ROVER COMPONENTS

The Perseverance Rover Has the Following Parts:

1.body: a structure that protects the rover's "vital organs"

2.brains: computers to process information

3.temperature controls: internal heaters, a layer of insulation, and more

4."Neck and head": a mast for the cameras to give the rover a human-scale view

5.eyes and ears: cameras and instruments that give the rover information about its environment

6.arm and "hand": way to extend its reach and collect rock samples for study

7.wheels and legs: parts for mobility

8.electrical power: batteries and power

9.communications: antennas for "speaking" and "listening"

1.BODY

Main Job-Carry and protect the computer, electronic, and instrument systems

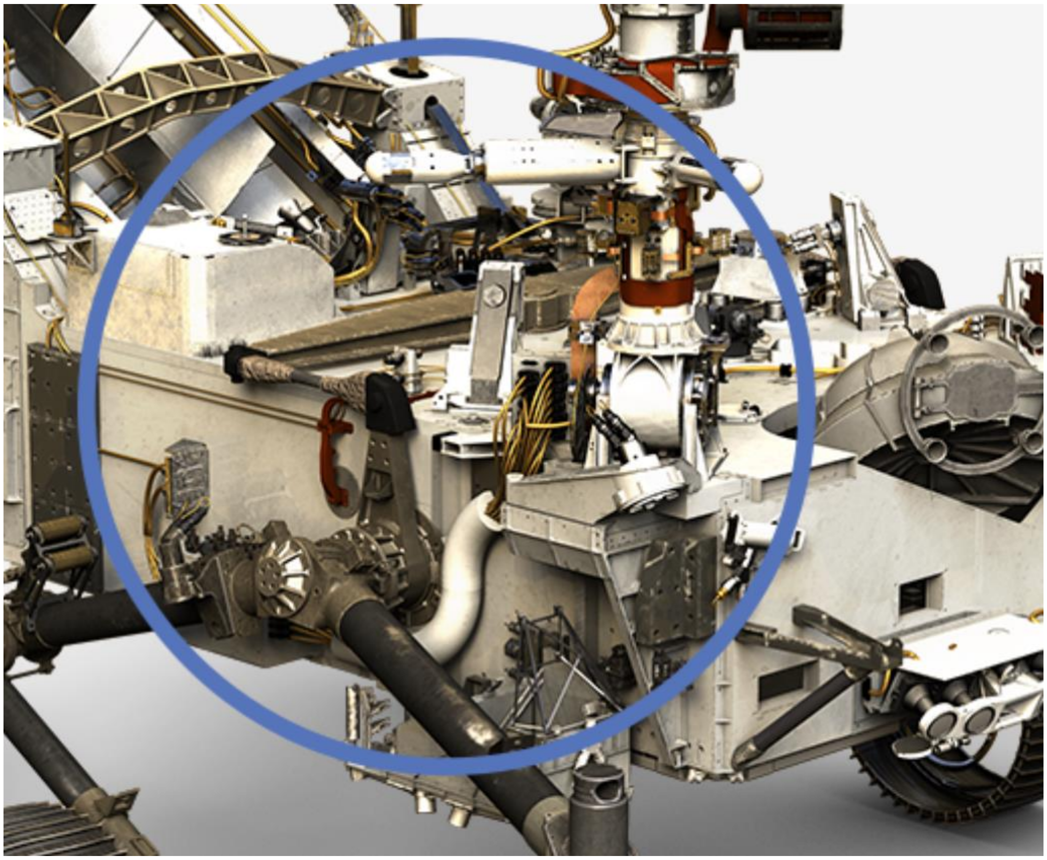
Length-10 feet (3 meters)

Width-9 feet (2.7 meters)

Height-7 feet (2.2 meters)

Weight / Mass2,260 pounds / 1,025 kilograms

Structure-Bottom and sides are the frame of the chassis; top is the rover equipment deck (its "back"); bottom is the belly pan. Note that for new Sampling and Caching interior workspace, the belly pan in that front end of the rover (about first 1 1/2 feet from front end) is dropped soon after the rover lands. This exposes the workspace to Martian atmosphere and makes more room for sample handling operations within that workspace.



2.BRAIN

Processor

Radiation-hardened central processor with PowerPC 750 Architecture: a BAE RAD 750

Operates at up to 200 megahertz speed, 10 times the speed in Mars rovers Spirit and Opportunity's computers

Memory

2 gigabytes of flash memory (~8 times as much as Spirit or Opportunity)

256 megabytes of dynamic random access memory

256 kilobytes of electrically erasable programmable read-only memory

3.CAMERA

The rover's "eyes" and other "senses"

The Perseverance rover has several cameras focused on engineering and science tasks. Some help us land on Mars, while others serve as our “eyes” on the surface to drive around. We use others to do scientific observations and aid in the collection of samples.

Descent Imaging Cameras

Engineering Cameras

Science Cameras

Descent Imaging Cameras For Landing

Entry, Descent, and Landing Cameras

Lander Vision System Camera

Entry, Descent, and Landing Cameras

Ever wonder what it would be like to have an "astronaut's" view of landing on Mars? For the touchdown of the Perseverance rover, the engineering team added several cameras and a microphone to document the entry, descent, and landing in even greater detail. The cameras recorded stunning views of the landing, capturing full-color video of the vehicle’s final descent to the Martian surface. The videos also provided data to help the team explore:

Unprecedented Visibility into Mars Landings: A suite of cameras on various parts of the Mars 2020 spacecraft will provide more detailed views of landing than ever before. Credit: NASA/JPL-Caltech. Full image and caption ›

These new eyes and ears of Perseverance were assembled from easily available commercial hardware. The cameras and microphone were flown as a "discretionary payload" – an optional add-on that would be an asset, but that wasn’t required for the mission.

