in diameter and strengthened to accommodate Perseverance's heavier mass.

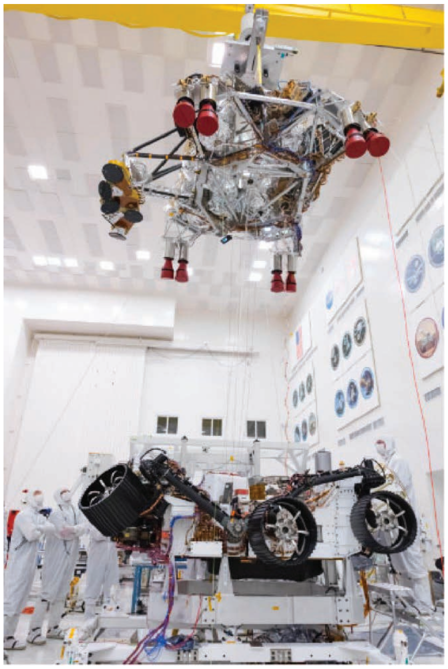
Parachute inflation will slow Perseverance further. The heat shield will be jettisoned before landing so that a radar and a new, specially developed Terrain-Relative Navigation system can help the rover land safely in Jezero Crater.

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.

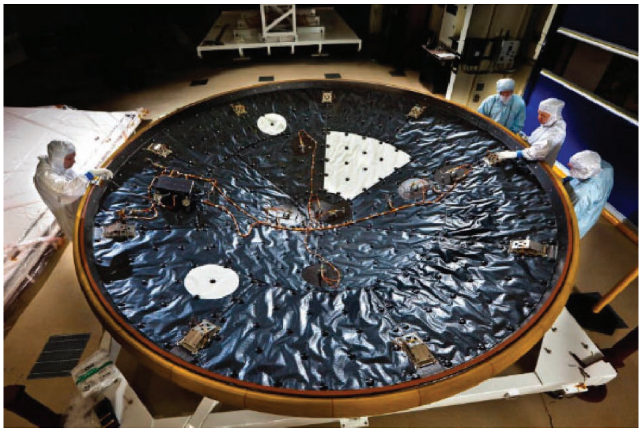
Descent Stage

At this point, Perseverance is still attached to the rocket-powered descent stage. Think of it 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, it slowly winches Perseverance down on a bridle as part of the sky crane maneuver.

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



Key Engineering Payloads for Entry, Descent and Landing



Technicians install electronics on the Curiosity rover's heat shield for the Mars Science Laboratory Entry, Descent and Landing System (MEDLI) at Lockheed Martin Space. Perseverance's MEDLI2 suite looks very similar. Image credit: NASA/JPL-Caltech

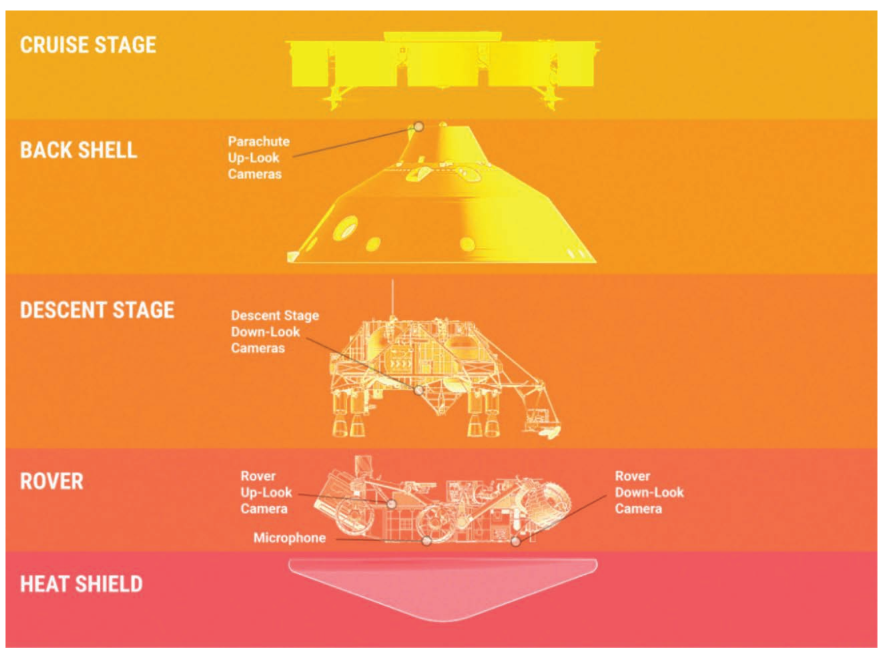
MEDLI2 - (Mars Science Laboratory Entry, Descent and Landing Instrumentation 2)

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.

The MEDLI2 suite is managed by NASA Langley Research Center in Hampton, Virginia.

More information about MEDLI2 can be found in this story.

Entry, Descent and Landing Cameras and Microphone



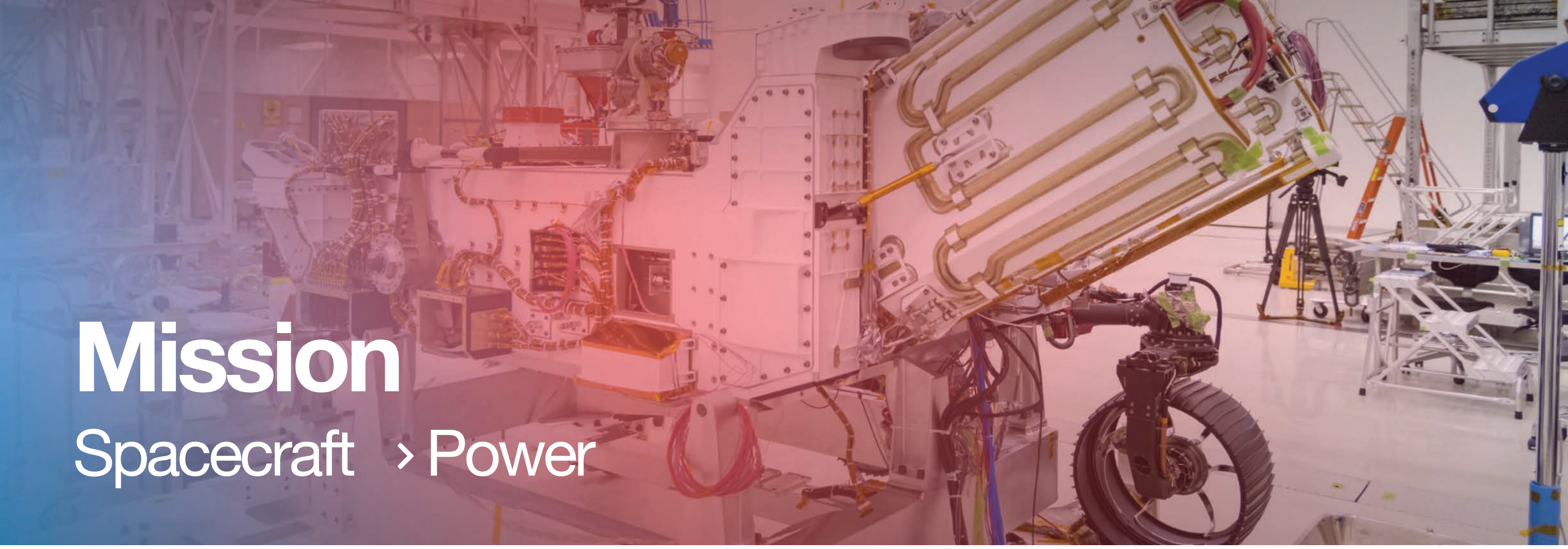
High-quality imagery is one of an engineer's best friends when it comes to understanding the in-flight operations of any system. Mars 2020 carries six color cameras (more than on any previous Mars landing mission) for public engagement and engineering reconstruction of what happened during entry, descent and landing. (There is one black-and-white camera specially dedicated to Terrain-Relative Navigation that plays a key role in the landing itself.)

