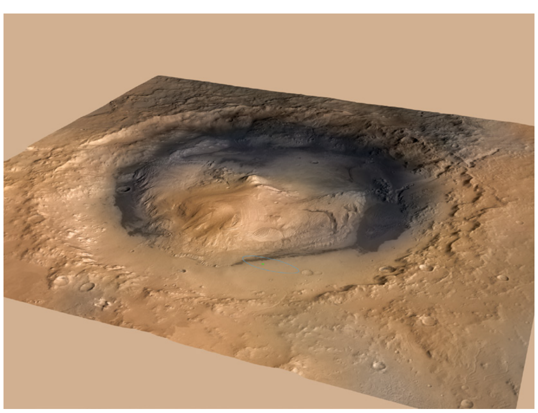
National Aeronautics and Space Administration

NASA facts

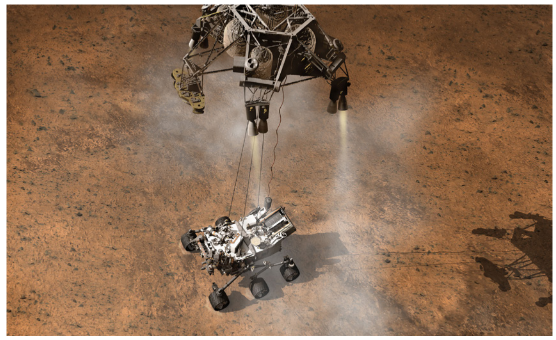
Mars Science Laboratory/Curiosity

NASA's Mars Science Laboratory mission set down a large, mobile laboratory — the rover Curiosity — at Gale Crater, using precision landing technology that made one of Mars' most intriguing regions a viable destination for the first time. Within the first eight months of a 23-month primary mission, Curiosity met its major objective of finding evidence of a past environment well suited to supporting microbial life. The rover studies the geology and environment of selected areas in the crater and analyzes samples drilled from rocks or scooped from the ground.

Curiosity carries the most advanced payload of scientific gear ever used on Mars' surface, a payload more than 10 times as massive as those of earlier Mars rovers. Its assignment: Investigate whether conditions have been favorable for microbial life and for preserving clues in the rocks about possible past life. More than 400 scientists from around the world participate in the science operations.



The rover's landing site, Gale Crater, is about the size of Connecticut and Rhode Island combined.



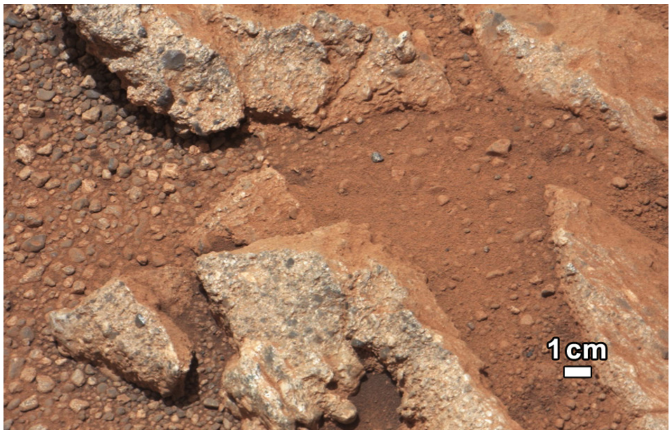
Curiosity touches down on Mars after being lowered by its Sky Crane.

Mission Overview

The Mars Science Laboratory spacecraft launched from Cape Canaveral Air Force Station, Florida, on Nov. 26, 2011. Mars rover Curiosity landed successfully on the floor of Gale Crater on Aug. 6, 2012 Universal Time (evening of Aug. 5, Pacific Time), at 4.6 degrees south latitude, 137.4 degrees east longitude and minus 4,501 meters (2.8 miles) elevation.

Engineers designed the spacecraft to steer itself during descent through Mars' atmosphere with a series of S-curve maneuvers similar to those used by astronauts piloting NASA space shuttles. During the three minutes before touchdown, the spacecraft slowed its descent with a parachute, then used retrorockets mounted around the rim of its upper stage. In the final seconds, the upper stage acted as a sky crane, lowering the upright rover on a tether to land on its wheels.

The touchdown site, Bradbury Landing, is near the foot of a layered mountain, Aeolis Mons ("Mount Sharp"). Selection of Gale Crater fol-



A rock outcrop called Link shows signs of being formed by the deposition of water.

lowed consideration of more than 30 Martian locations by more than 100 scientists participating in a series of open workshops. The selection process benefited from examining candidate sites with NASA's Mars Reconnaissance Orbiter and earlier orbiters, and from the rover mission's capability of landing within a target area only about 20 kilometers (12 miles) long. That precision, about a five-fold improvement on earlier Mars landings, made sites eligible that would otherwise be excluded for encompassing nearby unsuitable terrain. The Gale Crater landing site is so close to the crater wall and Mount Sharp that it would not have been considered safe if the mission were not using this improved precision.

