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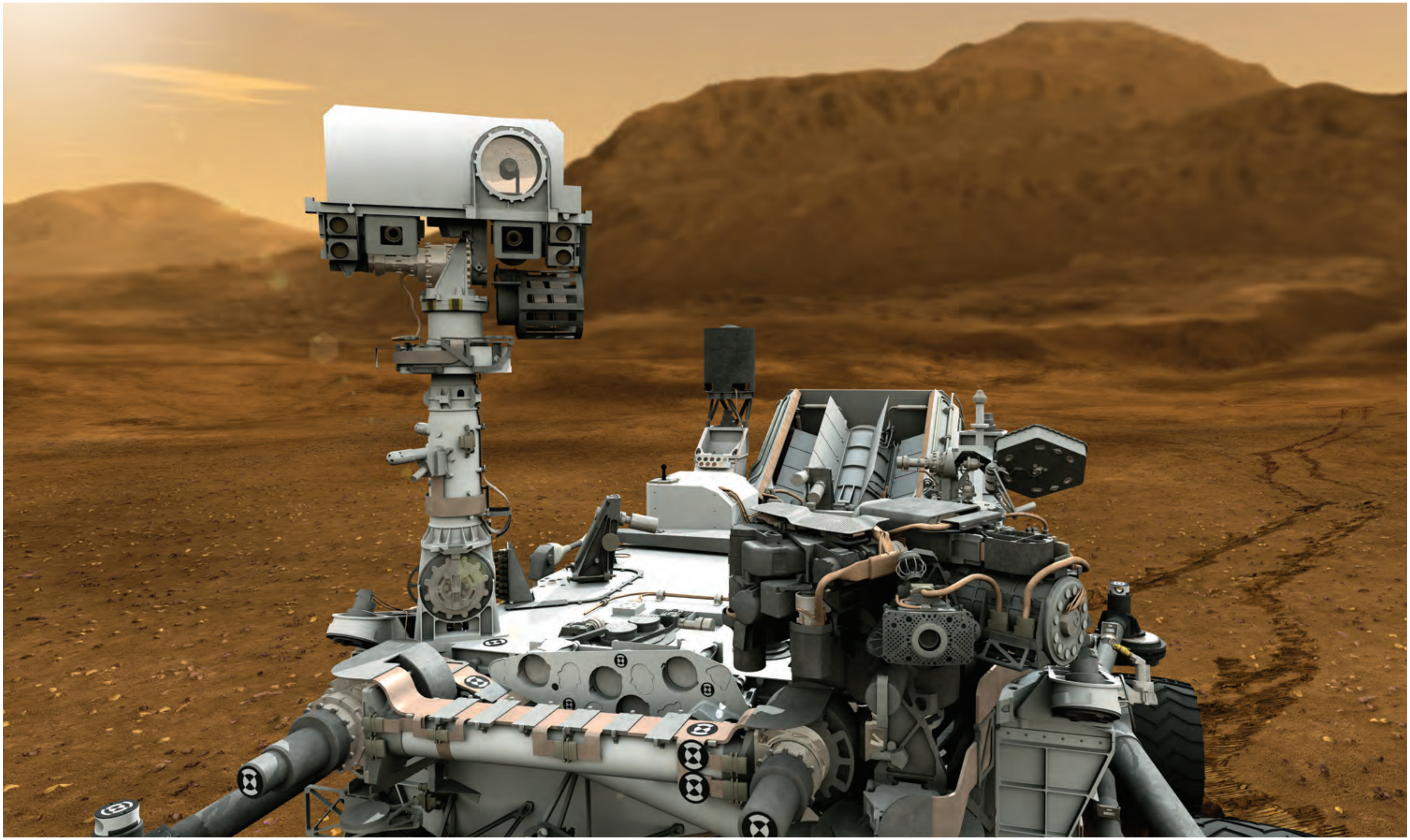

Mars Science Laboratory: Curiosity Rover

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Curiosity's Mission: Was Mars Ever Habitable?

Part of NASA's Mars Science Laboratory mission, Curiosity is the largest and most capable rover ever sent to Mars. Curiosity's mission is to answer the question: did Mars ever have the right environmental conditions to support small life forms called microbes?

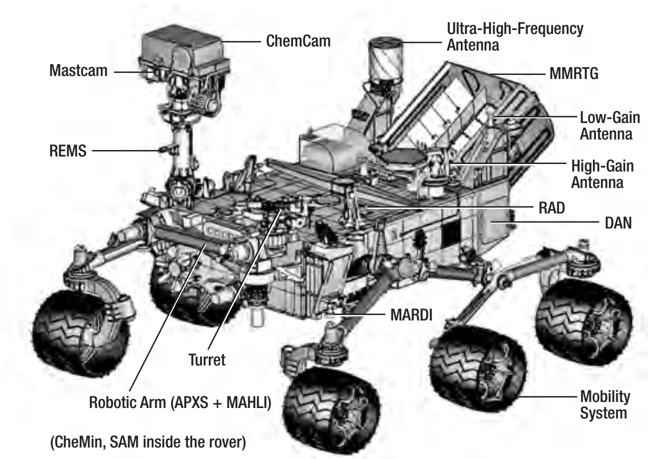
Taking the next steps to understand Mars as a possible place for life, Curiosity builds on an earlier "follow the water" strategy that guided Mars missions in NASA's Mars Exploration Program. Besides looking for signs of wet climate conditions and for rocks and minerals that formed in water, Curiosity also seeks signs of carbon-based molecules called organics. Organics are the chemical building blocks of life. If Mars had long-term water and organics, the chance that Mars had conditions to support microbial life is greater. Scientists expect that life on Mars, if it existed at all, would be microbial. For most of Earth's history, the only life forms were microbes. Microbes still make up most of the living matter on Earth.

Curiosity's Landing Site: Gale Crater

After an eight-month trip of about 354 million miles (570 million kilometers), Curiosity landed safely in the 96-mile-wide (154-kilometer-wide) Gale Crater, at the base of giant Mount Sharp. Pioneering precision landing techniques, engineers reduced the area of the landing ellipse by about four times, with the final ellipse measuring 4 miles wide and 12 miles long (7 kilometers by 20 kilometers). The 3-mile-high (5-kilometer-high) mountain has multiple rock layers. Each layer reveals information about a different time in Mars' history. Curiosity will study these layers for clues about ancient habitable environments and Mars' ability to preserve evidence of them. NASA selected Gale Crater in part because instruments on Mars orbiters previously found signs of special clay minerals that form in the presence of water and are known to preserve organics.

The Rover

To find out if Mars could have been a habitat for life, Curiosity surveys the environment at Gale Crater and acquires rock, soil, and air samples for onboard analysis. Curiosity is about the size of a small car and about as tall as a basketball player. Its large size allows the rover to carry an advanced kit of 10 science instruments. Among Curiosity's tools are 17 cameras, a laser to zap rocks, and a drill to collect rock samples. These all help in the hunt for special rocks that formed in water and/or have signs of organics. The rover also has three communications antennas.