The entry, descent and landing color camera suite consists of six off-the-shelf cameras:

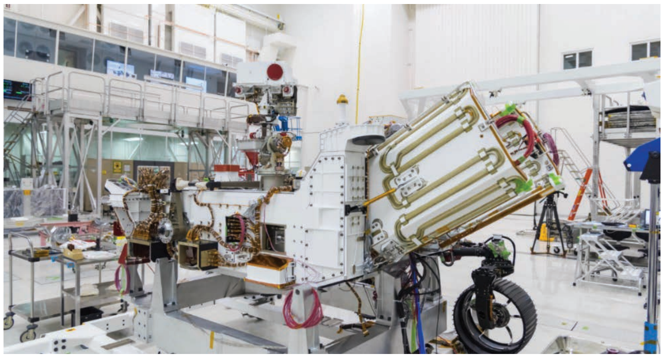
- Three cameras are on the bell-shaped back shell, looking upward to capture the parachute opening.
- One camera is on the descent stage, looking down at the rover and surface below.
- Two cameras are located on the Perseverance rover — one looking up at descent stage operations and one looking down at the Martian surface.

Perseverance also includes an off-the-shelf microphone located on an aft-side panel. The microphone is intended for public engagement and later entry, descent and landing analysis. It could possibly capture sounds during the landing sequence, including parachute deployment and firing of the descent stage's Mars landing engines.

More information about the entry, descent and landing phase is in the **Mission Overview section** of this press kit.



Power



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 from it keeps the rover's tools and systems at their correct operating temperatures.

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 on 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 this electrical power page.

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).

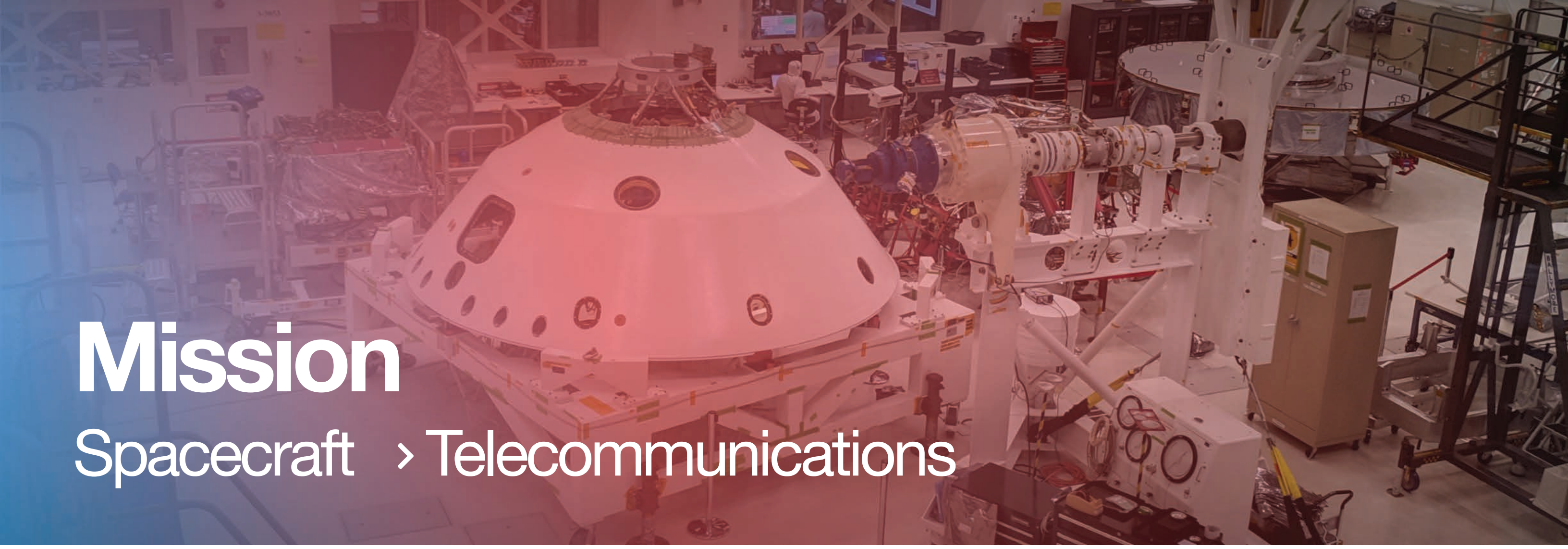
NASA has used similar radioisotope thermoelectric generators (RTGs) successfully for five decades, including on the Apollo missions to the Moon and the Viking missions to Mars. They have also been used on spacecraft that flew to the outer planets and Pluto, such as during the Pioneer, Voyager, Ulysses,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

What has NASA done to ensure Perseverance and its MMRTG will launch safely?

Like previous generations of this type of power system, Perseverance's MMRTG is built with several layers of protective material designed to contain its plutonium dioxide fuel in a range of potential accident conditions. The type of plutonium used in this kind of power system is different from the material used in weapons, and the system cannot explode like a bomb. For more details, NASA has provided this launch nuclear safety fact sheet.