The Mars 2020 entry, descent, and landing camera suite included:

Parachute "up look" cameras
Mounted on the backshell, looking upward at parachute deployment and inflation. Three cameras were installed, two of which successfully recorded the parachute.

Descent-stage "down look" camera
Mounted on the descent stage, looking downward at the rover as it was lowered during the skycrane maneuver

Rover "up look" camera
Mounted on the deck of the rover, looking upward at the descent stage during the skycrane maneuver and descent stage separation

Rover "down look" camera
Mounted beneath the rover, looking downward at the surface during landing

In addition to providing engineering data, the cameras can be considered a "public engagement payload." They certainly gave a dramatic sense of the ride down to the surface! Aside from computer animations, there had never been any views of a parachute opening in the Martian atmosphere, the rover being lowered down to the surface of Mars, or the descent stage flying away after rover touchdown. Perseverance gave us all a front-row seat to a Mars landing for the first time in the history of space exploration.

Tech Specs

Main JobTake pictures, looking up and down, during descent and landing on Mars

LocationMounted on various parts of the spacecraft, including the backshell, descent stage, and rover

Lander Vision System Camera

Another camera system used during the descent to Mars was critical to the rover’s safe touchdown: the Lander Vision System Camera took the images needed for Terrain-Relative Navigation.

While the spacecraft was dangling beneath the parachute, the wide-angle Lander Vision System Camera was looking downward, busily taking images of the rapidly approaching surface. A special computer on the rover quickly analyzed the images and compared them to an onboard map to determine the rover’s position relative to the ground. This helped Perseverance autonomously pick the safest touchdown site within its landing area.

Tech Specs

Main JobTake pictures during descent, looking downward from the rover, to aid in Terrain-Relative Navigation

LocationMounted on the left side near the front of the rover, pointed straight down

Image Size1024x1024 pixels

Engineering Cameras

Hazard Avoidance Cameras (HazCams)

Navigation Cameras (Navcams)

CacheCam

Mars 2020 uses a new generation of engineering cameras that build on the capabilities of past Mars rover cameras. These "enhanced” engineering cameras give much more detailed information, in color, about the terrain around the rover. They have various functions: they measure the ground around the rover for safe driving, check out the status of rover hardware, and support sample-gathering. Some help determine the best way to move closer to scientific targets.

"Enhanced" Engineering Cameras for Driving

The enhanced engineering cameras for driving help human operators on Earth drive the rover more precisely, and better target the movements of the arm, drill and other tools that get close to their targets. A much wider field-of-view gives the cameras a much better view of the rover itself. This is important for checking on the health of various rover parts and measuring changes in the amount of dust and sand that may accumulate on rover surfaces. The new cameras can also take pictures while the rover is moving.

The enhanced engineering cameras share the same camera body, but use different lenses selected for each camera's specific task.
These Mars 2020 navigation camera, or Navcam, views show a pile of rocks taken from a distance of about 15 meters (about 50 feet) in the "Mars Yard" testing area at JPL. The pictures illustrate one way the camera data can be used to reveal the contours of a target from a distance. Such measurements give the rover and its team the knowledge they need to plan precise travel and arm movements.

Tech Specs

Main JobUsed for driving around on Mars and for positioning the tools on the robotic arm

LocationVarious places on the rover

WeightLess than 425 grams (less than a pound)

Image Size5120 x 3840 pixels

Image Resolution20 megapixel

Hazard Avoidance Cameras (HazCams):

Perseverance carries six newly developed Hazard Detection Cameras, called HazCams: four on the front and two on the rear of the rover body. HazCams detect hazards to the front and back pathways of the rover, such as large rocks, trenches, or sand dunes.

Engineers also use the front HazCams to see where to move the robotic arm to take measurements, photos, and collect rock and soil samples.

When driving, the rover stops frequently to take new stereo images of the path ahead to evaluate potential hazards. The 3D views give Mars 2020 the ability to make its own decisions about where to drive without consulting on every move with the rover team on Earth.

Tech Specs

Main JobAid in autonomous navigation

LocationMounted at the front and rear of the rover's body, pointing down toward the ground

Navigation Cameras (Navcams):

Two color stereo Navigation Cameras, called Navcams, help engineers navigate Perseverance safely, particularly when the rover operates autonomously, making its own navigation decisions without consulting controllers on Earth.

Located up high on the rover's mast, these two cameras help engineers drive the rover around Mars. They can see an object as small as a golf ball from 82 feet (25 meters) away. Before Perseverance "drives blind," the navigation cameras initially help ensure a safe path. Blind-drive mode occurs when engineers command the rover to drive a certain distance in a certain direction, and the rover's computer "brains" calculate distance from wheel rotations without looking or checking for wheel slippage.

Tech Specs

Main JobAid in autonomous navigation

LocationMounted high on the rover's mast; left and right "eyes" are about 16.5 inches (42 centimeters) apart

New Camera to Record Sample Collection

CacheCam:

The "CacheCam" is a single camera that looks down at the top of the sample cache. It takes pictures of sampled materials and the sample tubes as they are being prepared for sealing and caching. This helps scientists "watch over" the samples as they are being obtained, and keeps a record of the entire process for each sample collected.

Tech Specs

Main JobTo see down into the top of a sample tube after the sample is gathered; to take microscopic pictures of the top of the sample material before the tube is sealed.

LocationInside the rover underbelly, at the top of the sample cache

The Science Cameras

Mastcam-Z

SuperCam

PIXL

SHERLOC

WATSON

Mastcam-Z

Mastcam-Z is a pair of cameras that takes color images and video, three-dimensional stereo images, and has a powerful zoom lens. Like the Mastcam cameras on the Curiosity rover, Mastcam-Z on Mars 2020 consists of two duplicate camera systems mounted on the mast that stands up from the rover deck. The cameras are next to each other and point in the same direction, providing a 3-D view similar to what human eyes would see, only better. They also have a zoom function to see details of faraway targets.