(CheMin, SAM inside the rover)

Science Instruments

Remote Sensing

Mastcam — Mast Camera
ChemCam — Chemistry and Camera
MARDI — Mars Descent Imager

Contact Instruments (Arm)

APXS — Alpha Particle X-Ray Spectrometer
MAHLI — Mars Hand Lens Imager

Analytical Laboratory (Rover Body)

SAM — Sample Analysis at Mars
CheMin — Chemistry and Mineralogy

Environmental Instruments

REMS — Rover Environmental Monitoring Station
RAD — Radiation Assessment Detector
DAN — Dynamic Albedo of Neutrons

Quick Facts

Launch — Nov. 26, 2011 from Cape Canaveral, Florida, on an Atlas V-541
Arrival — Aug. 6, 2012 (UTC)
Prime Mission — One Mars year, or about 687 Earth days (~98 weeks)

Main Objectives

- Search for organics and determine if this area of Mars was ever habitable for microbial life
- Characterize the chemical and mineral composition of rocks and soil
- Study the role of water and changes in the Martian climate over time
- Characterize the radiation environment for future human missions to Mars

Size

Length —10 feet (2 meters), not including the 7-foot (2.1-meter) arm
Width — 9 feet (2.8 meters)
Height — 7 feet (2.1 meters) tall
Weight — 900 kilograms (2,000 pounds)

Thermal and Electrical Power

Radioisotope Power System — a Multi-Mission Radioisotope Thermoelectric Generator (MMRTG)

More Information

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An artist's concept of the Curiosity rover on Mars.

Credit: NASA/JPL-Caltech

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Building, Testing, and Transporting NASA's Mars Rover Curiosity

www.nasa.gov

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Engineering Teamwork

Thanks to countless and demanding hours of effort from a workforce of thousands of people, Curiosity came together from a collection of individual instruments and rover systems to create an incredibly capable and sophisticated rover. Teamwork also enabled a radically new entry, descent, and landing (EDL) system for precision landing, and the assembly of a spacecraft system that carried Curiosity to Mars. Several universities, government research labs, and private labs built and tested individual instruments for the rover at locations in the United States, Spain, Russia, Canada, France, and Germany.

The Birth of a Mars Rover

Engineers built Curiosity and its spacecraft in a clean room at NASA's Jet Propulsion Laboratory (JPL) in Pasadena, California. A clean room has vents to send in clean air and extract particles of dust, skin, hair, chemical vapors, aerosols, and airborne organisms, protecting the spacecraft, the rover, and its science instruments. When in a clean room, engineers dress in "bunny suits" (hoods, coveralls, boots, and gloves) to minimize adding particles and bacteria to this environment. The eyes are the only part of the body that is not covered. Engineers built Curiosity in a "Class 10,000" clean room. That means that in every cubic foot (about 28 liters) of air, no more than 10,000 particles at one-half a micron (one half-millionth of a meter) or larger, and no more than 63 particles at five microns or larger, are present. That may sound like a lot of particles, but they are incredibly minute, and the particle counts are much less than for outside air. For example, one strand of human hair measures about 100 microns.

Rigorous Rover Testing

At every stage of assembly, engineers tested the spacecraft and rover, and their many parts. Not only does each part have to perform correctly, they all have to work together as designed. Some of the key systems tested include the rover's mobility system and its robotic arm, both critical to the rover's mission goals. For mobility, engineers ran the rover's six-wheel suspension system through obstacle courses and a series of drop tests to ensure its safe landing. Engineers also made sure to fine-tune the motions of Curiosity's long arm so it can be guided exactly where the mission team wishes it to go. While the arm is strong, it needs to be able to move accurately enough to drop an aspirin tablet into a thimble.

Prior to launch, engineers also go through a testing process fondly known as "shake and bake." Taking place in the 25-foot (8-meter) Space Simulator at JPL, this process ensures that the spacecraft, rover, and its instruments can withstand the intense vibrations and heat of launch, as well as the ultra-cold, high-vacuum and strong radiation exposure it will experience during the interplanetary cruise from Earth to Mars.

Transporting Curiosity to Florida

After months of building and testing the Curiosity rover, the team disassembled the rover and its cruise stage and carefully packed both for a cross-country trip from the rover's birthplace in California to its final Earth-bound destination, Cape Canaveral, Florida.

The large spacecraft components required two trips. An Air Force C-17 transport plane carried the spacecraft components on two flights, which began at March Air Reserve Base in Riverside, California. The rover's aeroshell (the protective covering made up of the back shell and heat shield, built by Lockheed Martin), required for entry and descent through Mars' atmosphere, and the cruise stage that carried the rover to Mars arrived at NASA's Kennedy Space Center first. On the second trip, the rover was accompanied by the rocket-powered descent stage that flew Curiosity in the final moments before touchdown on Mars.

Pre-launch Testing at Kennedy Space Center

Although arrival in Florida was a significant milestone for the mission, engineers still had considerable work to do to prepare Curiosity for launch. A team of engineers and technicians spent countless hours in the Payload Hazardous Servicing Facility clean room at NASA's Kennedy Space Center, reassembling the spacecraft and conducting even more tests.

While engineers readied Curiosity and its spacecraft components for launch, United Launch Alliance personnel at Kennedy Space Center also worked to get Curiosity's launcher, the Atlas V-541 rocket, ready for liftoff.

Curiosity successfully launched on Nov. 26, 2011, from Cape Canaveral, Florida, on an Atlas V-541.

More Information

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1 Connecting Curiosity's heat shield and back shell.

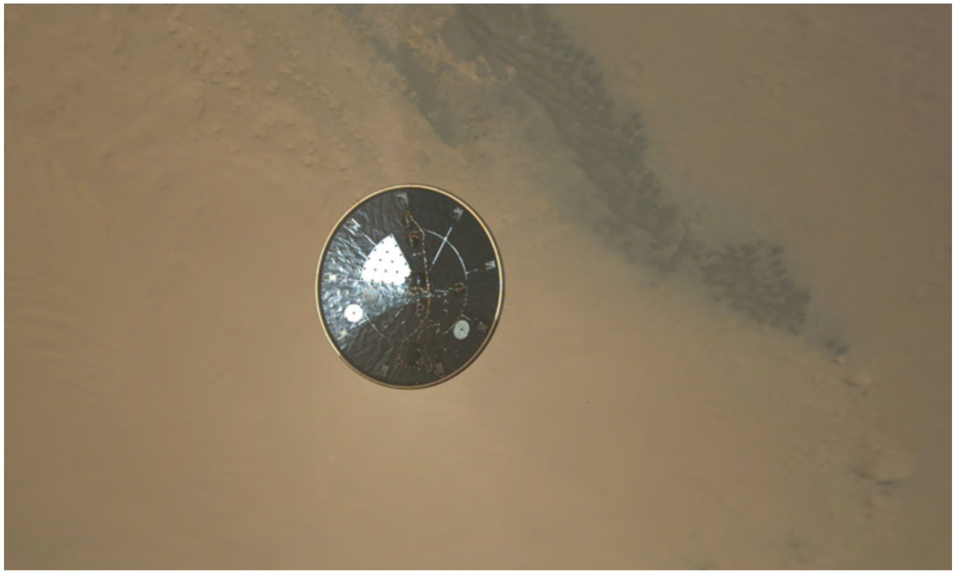
2 Ramp drive test of Curiosity's rocker bogie suspension system used to drive over uneven ground.