NASA prepares contingency response plans for every launch that it conducts. Ensuring the safety of launch-site workers and the public in the communities surrounding the launch area is the primary consideration in this planning.

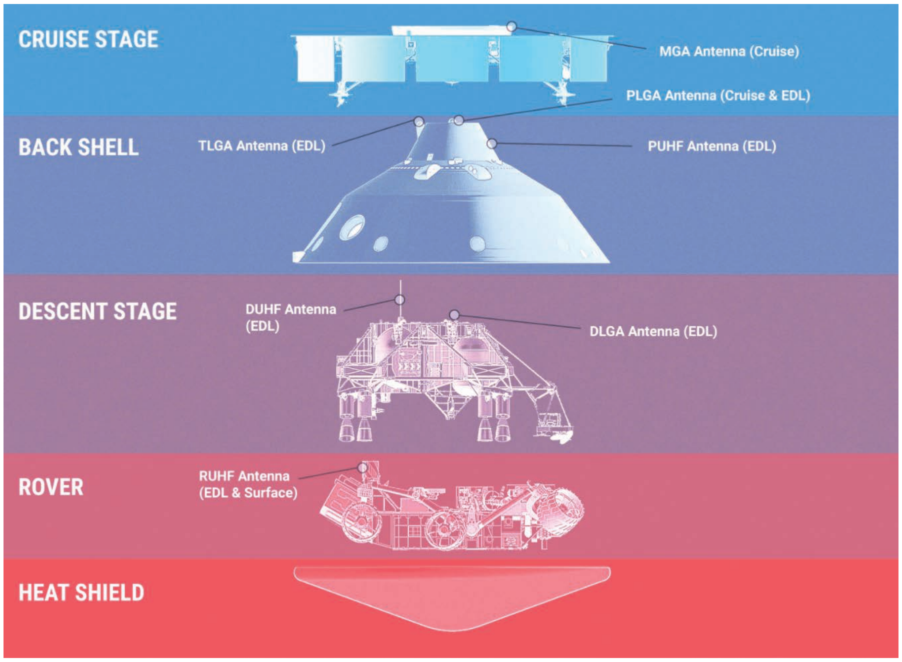
For more details on this contingency planning, NASA has provided this radiological contingency planning fact sheet.



Mission

Spacecraft › Telecommunications

Telecommunications: How Perseverance Talks to Earth



Launch

Radio transmissions from the United Launch Alliance Atlas V rocket to NASA's Tracking and Data Relay Satellite System enable ground controllers to monitor critical events and the status of both the launch vehicle and the Mars 2020 spacecraft that includes Perseverance.

The cruise stage of the Mars 2020 spacecraft will start communicating with the ground between about 70 and 90 minutes after launch, depending on when liftoff actually takes place. The variability is due to how long the spacecraft is in Earth's shadow for each launch opportunity. Our planet's shadow blocks light from reaching the spacecraft's solar panels, which charge batteries that power the communications radio. Mission controllers don't want to turn on the radio while the spacecraft is in shadow because this would draw down the batteries when they can't recharge.

The first ground station of NASA's Deep Space Network to receive communication from the spacecraft will be Canberra, Australia, followed a short time later by Goldstone in the California desert near Barstow.

Cruise

For the first two months of the journey to Mars, the spacecraft communicates using a low-gain antenna located 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 of which use Ultra-High Frequency (UHF) transmission (for talking with orbiting spacecraft like the Mars Reconnaissance Orbiter, which then relay the information back to Earth) and others that use more powerful X-band transmissions (for talking directly to Earth with simple messages).

X-band

Entry, descent and landing 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 related to its guided entry into the Martian atmosphere, it shifts to a tilted low-gain antenna, located on the spacecraft's back shell. After the separation of the back shell, a low-gain antenna on the descent stage takes over.

UHF

A UHF antenna mounted on the back shell starts transmitting several minutes before atmospheric entry until the shell separates from the descent stage. A UHF antenna on the descent stage takes over from there. For the final release to the surface, the UHF transmissions will use the rover's cylindrical, UHF low-gain antenna.

Perseverance will communicate detailed information during landing using the UHF antennas, which transmit that data to the Mars Reconnaissance Orbiter and MAVEN spacecraft. The Mars Reconnaissance Orbiter is expected to relay entry, descent and landing data to Earth in near-real-time, while MAVEN is expected to return its data after landing.

Surface

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

Perseverance can also communicate directly with Earth using its X-band high-gain antenna (the rotatable hexagonal "paddle" toward the back of the rover). These transmissions are routinely used to send commands to the rover each morning on Mars but are limited in transmitting data back to Earth.

If the views and distance to the Earth are favorable, Perseverance can also use an X-band low-gain antenna (a stubby pole located behind the high-gain antenna). This antenna is useful for emergency communications in a variety of situations.

Mission

Spacecraft › Biological Cleanliness

Biological Cleanliness

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

Planetary Protection

The United States has obligations under the international 1967 Outer Space Treaty to explore space in a manner that avoids harmful contamination of celestial bodies and also adverse effects to Earth's environment resulting from any return of extraterrestrial matter. To help meet these obligations, NASA's Planetary Protection Office draws up cleanliness standards known as planetary protection requirements. These requirements call for missions to take precautions to limit the amount of

Earth-sourced biological material carried by NASA robotic spacecraft that travel to Mars. Flight hardware for the Mars 2020 Perseverance mission and the Ingenuity Mars Helicopter have been designed and built to meet NASA planetary protection requirements.

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.

To meet these cleanliness standards, engineers assemble the rover and spacecraft in "clean rooms." This type of room has powerful air filters that limit dust particles, and its surfaces and floors 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 and are designed not to damage the spacecraft. This includes 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 is also using innovative new cleaning methods. For example, technicians use hydrogen peroxide vapor to clean some parts of the Mars 2020 spacecraft that cannot be treated with other methods.

At launch, the entire payload going to Mars (the Perseverance rover, the Ingenuity Mars Helicopter, and the cruise stage, aeroshell and descent stage) will carry 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 — must have no more than 300,000 spores in total. The rover itself is allowed to have just 41,000 spores, spread out over the vehicle's entire surface area.