SuperCam

SuperCam fires a laser at mineral targets that are beyond the reach of the rover's robotic arm, and then analyzes the vaporized rock to reveal its elemental composition. Like the ChemCam on rover Curiosity, SuperCam fires laser pulses at pinpoint areas smaller than 1 millimeter from more than 20 feet (about 7 meters) away. Its camera and spectrometers then examine the rock's chemistry. It seeks organic compounds that could be related to past life on Mars. When the laser hits the rock, it creates plasma, which is an extremely hot gas made of free-floating ions and electrons. An onboard spectrograph records the spectrum of the plasma, which reveals the composition of the material.

PIXL

PIXL uses X-ray fluorescence to identify chemical elements in target spots as small as a grain of table salt. It has a Micro-Context Camera to provide images to correlate its elemental composition maps with visible characteristics of the target area.

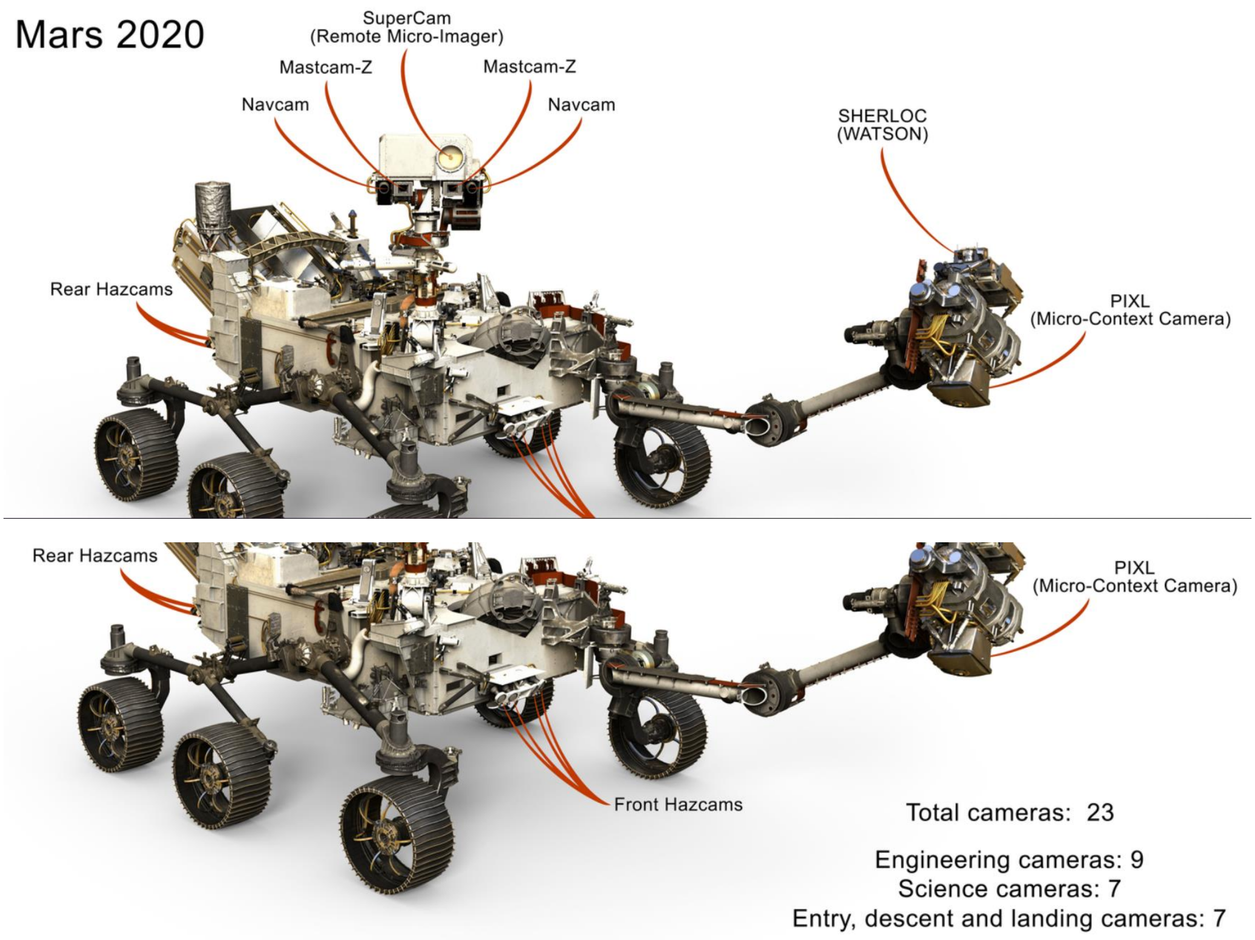
SHERLOC Context Imager

SHERLOC's main tools are spectrometers and a laser, but it also uses an integrated “context” macro camera to take extreme close-ups of the areas that are studied. This provides context for what the laser was targeting but also to help scientists see textures that might tell the story of the environment in which the rock formed.

WATSON

The WATSON camera is one of the tools on the "hand" or turret at the end of Perseverance's robotic arm. It is almost identical to the MAHLI hand-lens camera on the Curiosity rover. WATSON (Wide Angle Topographic Sensor for Operations and eNgineering) captures the images that bridge the scale from the very detailed images and maps that SHERLOC collects of Martian minerals and organics to the broader scales that SuperCam and Mastcam-Z observe from the mast. WATSON provides views of the fine-scale textures and structures in Martian rocks and the rocky debris and dust that cover so much of the Martian surface. These capabilities mean WATSON not only supports SHERLOC, but also helps identify targets of interest for the other rover instruments. Since WATSON can be moved around by the robotic arm, it also provides images of instruments and rover parts. For example, it can be pointed at the oxygen-making experiment MOXIE to help monitor how much dust accumulates around the inlet that lets in Martian air for the extraction of oxygen.