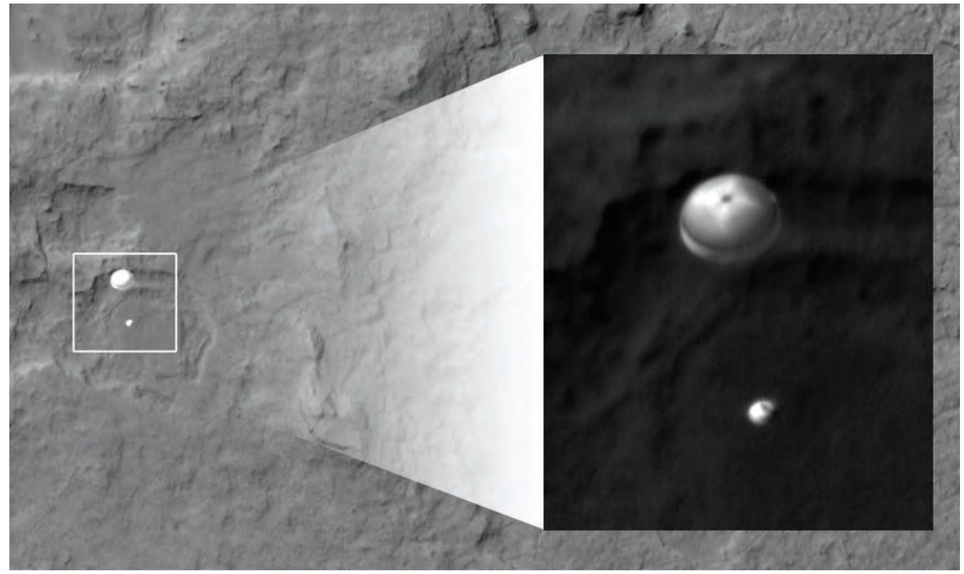
3 Mars rover Curiosity flexing its robotic arm.

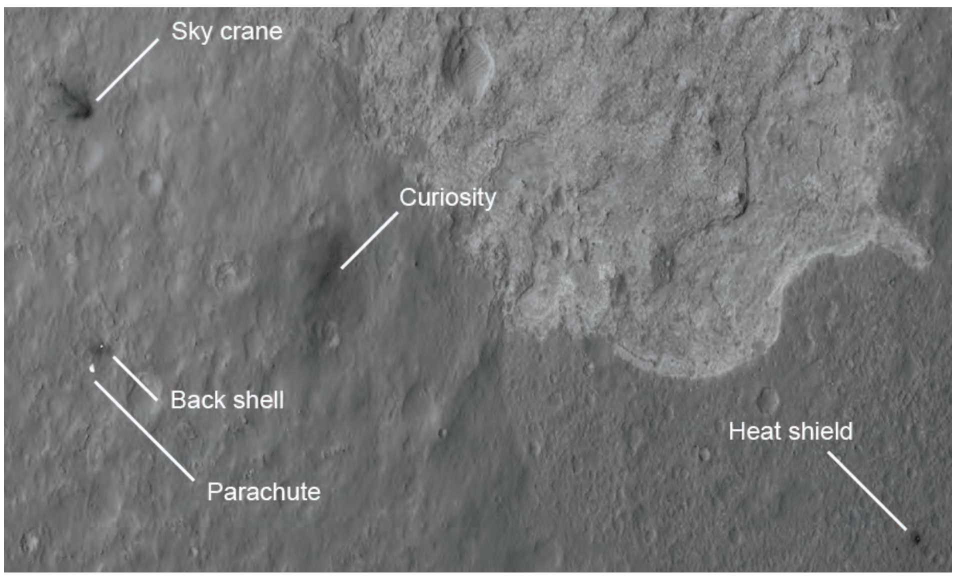
4 The Curiosity rover, turning in place.

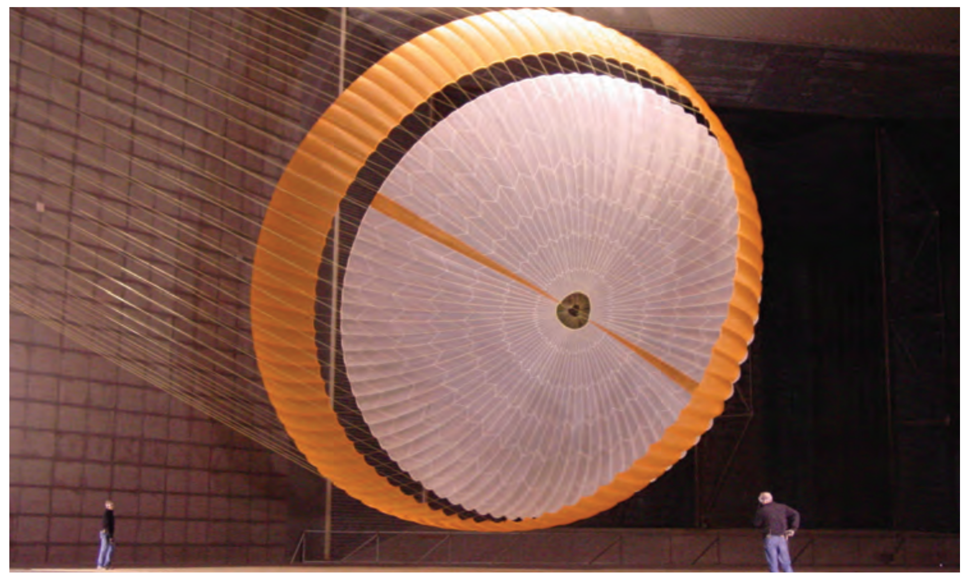
Credit: NASA/JPL-Caltech

National Aeronautics and Space Administration









NASA's Mars Rover Curiosity: Pioneering New Landing Technologies

www.nasa.gov

Curiosity's Mission: Was Mars Ever Habitable?