Science findings began months before landing. Measurements that Curiosity made of natural radiation levels during the flight from Earth to Mars will help NASA design for astronaut safety on future human missions to Mars.

In the first few weeks after landing, images from the rover showed that Curiosity touched down right in an area where water once coursed vigorously over the surface. The evidence for stream flow was in rounded pebbles mixed with hardened sand in conglomerate rocks at and near the landing site. Analysis of Mars' atmospheric composition early in the mission provided evidence that the planet has lost much of its original atmosphere by a process favoring loss from the top of the atmosphere rather than interaction with the surface.

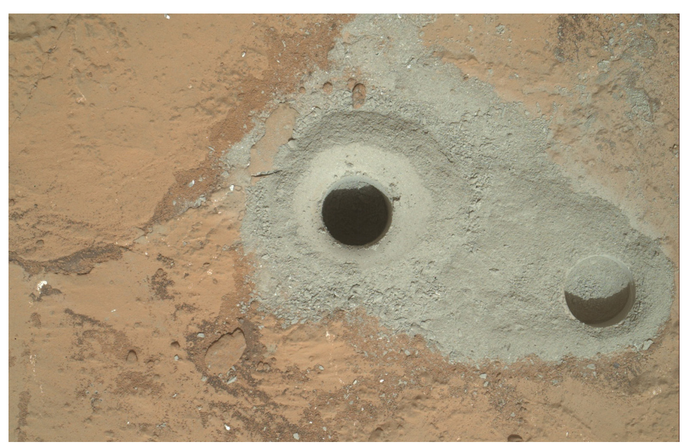
In the initial months of the surface mission, the rover team drove Curiosity eastward toward "Yellowknife Bay" to investigate an ancient river and fan system identified in orbital images.

The rover analyzed its first scoops of soil on the way to Yellowknife Bay. Once there, it collected the first samples of material ever drilled from rocks on Mars. Analysis of the first drilled sample, from a rock target called "John Klein," provided the evidence of conditions favorable for life in Mars' early history: geological and mineralogical evidence for sustained liquid water, other key elemental ingredients for life, a chemical energy source, and water not too acidic or too salty. On a subsequent drill sample, Curiosity was able to accomplish a first for measurements on another planet: determining the age of the rock. The measurements showed that the drilled material was 4.2 billion years old and yet had been exposed at the surface for only 80 million years.

In July 2013, Curiosity finished investigations in the Yellowknife Bay area and began a southwestward trek to the base of Mount Sharp. It reached the base layer of this main destination in September 2014. In the low layers of Mount Sharp during the rover's extended mission, researchers anticipate finding further evidence about habitable past environments and about the evolution of the Martian environment from a wetter past to a drier present.

Big Rover

Curiosity is about twice as long (about 3 meters or 10 feet) and five times as heavy as NASA's twin Mars Exploration Rovers, Spirit and Opportunity, launched in 2003. It inherited many design elements from them, including six-wheel



Curiosity's first sample drilling, at a rock called "John Klein."

A self-portrait of Curiosity, built up from pictures taken by its Mars Hand Lens Imager.

drive, a rocker-bogie suspension system, and cameras mounted on a mast to help the mission's team on Earth select exploration targets and driving routes. Unlike earlier rovers, Curiosity carries equipment to gather and process samples of rocks and soil, distributing them to onboard test chambers inside analytical instruments.

NASA's Jet Propulsion Laboratory (JPL), Pasadena, Calif., builder of the Mars Science Laboratory, engineered Curiosity to roll over obstacles up to 65 centimeters (25 inches) high and to travel up to about 200 meters (660 feet) per day on Martian terrain.

The rover's electrical power is supplied by a U.S. Department of Energy radioisotope power generator. The multi-mission radioisotope thermoelectric generator produces electricity from the heat of plutonium-238's radioactive decay. This long-lived power supply gives the mission an operating lifespan on Mars' surface of a full Mars year (687 Earth days) or more. At launch, the generator provided about 110 watts of electrical power to operate the rover's instruments, robotic arm, wheels, computers and radio. Warm fluids heated by the generator's excess heat are plumbed throughout the rover to keep electronics and other systems at acceptable operating temperatures. Although the total power from the generator will decline over the course of the mission, it was still providing more than 100 watts two years after landing.

The mission uses radio relays via Mars orbiters as the principal means of communication between Curiosity and the Deep Space Network's antennas on Earth. In the first two years after Curiosity's landing, the orbiters downlinked 48 gigabytes of data from Curiosity.