A calibration target for WATSON is attached to the front of the rover body. It contains a metric standardized bar graphic to help calibrate the instrument.



4.MICROPHONES

Microphone on SuperCam

SuperCam identifies minerals and rock compositions, and it seeks organic compounds that could be related to past life on Mars. It has a laser that can zap and study areas on a rock as small as the period at the end of this sentence. All from about 20 feet, or 7 meters away. Its camera and spectrometers then examine the rock's chemistry. The microphone on SuperCam gives scientists another "sense" with which to probe the rock targets they are studying.

Tech Specs

Main JobTo help study Mars rocks

LocationOn a short 15 mm boom on the head of the rover’s long mast

Listening whenwhen the SuperCam instrument is on, for a few milliseconds at a time. Or to listen to wind and for rover sounds for about 3.5 minutes at a time.

Weight30 grams, or about 1 ounce

What it can hearthe staccato pop caused when the laser studies rock, wind, and rover noises

Hearing the Sounds of a Laser Firing

When SuperCam fires a laser at a rock, a small amount of the rock vaporizes into a hot gas called "plasma", and heat and vibration creates a shockwave that makes a popping sound. SuperCam’s camera and spectrometer can "read" the hot gas to reveal the chemical makeup of the vaporized rock. At the same time, the microphone hears the staccato "pop" as the laser strikes rock several feet away from Perseverance.

The kind of "pop" it makes tells scientists about the mass and makeup of the rock. The intensity of the sound reveals the relative hardness of the rocks, which can tell us more about their geological context. For example, the hardness of the rock can help tell us whether the rock was formed in a lake or from wind-driven material, or how much pressure was involved in its formation. All without ever driving up and touching it.

SuperCam can listen for about 3.5 minutes at a time while performing science observations. This gives the rover the chance to hear the sounds of Mars, such as the high-pitched sound of sand grains over the surface, the wind whistling around the rover mast, and low-pitched howls of dust devils passing by. The microphone also records sounds of Perseverance using its arm, coring rocks, and the wheels crunching against the surface. The rover may hear the other instruments, internal mechanisms, and hear when we drop off the sample tubes. In some cases, sound can help the team diagnose the health of the rover's internal mechanisms or instruments.

Microphone to Record the Rover's Landing

Mars 2020's Entry Descent and Landing (EDL) system is similar to Mars Science Laboratory/Curiosity, but it carries a microphone with which to record the sounds of descent. This microphone records audio as the Perseverance rover descends to the surface. We may hear the friction of the atmosphere, the winds, and the sounds of dust displaced as the rover lands.

Tech Specs

Main JobTo record the sounds of landing

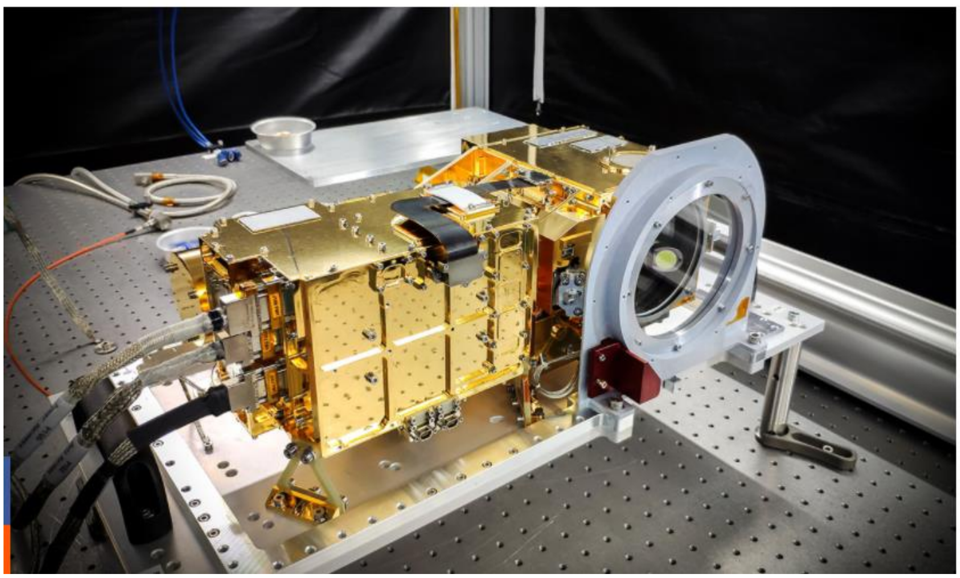
LocationThe EDL mic's "brains" are inside the body of the rover; its "ears” are on side of the rover body

Operatingas the rover descends on Mars

Recordingthe sounds of descent, friction from the atmosphere, dust blown up by the thrusters as the rover descends

Hearing the Sounds of the Rover

Engineers are optimizing this microphone for space from easily available, store-bought hardware. It is unlikely it will work beyond landing. If it does survive, we may be able to hear the sounds of the Martian winds and sounds of the working rover, such as the wheels turning, or the motors that turn its head, and the heat pumps that keep it warm.



5.WHEELS

Legs

MaterialsMade of titanium tubing formed with the same process used to make high-end mountain bike frames.