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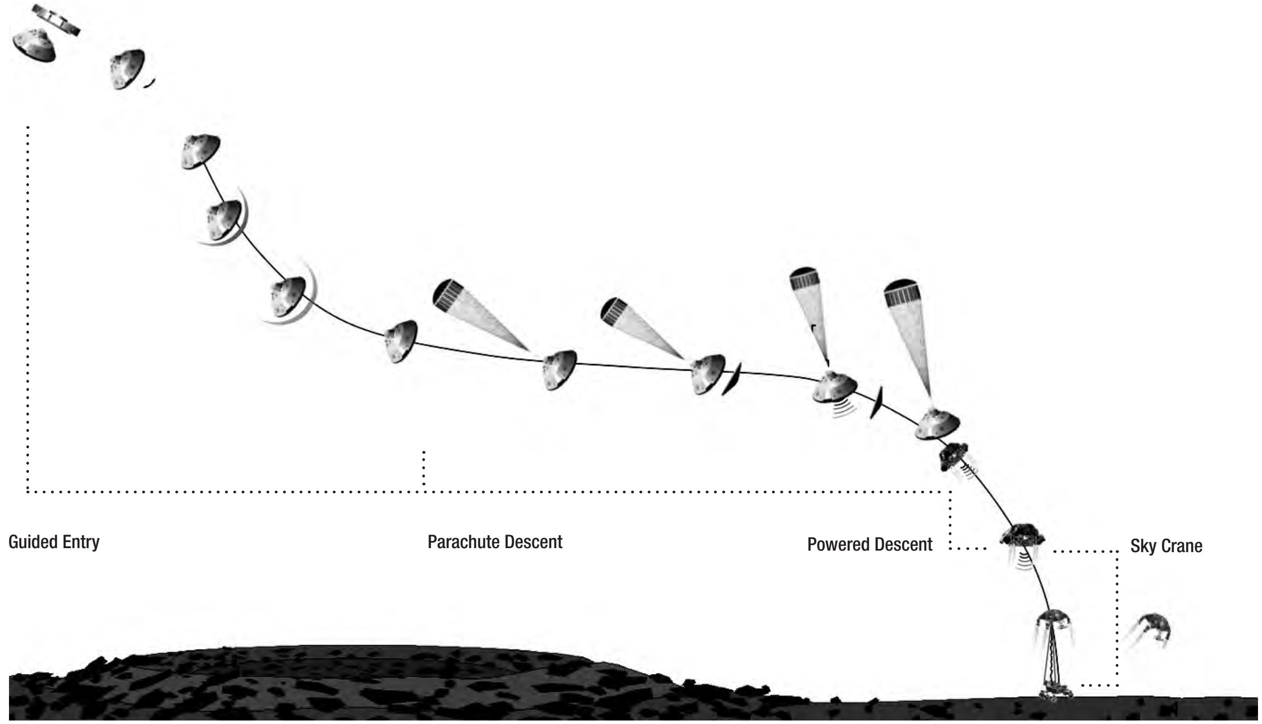
Seven Minutes of Terror

One of the most hair-raising and nail-biting parts of the mission after launch was Curiosity's landing, known to the mission team as "Seven Minutes of Terror." Curiosity descended from the top of the Martian atmosphere to the surface of Mars. Hundreds of things had to go right, with precise timing. The friction of the atmosphere slowed the spacecraft from 13,000 mph (about 21,000 kph) to about 900 mph (about 1,450 kph). The vehicle's heat shield reached 3,000 degrees Fahrenheit (1,648 degrees Celsius). The supersonic parachute slowed down the spacecraft from about 900 mph to 180 mph (about 1,450 kph to about 290 kph), the speed of a Formula One race car! While slowing down on its parachute, the heat shield popped off and Curiosity got its first view of Mars. The rover began taking video-quality pictures of its remaining 5-mile (8-kilometer) flight to the ground. The engines of the descent stage roared to life and lowered the rover the last mile to the surface. As it descended, the rover used radar to measure its speed and altitude to land safely. The descent stage lowered the rover on three nylon ropes to the surface before cutting the ropes and flying away. Curiosity landed safely in Gale Crater, slightly south of the equator of Mars and only 1.5 miles (2.4 kilometers) from the center of its landing ellipse, on Aug. 6, 2012 (UTC).

Pioneering New Landing Technologies

Given the rover's large size, engineers had to design a new guided entry, descent, and landing (EDL) system that would sufficiently slow it down in Mars' thin atmosphere. This mission is the first to use this precision landing technique. Successfully demonstrated, this system paves the way for advanced heavy payloads in future Mars missions and for landing in thousands of sites rather than a handful. Stunning video-quality images during descent could be used on future missions to detect and avoid rocks or other obstacles during landing.



Curiosity's new landing system had four phases:

Guided Entry — The aeroshell measured its deceleration and performed a set of banked turns that adjusted its altitude and distance to the landing site. This process improved landing accuracy from hundreds of miles to about 12 miles (20 kilometers). This control meant that no matter where the rover landed, it would land on safe terrain and be within driving range of the rocks and minerals targeted by the science team.

Parachute Descent — Upon nearing the landing site, a 70-foot-diameter (21-meter-diameter) parachute deployed and slowed the spacecraft further.

Powered Descent — Just a mile above the surface, the rover dropped out of the back shell and parachute, attached to a rocket "jet pack." Rockets controlled the spacecraft as it responded to measurements of distance from the surface.

Sky Crane — In the "sky crane" maneuver, a jet pack lowered the two-ton rover 27 feet (8 meters) down to the surface on three nylon ropes. The rover touched down directly on its wheels — a feat never before attempted on Mars.

More Information

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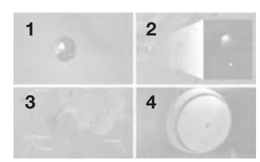


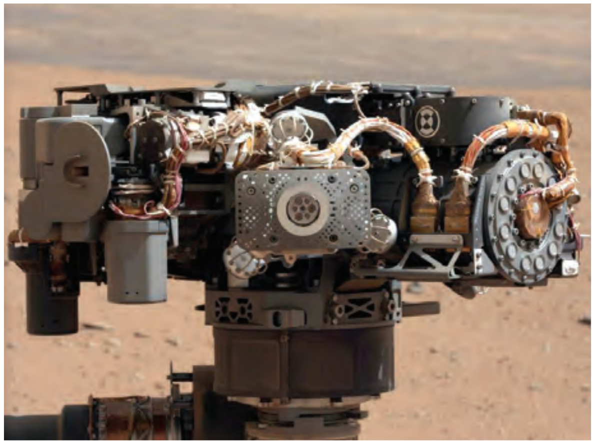
1 Curiosity snaps a photo of its heat shield during descent.