Another way of making sure the mission avoids transporting unwanted Earth materials to Mars is to ensure that hardware that does not meet cleanliness standards does not go to Mars accidentally. Because only some portions of the Atlas V rocket ferrying the Mars 2020 Perseverance spacecraft into space can be cleaned as thoroughly as the spacecraft, the rocket will be initially pointed along a trajectory that does not intercept Mars. After the spacecraft separates from the launch vehicle's upper stage, Perseverance will be redirected toward landing on Mars. This technique, known as "trajectory biasing," is 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 the samples collected by the Perseverance rover could 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 that participate 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. 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 are also identifying and keeping track of any known materials that remain on the spacecraft after thorough cleaning. This helps maintain a list of what's known to be on board before the sample tubes leave Earth, which can be compared with future measurements of the samples. Perseverance's sampling system will also carry "witness" tubes that will 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 remained on after touchdown on Mars.

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

For more information, NASA has provided a fact sheet on Perseverance's biological cleanliness.

Mission

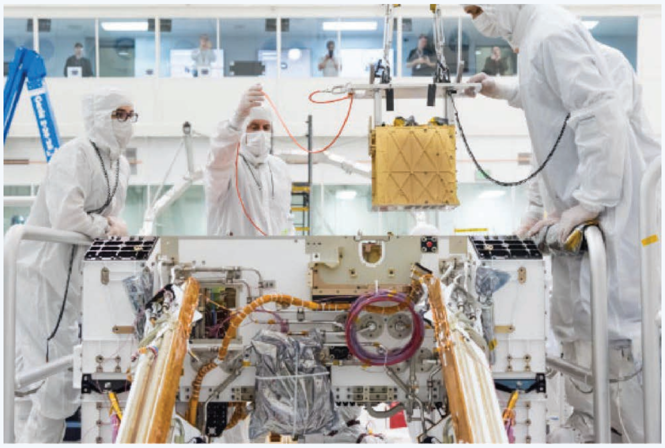
Spacecraft › Experimental Technologies

Experimental Technologies

Several brand new or next-generation technologies will be riding on the rocket to Mars. Two of these 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 are 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)

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.

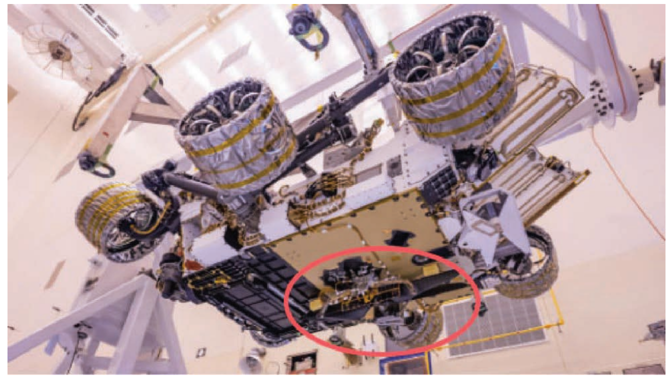


MOXIE also serves as one of Perseverance’s payload instruments; more information is available in the **Payload Instruments section** of this press kit.

Ingenuity Mars Helicopter

Weighing just about 4.0 pounds (1.8 kilograms), the Ingenuity Mars Helicopter is a small, autonomous rotorcraft designed to test — for the first time — powered 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 their journey to the Red Planet. This system protects Ingenuity from debris during landing and will deploy the helicopter onto the Martian surface roughly two-and-a-half months later.

Key Objectives

Demonstrate powered flight in the thin atmosphere of Mars.

- The Red Planet has lower gravity (about one-third that of Earth) but its atmosphere is only 1% as thick, making it much harder to generate lift.
- The first test flight is expected to take place in the spring of 2021 after about six sols of activities to check out the helicopter.
- The helicopter could fly as high as 15 feet (5 meters) in altitude and as far as 160 feet (50 meters) downrange.
- The longest that engineers will try to fly the helicopter on each flight will be 90 seconds.

Demonstrate miniaturized flying technology on another planet.

- To fly in the thin atmosphere, Ingenuity was limited to a total mass of about 4.0 pounds (1.8 kilograms).
- The rotor system, solar panel, landing gear, fuselage and other components must be very lightweight.

- To fit in a fuselage just 0.45 feet by 0.54 feet by 0.64 feet (14 centimeters by 16 centimeters by 20 centimeters), onboard computers, batteries, sensors, heaters and telecommunications hardware also need to be very small.
- These components also had to be stress-tested to be sure they could survive the cold temperatures and radiation in deep space and on Mars.

Operate autonomously.

- Like the rover, the helicopter is too far from Earth to be operated with a joystick. So engineers will have to learn how to operate an aerial vehicle very remotely.
- The helicopter is designed to fly, land, communicate, manage its energy and keep warm autonomously.
- Innovative mathematical algorithms will optimize flight efficiency and survival.

Milestones

Given the high-risk, high-reward nature of Ingenuity's mission, the team has many milestones that they need to hit on the road to success:

- Surviving launch, the cruise to Mars and landing on the Red Planet.
- Deploying safely to the Martian surface from the belly pan of the Perseverance rover and unfolding from its stowed position correctly.
- Autonomously keeping warm through the intensely cold Martian nights (as frigid as minus 130 degrees Fahrenheit, or minus 90 degrees Celsius).
- Autonomously charging with its solar panel.
- Confirming communications with the rover and flight operators on Earth.
- Spinning up its rotor blades for the first time (to a speed below what would be needed for flight).
- Lifting off for the first time in the thin Martian atmosphere.
- Flying autonomously.
- Landing successfully.

If all those steps are successful, Ingenuity will attempt up to four additional test flights. All test flights will take place within a 30-Martian-day (31-Earth-day) window of activities allowed for the helicopter, after which point the Perseverance rover will need to move on for its science operations.

Key Features

What makes the helicopter a special piece of technology?