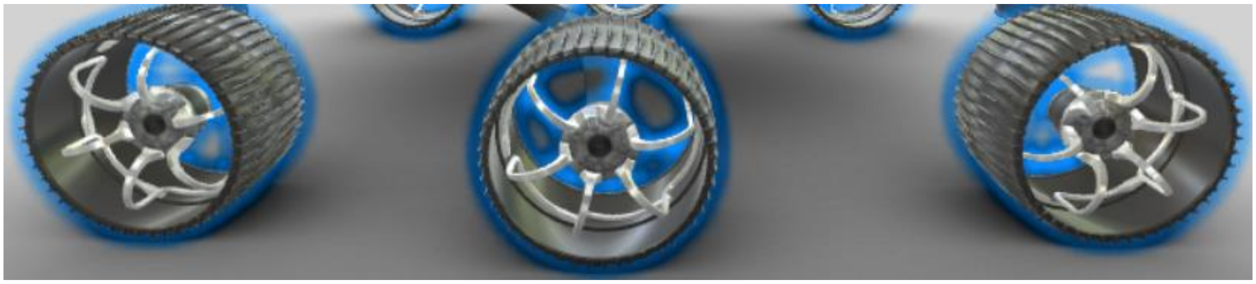
OtherEnable the rover to drive over knee-high rocks as tall as 40-centimeters (15.75-inches).

Wheels

MaterialsMade of aluminum, with cleats for traction and curved titanium spokes for springy support.

Size52.5 centimeters (20.7-inches) in diameter

OtherOne full turn of the wheels with no slippage drives the rover 1.65 meters (65-inches).



6.SAMPLE HANDLING

The Perseverance rover will gather samples from Martian rocks and soil using its drill. The rover will then store the sample cores in tubes on the Martian surface. This entire process is called "sample caching".

Mars 2020 will be the first mission to demonstrate this on Mars. It could potentially pave the way for future missions that could collect the samples and return them to Earth for intensive laboratory analysis.

The three major steps in sample handling are:

Step 1: Collecting the Samples

Step 2: Sample Sealing and Storing Onboard

Step 3: Depositing the Samples on the Surface

Tech Specs

Main JobCollect and store a compelling set of rock and soil samples that could be returned to earth in the future.

Sample Containers43 sample tubes (including 5 witness tubes)

Samples to be collectedat least 20 samples

STEP 1: Collecting Samples

A big job for the rover is collecting carefully selected samples of Mars rock and soil. These samples will be sealed in tubes and left in a well-identified place, or more than one spot, on the surface of Mars. Detailed maps will be provided for any future mission that might go to Mars and pick up these samples for study by scientists.

Sampling Equipment in the Rover Belly

The belly of the rover houses all the equipment and supplies needed to collect samples. It contains a rotating drill carousel, which is a wheel that contains different kinds of drill bits. Next to that are the 43 sample tubes waiting to be filled.

While the rover’s big arm reaches out and drills rock, the rover belly is home to a small robotic arm that works as a "lab assistant" to the big arm. The small arm picks up and moves new sample tubes to the drill, and transfers filled sample containers into a space where they are sealed and stored.

Witness Tubes

Perseverance must meet extraordinary cleanliness requirements. These measures are in place to avoid contaminating Martian samples with terrestrial contaminants that may inadvertently be brought from Earth. Strict rules limit the amount of inorganic, organic and biological materials from Earth in the rover and its sample handling system.

Perseverance carries five "witness tubes" along with sample collection tubes. The witness tubes are similar to the sample tubes except they are pre-loaded with a variety of witness materials that can capture molecular and particulate contaminants, such as:

gases that may be released, or "outgassed," from different materials on the rover;

chemical remnants from the firing of the landing propulsion system;

any other Earthly organic or inorganic material that may have arrived on Mars with the rover.

One at a time, the witness tubes will be opened on the Martian surface to "witness" the ambient environment near sample collection sites. They are exposed to the local environment where samples are collected and they go through the motions of drilling and other movements that the sample containers experience. The witness tubes do not, however, collect soil or rock samples. The witness tubes will also be sealed and cached like the actual Mars samples.

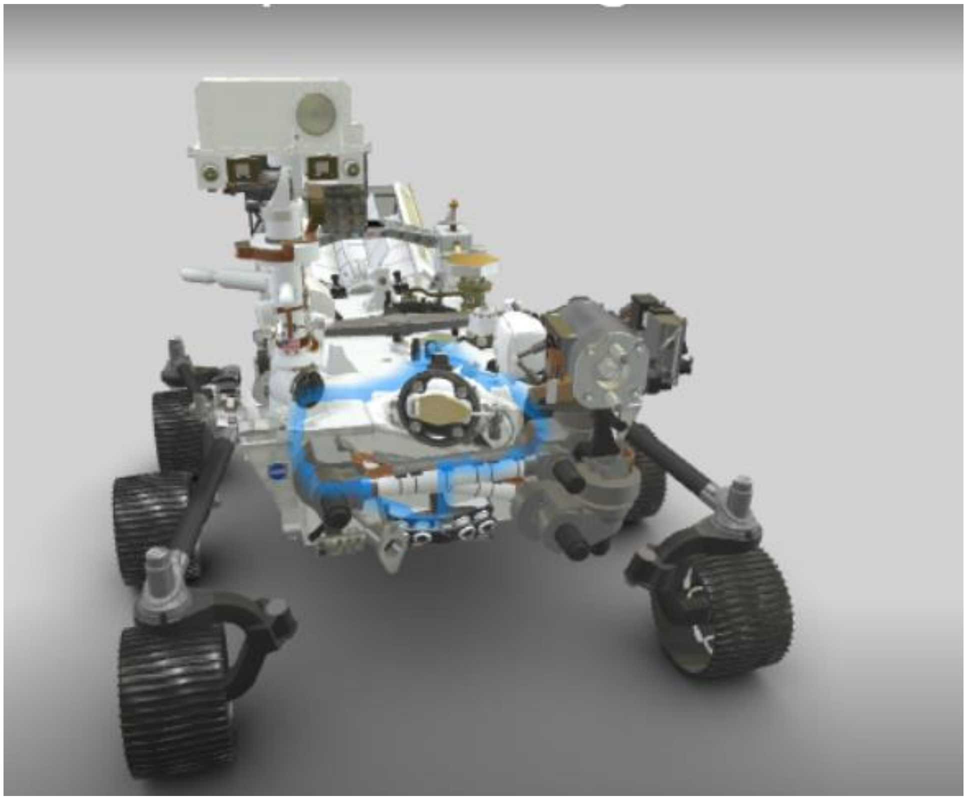
In the future, if the Perseverance samples are returned to Earth for analysis, the witness tubes will show whether Earth contaminants were present during sample collection. This will help scientists tell which materials in the Martian materials may actually be of Earth origin.