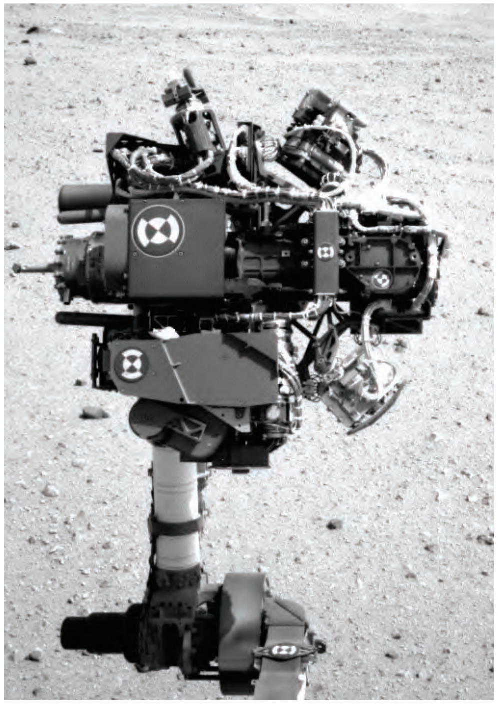
2 Mars Reconnaissance Orbiter catches the Curiosity rover and parachute during descent.

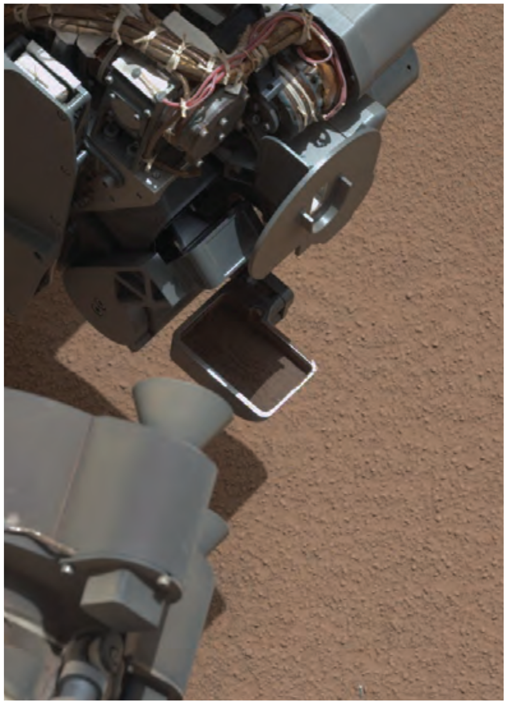
3 This picture shows the four main pieces of hardware to land Curiosity on Mars.

4 Testing the parachute in the world's largest wind tunnel.

Credits: NASA/JPL-Caltech/UofA (1-3); NASA/JPL-Caltech/Pioneer Aerospace (4)







NASA's Mars Rover Curiosity and Its Robotic Arm

Curiosity’s Mission: Was Mars Ever Habitable?

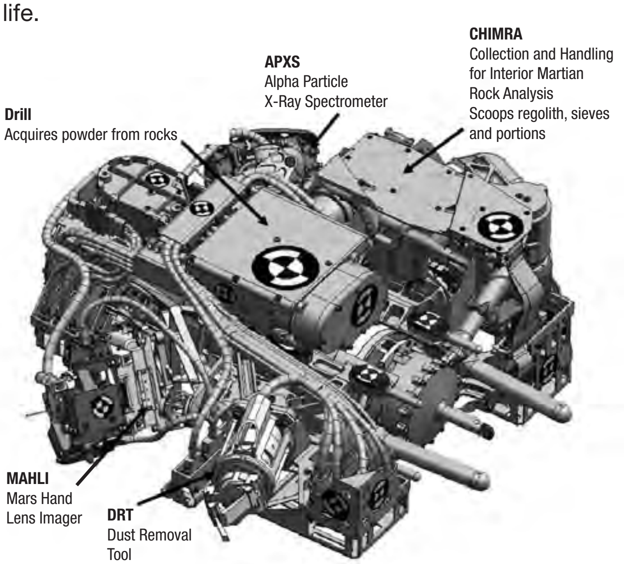
Part of NASA’s Mars Science Laboratory mission, Curiosity is the largest and most capable rover ever sent to Mars. Curiosity’s mission is to answer the question: did Mars ever have the right environmental conditions to support small life forms called microbes?

Curiosity’s Robotic Arm

Curiosity’s 7-foot (2.1-meter) arm holds and moves tools to help scientists get up-close and personal with Martian rocks and soil. Curiosity’s arm has a shoulder, elbow, and wrist for maximum flexibility. Its main job is to bend and stretch to deliver instruments on its “hand” for close-up study of rocks and other targets. It can angle tools precisely against a rock to work as a human geologist would, brushing away dust, taking microscopic images and analyzing the elemental composition of the rocks and soil.

Curiosity’s “Hand”

The “hand” at the end of Curiosity’s arm is called a turret. The turret carries a drill, a brush to remove dust, a soil scoop, and two important science tools to understand if Mars ever had habitable conditions for microbial life.



Elemental Chemistry Tool

One science tool on Curiosity’s turret, the Alpha Particle X-Ray Spectrometer (APXS), helps identify chemical elements in rocks and soil and how much of each is present. Identifying the elemental composition of lighter elements (sodium, magnesium, or aluminum) and heavier elements (iron, nickel, or zinc) helps scientists identify the main materials in the Martian crust. This information is used to select rock and soil samples, characterize the composition of rocks after brushing off the dust, determine how the material formed long ago, and whether it was altered by wind, water, or ice. All previous rovers have carried a tool like this one.

“Magnifying Glass” Arm Camera

Curiosity has a magnifying lens camera that allows it to image very fine detail in soil and rocks. Much like a geologist’s hand lens, this camera, the Mars Hand Lens Imager (MAHLI), provides close-up views of minerals, textures, and structures in Martian rocks at scales smaller than the width of a human hair. That information will help us understand if any rocks formed in water. Water is necessary to life as we know it, so finding rocks with a connection to water helps scientists select which ones to study further. With other rover instruments, ultimately the science team hopes to find rocks and minerals that formed under habitable conditions and may contain signs of organics, the chemical building blocks of life.

The magnifying lens camera also has a long-distance focus for imaging hard-to-reach objects more than an arm’s length away, and for providing views of the overall terrain around the rover. With two white LED lights, it can take pictures at night, and with ultraviolet LEDs, can look for minerals that fluoresce. It can also send high-definition video back to Earth and even be used to take rover self-portraits, helpful for monitoring the rover for engineering purposes.

Scoop and Sieve

Curiosity has a clamshell-shaped scoop to collect samples from the Martian surface. This tool, known as the Collection and Handling for Interior Martian Rock Analysis (CHIMRA), has a system of chambers and labyrinths used to sort, sift, and portion samples.