Science Payload

In April 2004, NASA solicited proposals for specific instruments and investigations to be carried by Mars Science Laboratory. The agency selected eight of the proposals later that year and also reached agreements with Russia and Spain to carry instruments those nations provided.

A suite of instruments named **Sample Analysis at Mars** analyzes samples of material collected and delivered by the rover's arm, plus atmospheric samples. It includes a gas chromatograph, a mass spectrometer and a tunable laser spectrometer with combined capabilities to identify a wide range of carbon-containing compounds and determine the ratios of different isotopes of key elements. Isotope ratios are clues to understanding the history of Mars' atmosphere and water. The principal investigator is Paul Mahaffy of NASA's Goddard Space Flight Center, Greenbelt, Md.

An X-ray diffraction and fluorescence instrument called **CheMin** also examines samples gathered by the robotic arm. It is designed to identify and quantify the minerals in rocks and soils, and to measure bulk composition. The principal investigator is David Blake of NASA's Ames Research Center, Moffett Field, Calif.

Mounted on the arm, the **Mars Hand Lens Imager** takes extreme close-up pictures of rocks and soil, revealing details smaller than the width of a human hair. It can also focus on hard-to-reach objects more than an arm's length away and has taken images assembled into dramatic self-portraits of Curiosity. The principal investiga- tor is Kenneth Edgett of Malin Space Science Systems, San Diego.

Also on the arm, the **Alpha Particle X-ray Spectrometer** determines the relative abundances of different elements in rocks and soils. Dr. Ralf Gellert of the University of Guelph, Ontario, Canada, is principal investigator for this instrument, which was provided by the Canadian Space Agency.

The **Mast Camera**, mounted at about human-eye height, images the rover's surroundings in high-resolution stereo and color, with the capability to take and store high-definition video sequences. It can also be used for viewing materials collected or treated by the arm. The principal investigator is Michael Malin of Malin Space Science Systems.

An instrument named **ChemCam** uses laser pulses to vaporize thin layers of material from Martian rocks or soil targets up to 7 meters (23 feet) away. It includes both a spectrometer to identify the types of atoms excited by the beam, and a telescope to capture detailed images of the area illuminated by the beam. The laser and telescope sit on the rover's mast. Chemcam also serves as a passive spectrometer to measure composition of the surface and atmosphere. Roger Wiens of Los Alamos National Laboratory, Los Alamos, N.M., is the principal investigator.

The rover's **Radiation Assessment Detector** characterizes the radiation environment at the surface of Mars. This information is necessary for planning human exploration of Mars and is relevant to assessing the planet's ability to harbor life. The principal investigator is Donald Hassler of Southwest Research Institute, Boulder, Colo.

In the two minutes before landing, the **Mars Descent Imager** captured color, high-definition video of the landing region to provide geological context for the investigations on the ground and to aid precise determination of the landing site. Pointed toward the ground, it can also be used for surface imaging as the rover explores. Michael Malin is principal investigator.

Spain's Ministry of Education and Science provided the **Rover Environmental Monitoring Station** to measure atmospheric pressure, temperature, humidity, winds, plus ultraviolet radiation levels. The principal investigator is Javier Gómez-Elvira of the Center for Astrobiology, Madrid, an international partner of the NASA Astrobiology Institute.

Russia's Federal Space Agency provided the **Dynamic Albedo of Neutrons** instrument to measure subsurface hydrogen up to 1 meter (3 feet) below the surface. Detections of hydrogen may indicate the presence of water bound in minerals. Igor Mitrofanov of the Space Research Institute, Moscow, is the principal investigator.

In addition to the science payload, equipment of the rover's engineering infrastructure contributes to scientific observations. Like the Mars Exploration Rovers, Curiosity has a stereo Navigation Camera on its mast and low-slung, stereo Hazard-Avoidance cameras. The wide view of the Navigation Camera is also used to aid targeting of other instruments and to survey the sky for clouds and dust. Equipment called the Sample Acquisition/Sample Preparation and Handling System includes tools to remove dust from rock surfaces, scoop up soil, drill into rocks to collect powdered samples from rocks' interiors, sort samples by particle size with sieves, and deliver samples to laboratory instruments.

The Mars Science Laboratory Entry, Descent and Landing Instrument Suite is a set of engineering sensors that measured atmospheric conditions and performance of the spacecraft during the arrival-day plunge through the atmosphere, to aid in design of future missions.

Program/Project Management

The Mars Science Laboratory is managed for NASA's Science Mission Directorate, Washington, D.C., by JPL, a division of the California Institute of Technology in Pasadena. At NASA Headquarters, David Lavery is the Mars Science Laboratory program executive and Michael Meyer is program scientist. In Pasadena, Jim Erickson of JPL is project manager, a role fulfilled earlier by JPL's Peter Theisinger and Richard Cook, and John Grotzinger of Caltech is project scientist.

National Aeronautics and Space Administration

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