Ingenuity:

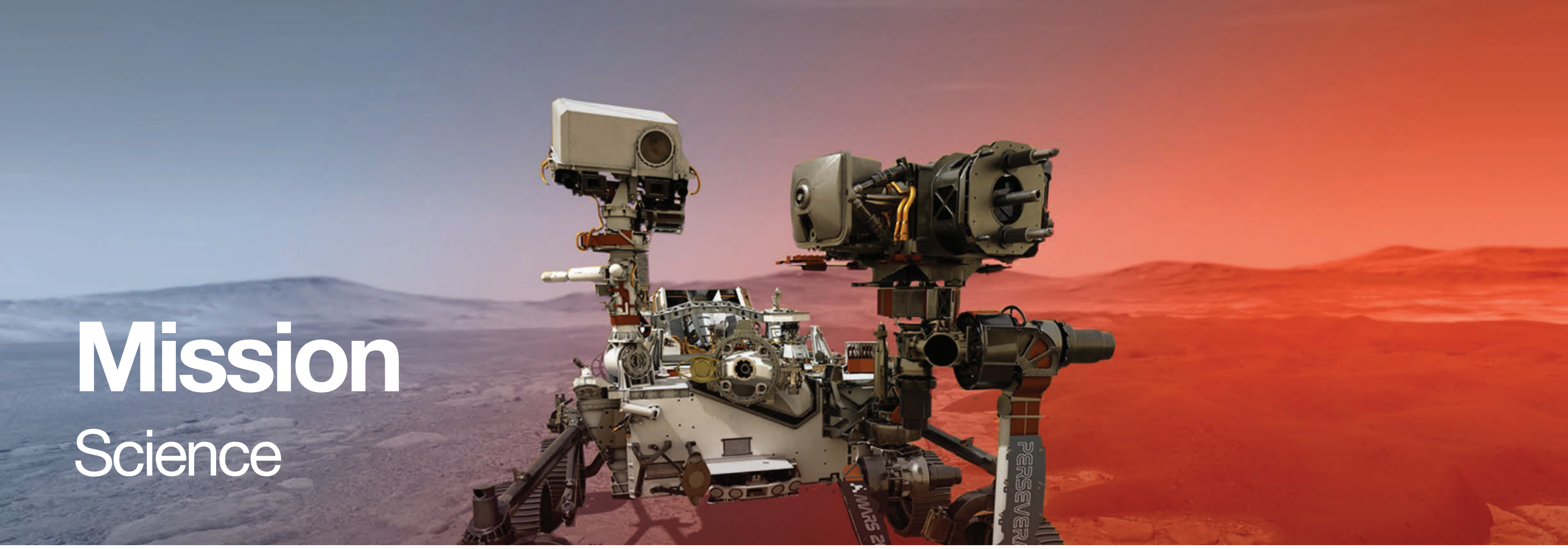
- Weighs about 4.0 pounds (1.8 kilograms).
  Is solar-powered and recharges on its own.

- Communicates wirelessly with Perseverance by remaining within a 0.6-mile (1- kilometer) radius of the rover. The rover then communicates with relay orbiters that send the signal back to Earth.

- Has a rotor system made of four carbon-fiber blades arranged into two 4-foot (1.2-meter) counter-rotating rotors, spinning at about 2,400 rpm. This first-of-its-kind rotor system was created in partnership with AeroVironment, Inc., of Simi Valley, California.

- Is equipped with computers, navigation sensors and two cameras (one color and one black-and-white).

More information can be found at the Ingenuity Mars Helicopter website.



Mission

Science

Why This Mission

Billions of years ago, Earth and Mars were much 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. If life developed on Earth at that time, could it have also developed on Mars?

NASA has sent rovers, landers and orbiters to investigate that key astrobiological question at the Red Planet. Scientists can study rocks and sediment on the Martian landscape to learn when liquid water disappeared, and when the atmosphere started to thin. This record can reveal when Mars had the ideal conditions for life.

But Perseverance will be different: It's the first Mars rover designed to collect samples that could one day be returned to Earth. Despite all of the rover's immense technical capabilities, 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 can benefit future generations of scientists who will use technology that hasn't been invented yet.

The Mars 2020 mission will also look ahead to the day when astronauts travel to Mars. Perseverance carries a new experiment called MOXIE that will test technology to convert carbon dioxide in the Martian atmosphere into oxygen that could be used for rocket propellant or breathing. The rover will also test new automated technologies that will be useful for landing humans or equipment on Mars. These efforts 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 of these 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.

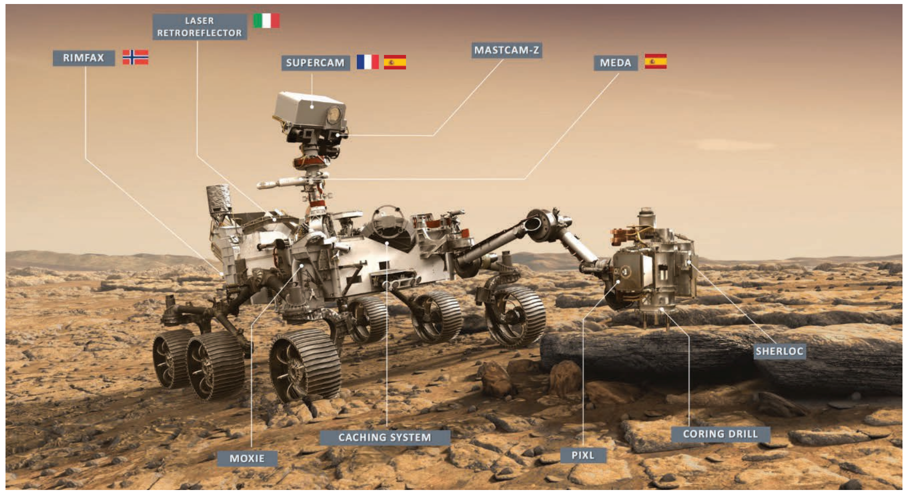
NASA has also tasked the Mars 2020 team with a mission objective to prepare for future human exploration by conducting the following investigations:

- 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 as rocket propellant and for breathing (more on MOXIE below).
- 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).
- Use sensors in the rover's descent stage 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

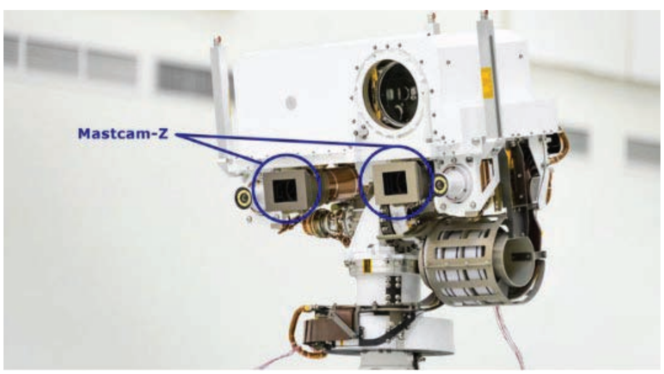
Science instruments are state-of-the-art tools for acquiring information about Martian geology, atmosphere, environmental conditions and potential signs of life (biosignatures). The mission's science supports the field of astrobiology, which aims to understand the origin, evolution and distribution of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

Perseverance has seven primary science instruments.