Curiosity sorts samples by flexing the wrist joint on its arm to position the turret, while using a vibration device to move material through the chambers, passages, and sieves. The vibration device also creates the right portion size for dropping material into the inlet ports on the rover deck for rock-analyzing instruments (SAM and CheMin) inside the rover’s body.

More Information

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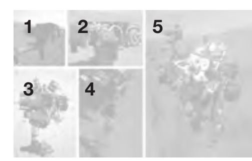

1 Curiosity’s robotic arm.

2 Portrait of Curiosity’s chemistry tool (APXS) on the robotic arm.

3 Curiosity’s turret “hand” at the end of the robotic arm.

4 View of Curiosity’s first scoop.

5 Self-portrait of Curiosity taken by the arm camera, MAHLI.

Credits: NASA/JPL-Caltech (1,3); NASA/JPL-Caltech/MSSS (2,4,5)

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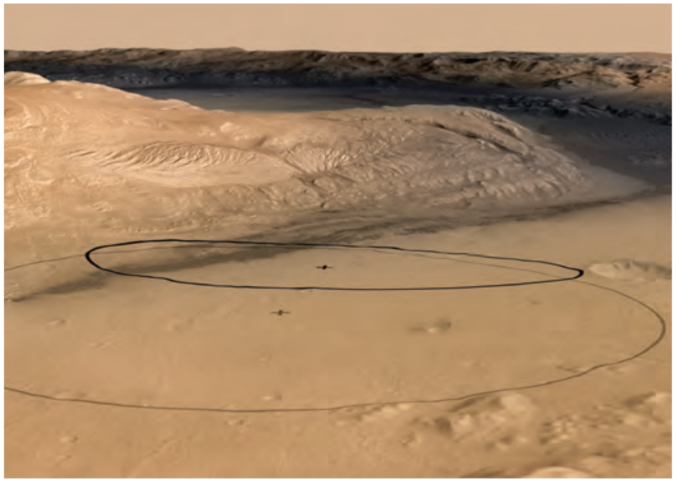

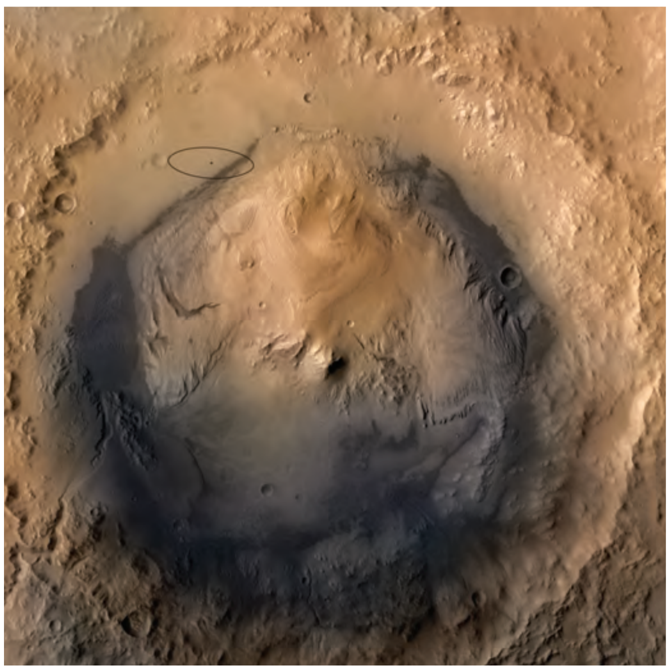

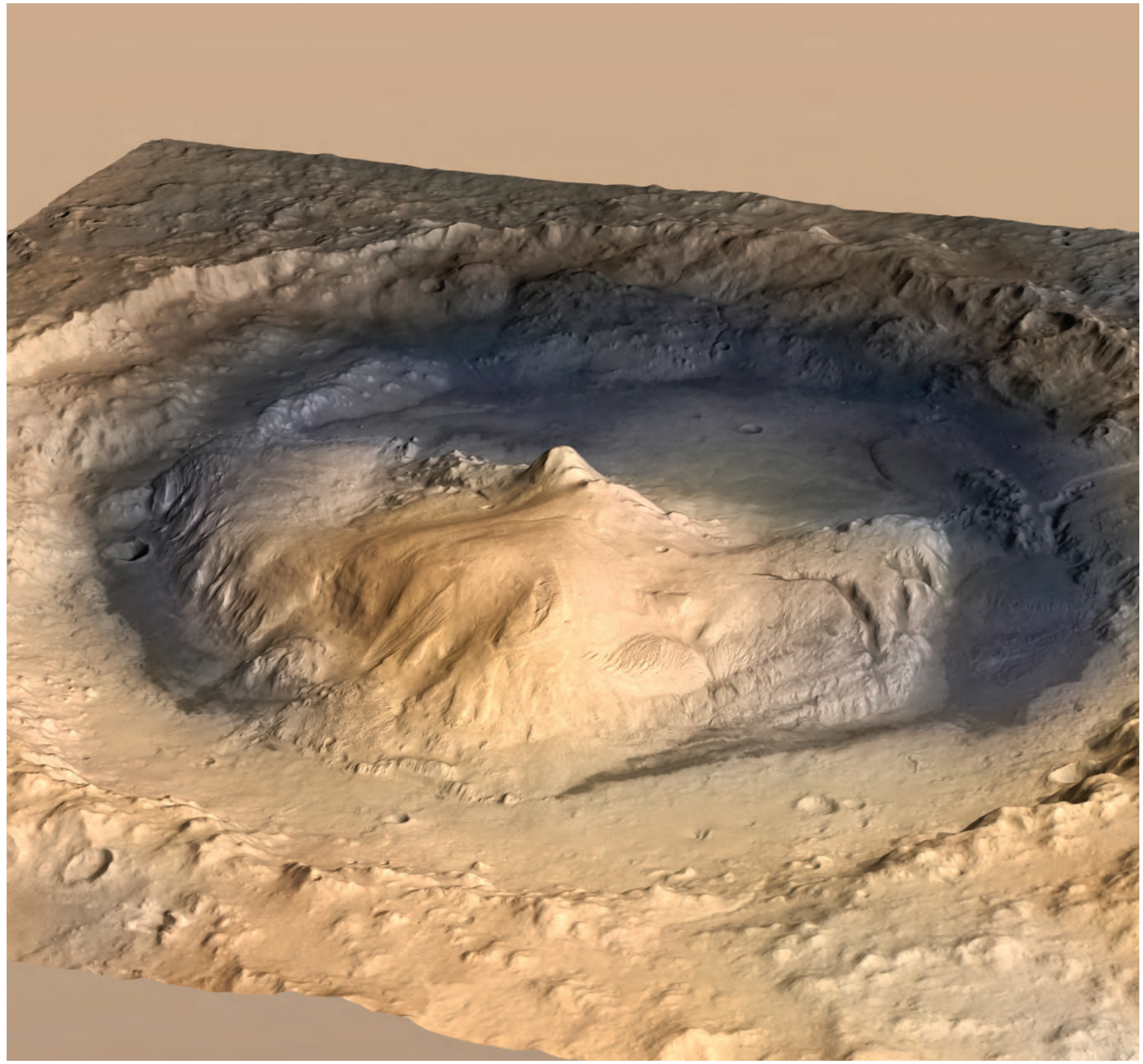

Curiosity’s Landing Site — Gale Crater

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Curiosity's Mission: Was Mars Ever Habitable?