STEP 2: Storing Onboard

After a sample is collected, the sample tube is transferred back to the rover's belly. There, it is handed off to the small interior robotic arm and moved to inspection and sealing stations. Once the tube is hermetically sealed, nothing can enter or leave it. The tubes are stored in the rover belly until the team decides on the time and place to drop the samples off on the surface.

STEP 3: Depositing Samples on the Surface

At a time and place of the team's choosing, the samples are deposited on the surface of Mars at a spot that the team designates as a "sample cache depot." The depot location or locations must be well-documented by both local landmarks and precise coordinates from orbital measurements. The cache of Mars samples remains at the depot, available for pickup and potential return to Earth.



7.POWER

Main JobProvide electricity to the rover

LocationAft end of the rover

Size25 inches (64 centimeters) in diameter by 26 inches (66 centimeters) long

WeightAbout 99 pounds (45 kilograms)

Power SystemUses 10.6 pounds (4.8 kilograms) of plutonium dioxide as the source of the steady supply of heat

Electrical Power ProducedAbout 110 watts at launch, declining a few percent per year

BatteriesTwo lithium-ion rechargeable batteries to meet peak demands of rover activities when the demand temporarily exceeds the MMRTG's steady electrical output levels.

ReliabilityThe electrical power system on the Mars 2020 Perseverance rover is just like the one used on the Mars Science Laboratory Curiosity rover. NASA has used similar power systems reliably for decades, including the Apollo missions to the Moon, the Viking missions to Mars, and on spacecraft that flew to the outer planets and Pluto, including the Pioneer, Voyager, Ulysses, Galileo, Cassini, and New Horizons missions.

SafetyThe fuel inside each General Purpose Heat Source module is surrounded by several layers of protective materials, including the type of tough material used in the nose cones of missiles designed to survive fiery conditions during re-entry into Earth’s atmosphere. In addition, the radioisotope fuel is manufactured in a ceramic form (similar to the material in a coffee mug) that resists being broken into fine pieces, reducing the chance that hazardous material could become airborne or ingested. In the unlikely event of a Mars 2020 launch site accident, the estimated maximum dose an exposed individual could receive is 210 millirem. A resident of the United States receives, on average, 310 millirem of radiation each year from natural sources, such as radon and cosmic rays from space.

The MMRTG is provided to NASA by the U.S. Department of Energy

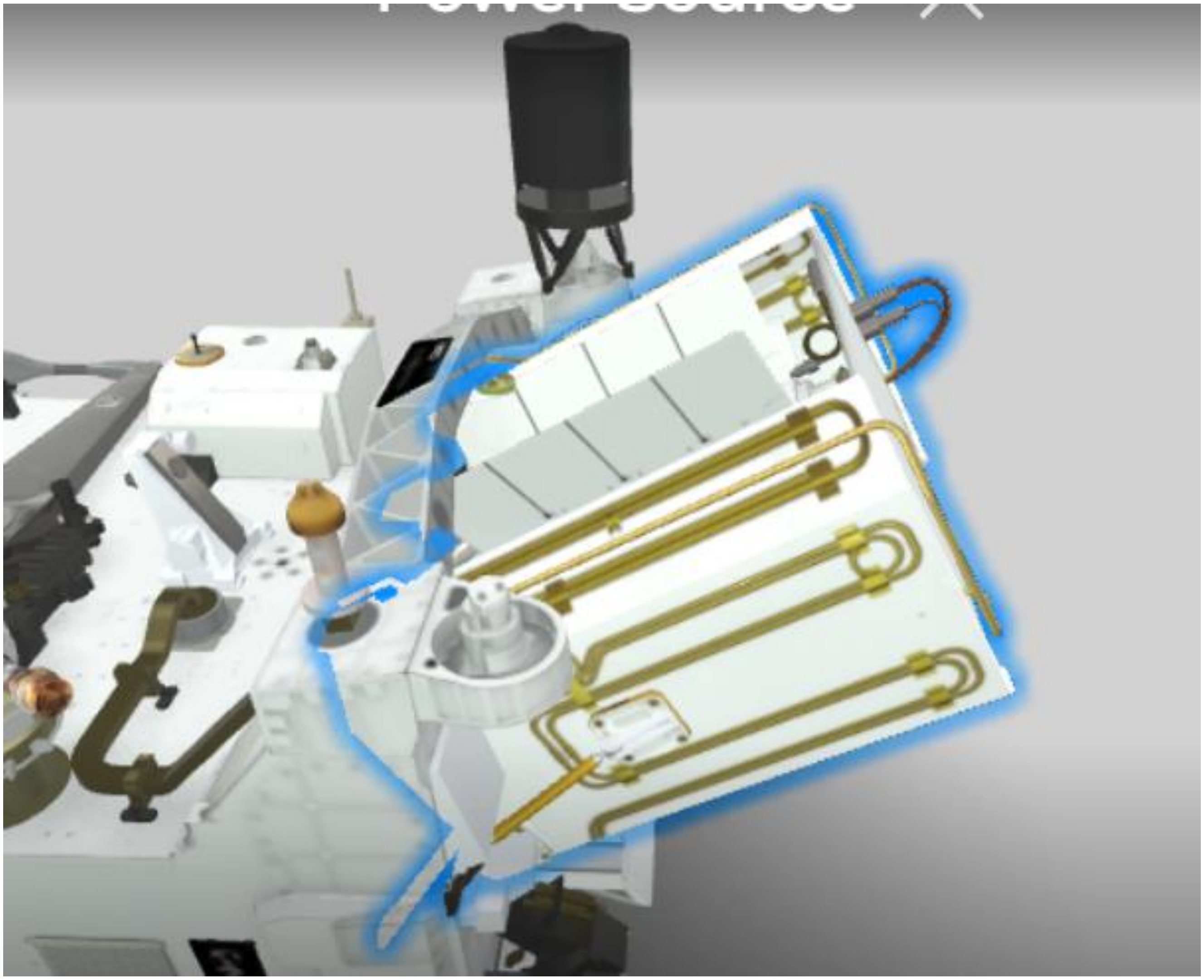
This power system provides several advantages:

The 14-year operational lifetime of an MMRTG provides significant reserve for Mars 2020 prime mission duration of 1.5 Mars years (three Earth years)

It gives the rover greater mobility over a large range of latitudes and altitudes

It allows scientists to maximize the capabilities of the rover's science instruments

It provides engineers with a lot of flexibility in operating the rover (e.g., day and night, and through the winter season)



8.COMMUNICATIONS

The Mars 2020 rover, Perseverance, has three antennas that serve as both its "voice" and its "ears." They are located on the rover equipment deck (its "back"). Having multiple antennas provides operational flexibility and back-up options just in case they are needed. Antennas on rover deck:

Ultra-High Frequency Antenna

X-band High-Gain Antenna

X-band Low-Gain Antenna

Ultra-High Frequency Antenna

Most often, Mars 2020 uses its ultra-high frequency (UHF) antenna (about 400 megahertz) to communicate with Earth through NASA's orbiters around Mars. Because the rover and orbiter antennas are within close range of each other, they act a little like walkie-talkies compared to the long-range telecommunications with Earth provided by the low-gain and high-gain antennas. It generally takes about 5 to 20 minutes for a radio signal to travel the distance between Mars and Earth, depending on planet positions. Using orbiters to relay messages is beneficial because they are much closer to Perseverance than the Deep Space Network (DSN) antennas on Earth. The mass- and power-constrained rover can achieve high data rates of up to 2 megabits per second on the relatively short-distance relay link to the orbiters overhead. The orbiters then use their much larger antennas and transmitters to relay that data on the long-distance link back to Earth.

Tech Specs

Main JobTransmitting Data to Earth through Mars Orbiters

Radio FrequencyUltra-High Frequency (UHF) band (about 400 megahertz)

Transmission RatesUp to 2 megabits per second on the rover-to-orbiter relay link.

The X-Band High-Gain Antenna

The high-gain antenna is steerable so it can point its radio beam in a specific direction. The benefit of having a steerable antenna is that the entire rover doesn't need to change position to talk to Earth, which is always moving in the Martian sky. Like turning your neck to talk to someone beside you rather than turning your entire body, the rover can save energy and keep things simple by moving only the antenna. Its high gain allows it to focus its beam, allowing higher data rates on the long link back to Earth.

Tech Specs

Main JobTransmitting data directly to and from Earth

Radio FrequencyX band (7 to 8 gigahertz)

LocationMounted mid-aft portside of Mars 2020 deck ("back")

SizeHexagonally shaped, 1 foot (0.3 meters) in diameter

Transmission/ Reception Rates160/500 bits per second or faster to/from the Deep Space Network's 112-foot-diameter (34-meter-diameter) antennas or at 800/3000 bits per second or faster to/from the Deep Space Network's 230-foot-diameter (70 meter-diameter)

Provided bySpain

The X-Band Low-Gain Antenna

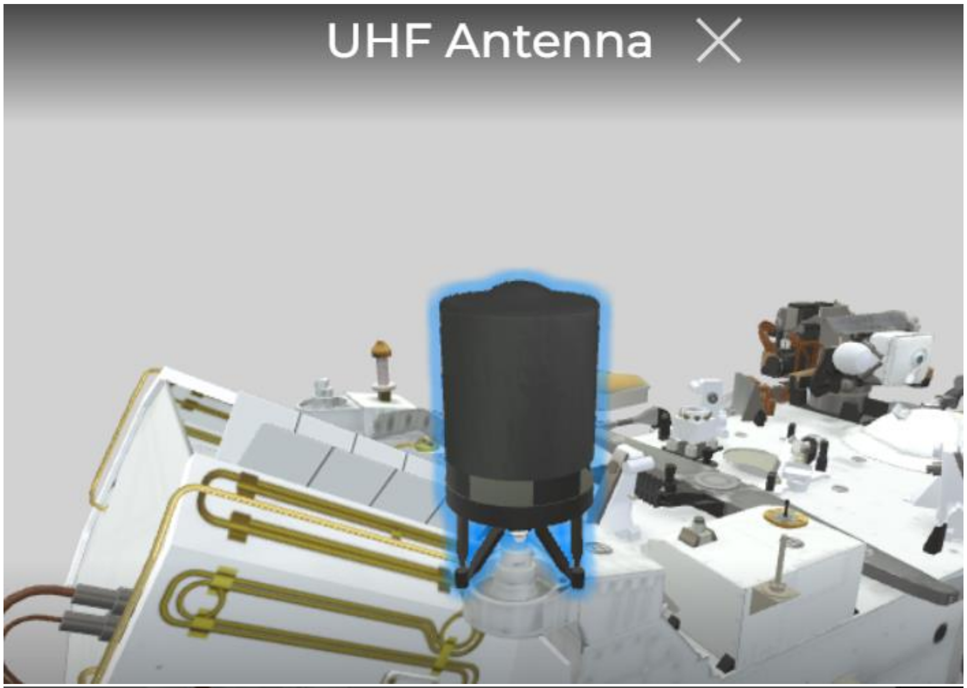
Mars 2020 uses its low-gain antenna primarily for receiving signals. This antenna can send and receive information in every direction; that is, it is "omni-directional." The antenna transmits at low data rate to the Deep Space Network antennas on Earth. Because it doesn’t need to be pointed, it provides a robust way to always communicate with the rover.