Several instruments on Perseverance involve international partners.
Image credit: NASAS/JPL-Caltech

Mastcam-Z



Principal Investigator:

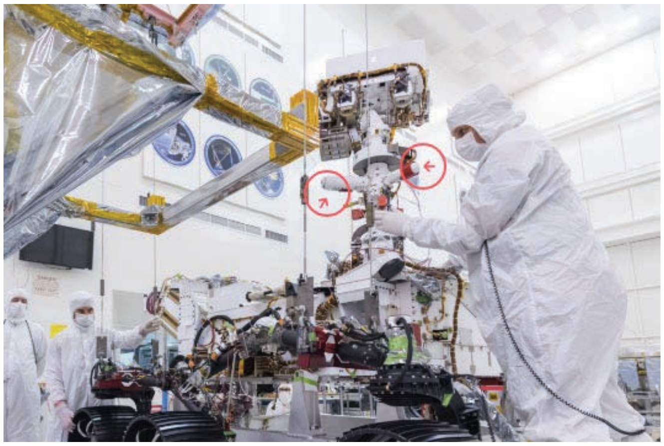
Jim Bell, Arizona State University

Mastcam-Z is a pair of next-generation science cameras that sit 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. These images help rover operators drive and place the rover's arm instruments. Analysis of the geology and colors of the landscape help scientists determine the composition and past 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 rover driving and science.

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, Madrid, Spain

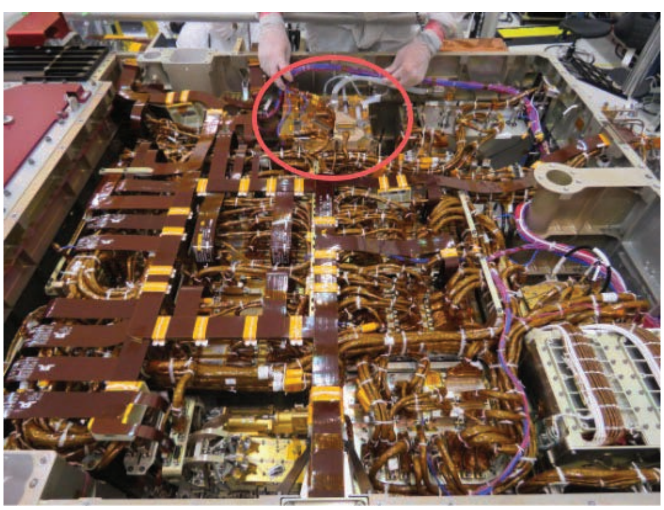
MEDA is a set of sensors distributed across Perseverance's mast and body that measures wind speed and direction, air pressure, relative humidity, ambient temperature and solar radiation. Solar radiation affects the surface environment and is important to understand more fully before sending humans to 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 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 cloud abundances and types.

MOXIE (Mars Oxygen ISRU Experiment)



Principal Investigator:

Michael Hecht, Massachusetts Institute of Technology

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. Larger versions of MOXIE could be brought to Mars in the future to enable astronauts to launch themselves back to Earth. (Launching humans off of Mars will take tens of metric tons of liquid oxygen, which is much more than MOXIE can produce.) Oxygen from MOXIE technology could also be used for breathing, though future systems will need to be about 200 times larger for human missions.

MOXIE

- Is about the size of a car battery and 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)

Principal Investigator:

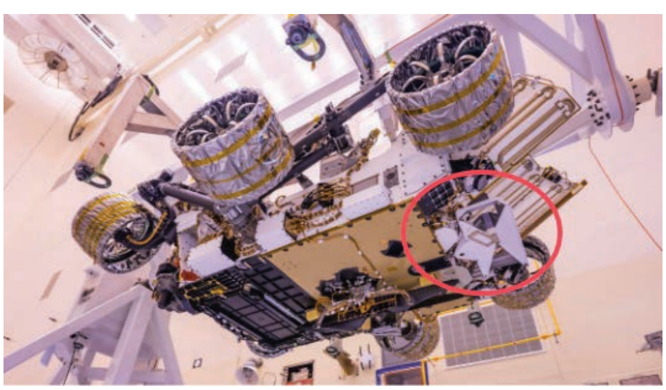
Abigail Allwood, JPL

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-sized 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 (six motorized legs) to scan the instrument and ensure accurate positioning.

RIMFAX (Radar Imager for Mars' Subsurface Experiment)



Principal Investigator:

Svein-Erik Hamran, University of Oslo

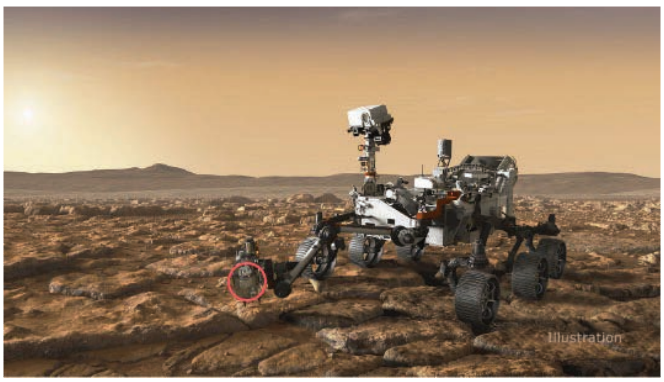
RIMFAX is the first ground-penetrating radar to be carried by a rover or lander to Mars. Such radars have been used by orbiting spacecraft, but bringing them to the surface offers much higher-resolution data. RIMFAX determines how different layers of the Martian surface formed over time.

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

RIMFAX

- Is based on the design of ground-penetrating radars 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 is too warm to harbor subsurface water ice.)

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



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

Principal Investigator:

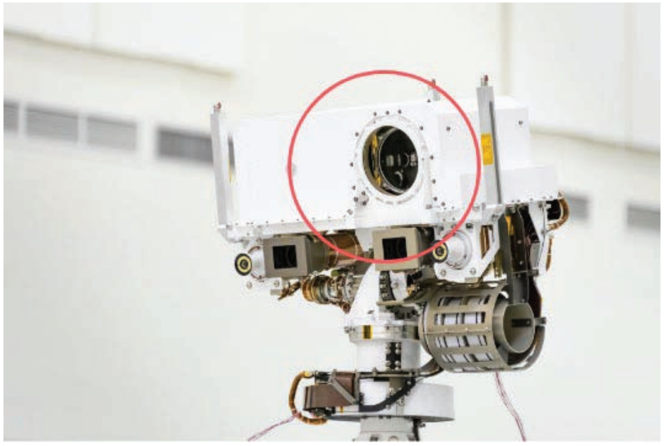
Luther Beegle, JPL

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 organics and minerals are present. SHERLOC also has a camera for taking microscopic images of rock grains and surface textures.