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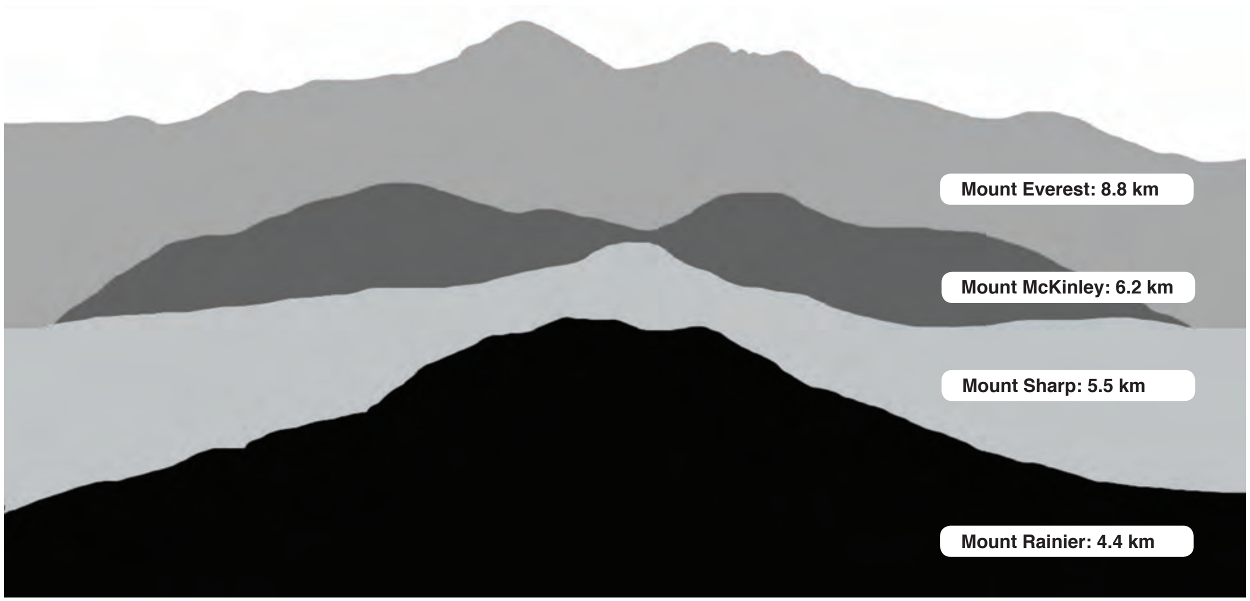
The Curiosity rover landed at the base of a 3-mile-high (5-kilometer-high) mountain inside Gale Crater. NASA selected Gale Crater in part because instruments on Mars orbiters previously found signs of special clay minerals that form in the presence of water under different conditions.

Gale Crater shows many signs that water was present over its history. Water is a key ingredient for life as we know it. Minerals called clays and sulfates, which are by-products of water-related processes, are present at Gale Crater and have been seen by orbiters flying overhead. Some of these clay minerals near Curiosity's landing ellipse may preserve organic compounds, the chemical building blocks of life. The history of water at Gale Crater, as recorded in its rocks, will give Curiosity lots of clues to study as it pieces together whether Mars ever could have been a habitat for microbial life.



Gale Crater Overview

Gale is a huge crater, about 96 miles (154 kilometers) across. You could almost fit the states of Connecticut and Rhode Island inside of Gale Crater! Gale is just south of the Martian equator, in the Aeolis region (latitude: 4.5 degrees south; longitude: 137.4 degrees east). Gale Crater sits at a low elevation relative to most of the surface of Mars, suggesting that if Mars ever had much flowing water, some of it would have pooled inside Gale.

In the middle of Gale Crater is a mound, informally named Mount Sharp, rising about 3 miles (5 kilometers) above the crater floor, which is higher than Mount Rainier rises above Seattle. The slopes of Mount Sharp are gentle enough for Curiosity to climb, though during the prime mission of one Martian year (98 weeks), Curiosity will probably not go beyond the intriguing layers near the base that are likely made of clays called phyllosilicates. These clays are known to preserve signs of organics, the chemical building blocks of life.

Mount Sharp

Mount Sharp has thousands of individually stacked layers of rock and dust. The mound is more than twice as thick as the stack of rocks exposed in the Grand Canyon. The sedimentary rock layers that make up Mount Sharp suggest that they were laid down over long periods of geologic time after the impact that created Gale Crater. Each layer preserves a sliver of the Martian past. These layers may record a time period going back more than 3 billion years! They may have formed from water flowing into the crater, debris blown in by the wind, volcanic ash falling from the sky, or remnants of a lake that dried up and left the sediments. Or, all of the above! The changes in rocky material from the lower (older) layers to the upper (younger) layers in the mound may contain the story of when and why Mars lost much of its liquid water.

Curiosity's highest priority is to head for the mound and sample each layer as it goes up. It may take Curiosity up to a year to get to the crater mound from its landing site.