Tech Specs

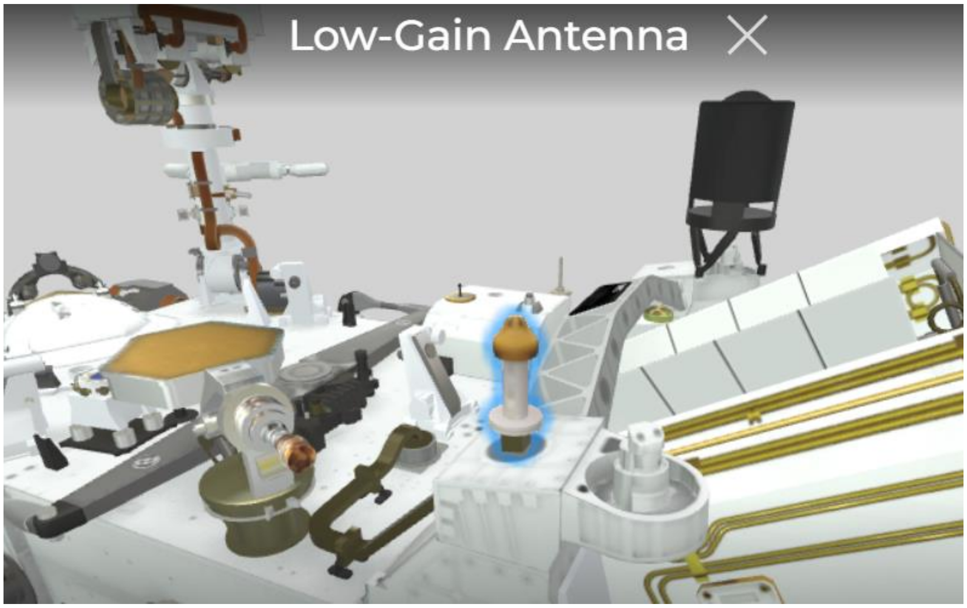
Main JobReceiving Data

Radio FrequencyX band (7 to 8 gigahertz)

Reception RatesApproximately 10 bits per second or faster from the Deep Space Network's 112-foot-diameter (34-meter-diameter) antennas or approximately 30 bits per second or faster from the Deep Space Network's 230-foot-diameter (70-meter-diameter) antenna


UHF Antenna


High-Gain Antenna



9.ARM

Length7 feet (2.1 meters)

Degrees of FreedomThere are five. They are made possible by tiny motors called "rotary actuators." The five degrees of freedom are known as the shoulder azimuth joint, shoulder elevation joint, elbow joint, wrist joint and turret joint.

"Hand" TurretAt the end of the arm is the "turret." It's like a hand that carries scientific cameras, mineral and chemical analyzers for studying the past habitability of Mars, and choosing the most scientifically valuable sample to cache.

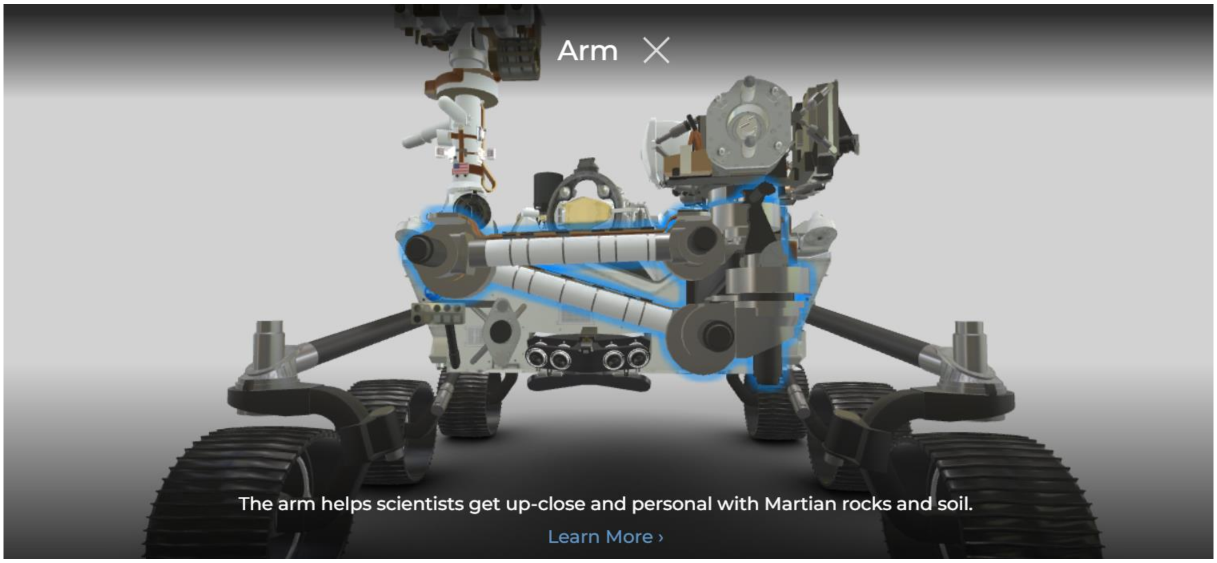
Names of Tools on the TurretSHERLOC and WATSON, PIXL, GDRT (Gaseous Dust Removal Tool), Ground Contact Sensor, Drill

DrillThe drill is a rotary percussive drill designed to extract rock core samples from the surface of Mars.

Drill BitsA suite of interchangeable bits: coring bits, regolith bit and an abrader.

Main FunctionAssist in Mars surface investigation and sample collection

Diameter of drilled holes1 inch (27 mm)


Arm
The arm helps scientists get up-close and personal with Martian rocks and soil.
Learn More ›