PIXL

- 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 soil. 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 that is generated by the laser zaps. More information about its techniques is available in this feature story about the instrument.

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 and local and regional governments.

SuperCam

- Has a laser that can analyze material from up to 20 feet (7 meters) away.
- Records the sound of laser zaps up to 12 feet (4 meters) away with a microphone. The sound changes subtly based on different rock material.
- 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.

Mars 2020 Science Team Leadership

Project Scientist:

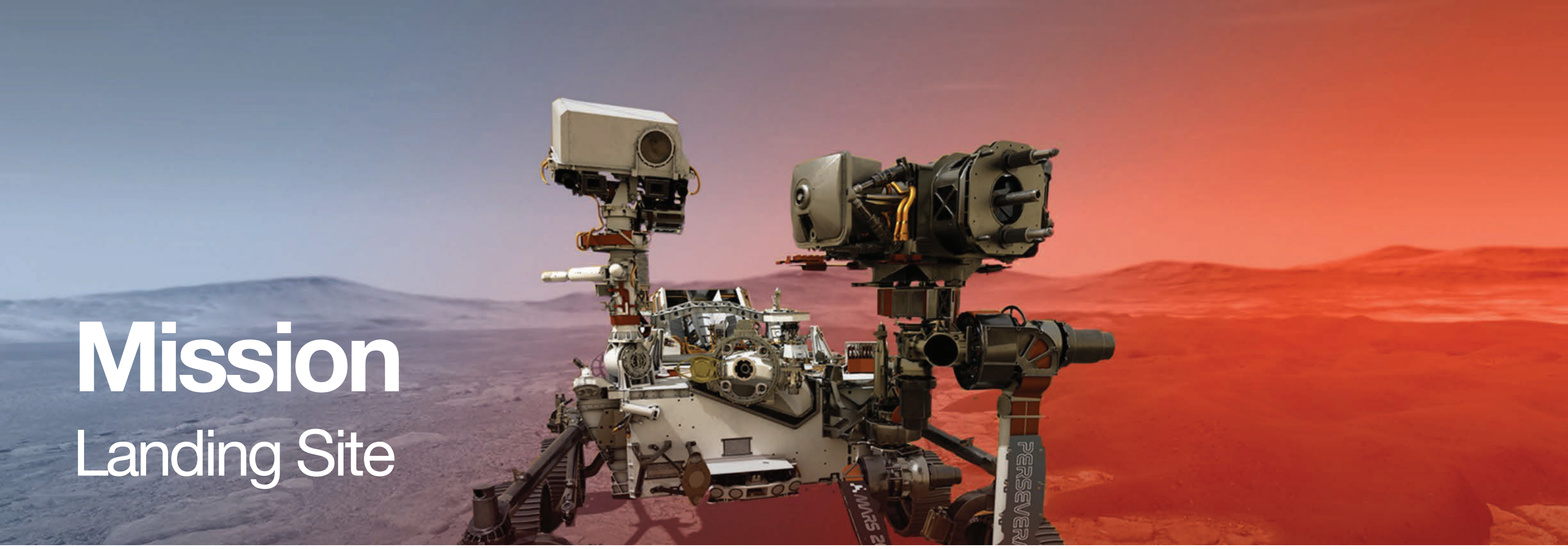
Ken Farley, Caltech, Pasadena, California

Deputy Project Scientist:

Katie Stack Morgan, JPL

Ken Williford, JPL

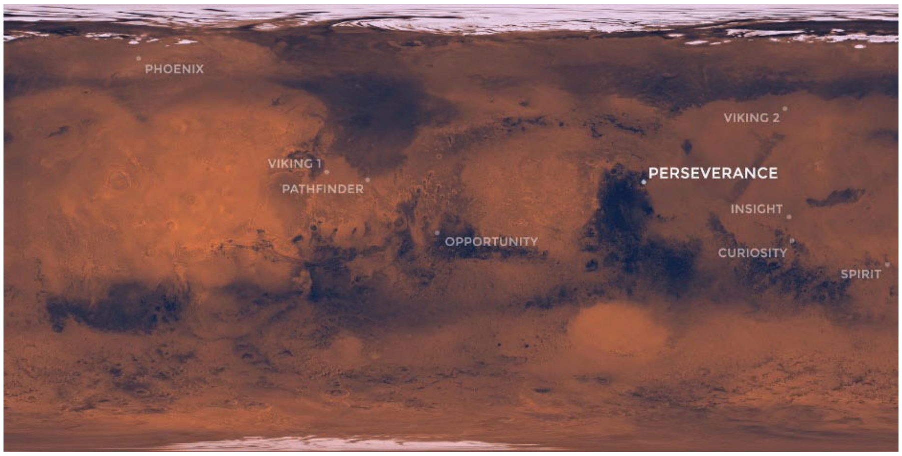
For a full list of science team members associated with Perseverance's instruments, visit: mars.nasa.gov/mars2020/mission/team



Mission

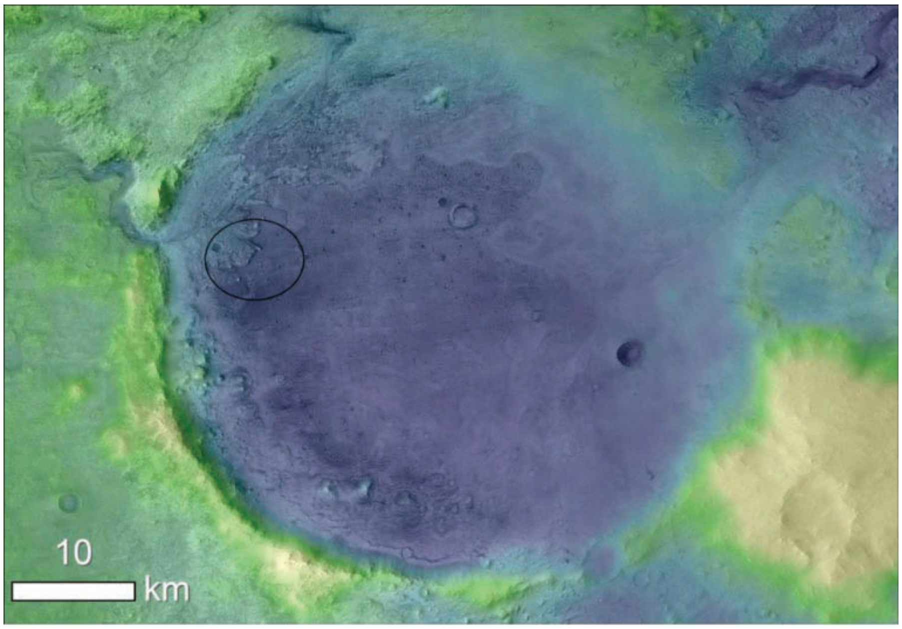
Landing Site

Landing Site



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 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 3.5 billions of 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.