More Information

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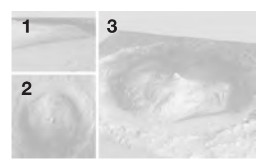
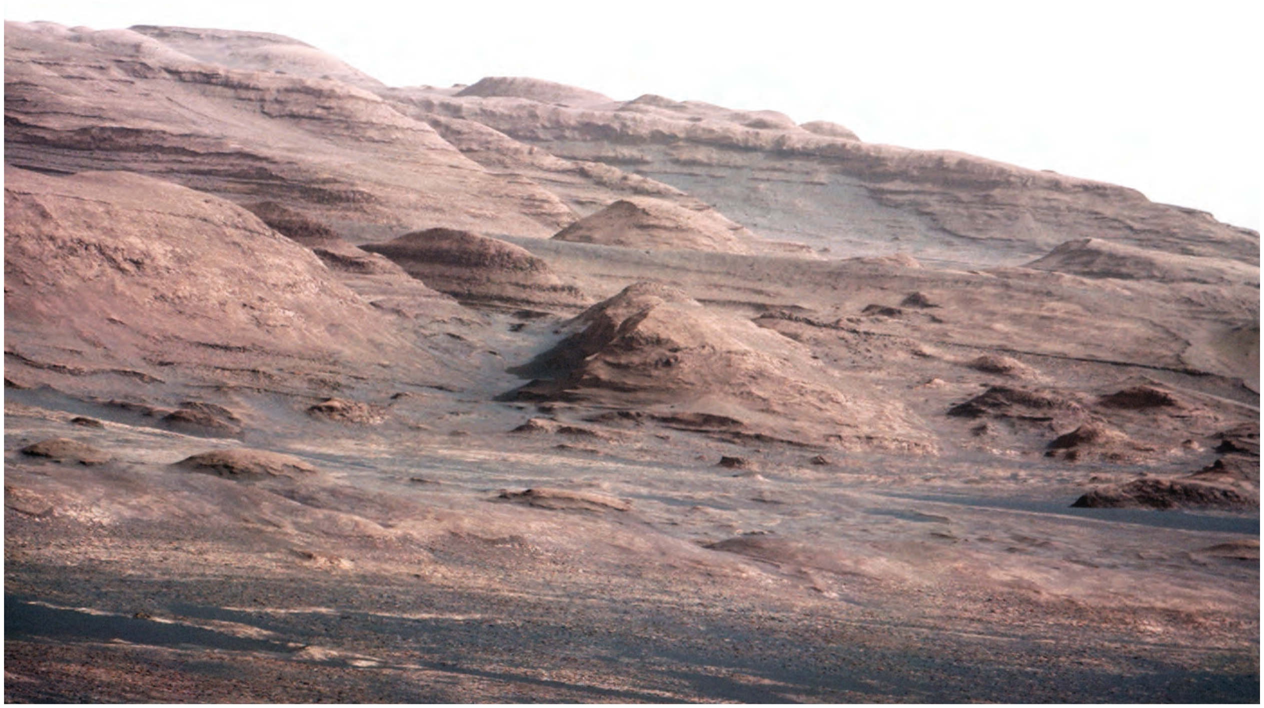


1 Curiosity's landing ellipse within Gale Crater.
2 Curiosity's landing site, Gale Crater.
3 Oblique view of Gale Crater.

Credit: NASA/JPL-Caltech/ESA/DLR/FU Berlin/MSSS



Looking for Habitable Environments

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What conditions does life need?

If all three of the following conditions exist in the same place, the possibility of Mars as a place for life (a habitat) is much greater.

1. Molecules that contain carbon — Most scientists assume that if life exists beyond Earth, it would probably be carbon-based. That's because life on Earth is made of molecules that contain carbon. Carbon atoms bond easily with other carbon atoms, allowing them to make a lot of the complex molecules life needs (proteins, nucleic acids, fats, and carbohydrates). These molecules are called "organics," the chemical building blocks of life.

However, it's hard to find organics, which break down easily when exposed to heat, sunlight, and oxidants. Examples of oxidants are the iron oxides (rust) in rocks that give Mars its reddish color. The environment on Mars is harsh on organics. With a very thin atmosphere and no global magnetic field, Mars has no protection from intense ultraviolet radiation and cosmic rays from space. Created by this radiation, superoxides on the Martian surface would break down organic molecules rapidly and are toxic to life. Rocks exposed to radiation for a long time on the surface of Mars cannot preserve organics. Buried rocks, rock interiors, would help shield any organics.

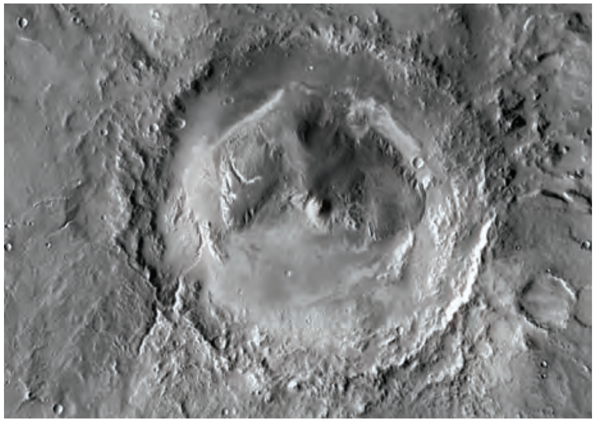
One of the best places to look for organics is in sediment that settled at the bottom of a standing body of water long ago. When microbes (or plants and animals on Earth) die in wet mud or fall to the bottom of a lake or sea, the next layer of sediment covers them. Together, the microbes and sediments compress into rock over time. When microbes are rapidly trapped, chances are greater they will be preserved. Low temperatures like those on Mars can help preserve traces of them. Sedimentary rocks, such as clays and sulfates, are especially good at protecting organics from oxidation and preserving them. NASA selected Gale Crater as Curiosity's landing site because Mars orbiters detected signs of both minerals in the layers of Mount Sharp in the middle of the crater.

2. Water in liquid form — What life on Earth has in common is a dependence on liquid water, which allows carbon atoms to combine into complex organic molecules. Although the Martian atmosphere is too thin for water to persist on the surface today, prior Mars missions found landforms likely shaped by water earlier in Martian history, subsurface water-ice, and traces of water bound in the mineral structure of rocks at or near the surface of Mars. The rocks Curiosity will study hold the preserved evidence of the watery conditions that formed them. Some rocks are formed by flowing water, while others are formed by sediment settling to the bottom of a still lake or sea.

Right away, Curiosity found rounded pebbles and conglomerate rocks that form in flowing water. Scientists believe that a knee-to-hip-high stream once ran by the rover's landing site. Scientists especially want to study special rocks that form in water that is "just right" for most life forms: not too acidic and not too alkaline. These rocks could include mineral clays called phyllosilicates and sulfates, which can form in hydrothermal areas like those at Yellowstone National Park and often preserve organics. When Curiosity studies clay and sulfate layers in Mount Sharp, they may indicate relatively when and how long habitable environments lasted. Carbonate, silica, and other crystalline minerals can preserve biosignatures, or fragments of organic molecules.

3. A source of energy such as heat, sunlight, or food — Energy for life can come from solar radiation, heat, or chemical reactions. It is possible that any microbes on Mars process chemicals such as hydrogen or perchlorate as "food." Perchlorate exists in Martian soil as a potential energy source for microbes. As a salt, it acts as an anti-freeze, lowering the freezing point of water substantially, making liquid water possible during warmer periods on Mars.

If Curiosity detects these three conditions, the possibility of Gale as a habitat may be greater.



More Information

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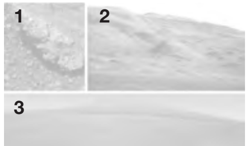
The Jet Propulsion Laboratory, a division of the California Institute of Technology, manages the Mars Science Laboratory mission for NASA's Science Mission Directorate.



1 Conglomerate rock outcrop and rounded pebbles as seen by Curiosity.

2 Layers at the base of Mount Sharp.

3 Curiosity's view of Mount Sharp.

Credit: NASA/JPL-Caltech/MSSS