Jezero Crater's ancient lake-delta system offers many promising sampling targets of at least five kinds of rock. Scientists are particularly eager to explore the rim of Jezero Crater: Parts of Jezero are especially rich in carbonates, minerals that, on Earth, help preserve fossilized signs of ancient life. And new landing technologies will allow Perseverance to touch down even closer to the most promising locations than any Mars mission before it.



For more, visit the mission's **landing site** page.
mars.nasa.gov/mars2020/mission/science/landing-site/

Management

NASA Leadership

At NASA Headquarters in Washington, **Jim Bridenstine** is the agency administrator. **Thomas Zurbuchen** is the associate administrator for the Science Mission Directorate. **Lori Glaze** is the director of the Planetary Science Division. **Jim Watzin** is the director of the Mars Exploration Program and **Michael Meyer** is the chief scientist for Mars Exploration.

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 the Science Mission Directorate. At JPL, **John McNamee** is the Mars 2020 Perseverance project manager and **Matt Wallace** is the deputy project manager. **Ken Farley** of Caltech is the project scientist. **Katie Stack Morgan** and **Ken Williford** of JPL are the deputy project scientists.

NASA's Launch Services Program, based at the agency's Kennedy Space Center in Florida, is responsible for launch management. For Mars 2020 Perseverance launch services, **Omar Baez** is the launch director and **John Calvert** is the mission manager.

For more detail on team members, visit the **Mars 2020 mission team page:** mars.nasa.gov/mars2020/mission/team

Ingenuity Mars Helicopter Technology Demonstration

At NASA Headquarters, **Dave Lavery** is the program executive for the Ingenuity Mars Helicopter. At JPL, **MiMi Aung** is the project manager and **Bob Balaram** is chief engineer. JPL built and will manage operations for Ingenuity.

More on Mars

Gallery

Images

Perseverance Rover on Mars 2020 Mission Website
go.nasa.gov/perseverance-images

Ingenuity Mars Helicopter Images on Mars Website
go.nasa.gov/mars-helicopter-images

United Launch Alliance Flickr Feed for the Rocket
bit.ly/perseverance-rocket

Perseverance Naming Announcement
bit.ly/perseverance-name

NASA Headquarters Flickr Feed
flickr.com/photos/nasahqphoto/

Web Videos

NASA's Latest Rover Has a Name (Recap Video)

bit.ly/perseverance-name-video

First Drive Test of NASA's Perseverance Rover

bit.ly/perseverance-drive

Mars Science Teams Investigate Ancient Life in Australia

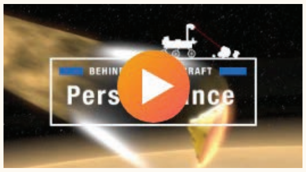
bit.ly/mars-science-australia

Building NASA's Perseverance Rover

bit.ly/building-perseverance

Testing Perseverance

bit.ly/testing-perseverance



Behind the Spacecraft (Team Member Profiles) Playlist

bit.ly/3eaLSPz

NASA's Mars Helicopter, Ingenuity (UHD Trailer)

bit.ly/3e1wDs6

Mars Playlist

bit.ly/mars-playlist

Animations and Raw Video

Perseverance B-Roll Media Reel

go.nasa.gov/perseverance-b-roll

NASA Announces Mars 2020 Rover Name Video File

go.nasa.gov/perseverance-name-video-file

Ingenuity Mars Helicopter B-Roll Media Reel

go.nasa.gov/mars-helicopter-b-roll

Ingenuity Mars Helicopter Animations Media Reel

go.nasa.gov/mars-helicopter-animations

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 on 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 9/26/10, 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, currently conducting prime mission at Elysium Planitia

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

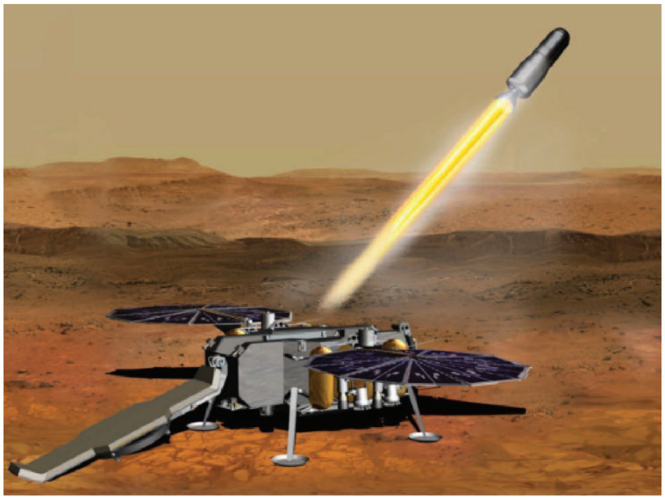
Mars Global Remote Sensing Orbiter and Small Rover (Huoxing-1): China; expected summer 2020; orbiter and rover

Emirates Mars Mission (Hope): United Arab Emirates; expected summer 2020; orbiter

Future

The European Space Agency and Russia's space agency (Roscosmos) plan to launch the ExoMars 2022 mission in 2022 to deliver a European rover (Rosalind Franklin) and a Russian surface platform (Kazachok).

NASA and the European Space Agency (ESA) are solidifying concepts for a Mars Sample Return campaign after NASA's Perseverance rover collects rock and sediment samples, 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 will deliver a lander with a NASA rocket (the Mars Ascent Vehicle) and ESA's Sample Fetch Rover. The fetch rover will gather the cached samples and carry them to the lander for transfer to the ascent vehicle; samples could also be delivered by Perseverance.

ESA will put a spacecraft in orbit at Mars. The ascent vehicle will then launch a special container holding the samples into Mars orbit. The orbiter will rendezvous with and capture the orbiting samples in order to return them to Earth. NASA will provide the payload module for the orbiter, performing the capture and containment of the orbiting samples at Mars and landing the samples on Earth.