The Mars Science Laboratory
“Curiosity” Rover

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Recent missions have discovered that Mars’ surface reveals a diverse and dynamic history, including evidence for sustained interactions with liquid water.

By studying a potentially habitable, ancient environment, MSL is a bridge to future missions that focus on life detection or returning samples.
Rover Family Portrait

Spirit and Opportunity
2003

Sojourner
1996

Curiosity
2011
Curiosity’s Capabilities

A Robotic Field Geologist
- Long life, ability to traverse many miles over rocky terrain
- Landscape and hand-lens imaging
- Ability to survey composition of bedrock and regolith

A Mobile Geochemical and Environmental Laboratory
- Ability to acquire and process dozens of rock and soil samples
- Instruments that analyze samples for chemistry, mineralogy, and organics
- Sensors to monitor water, weather, and natural high-energy radiation
Curiosity’s primary scientific goal is to explore and quantitatively assess a local region on Mars’ surface as a potential habitat for life, past or present.

Objectives include:

• Assessing the biological potential of the site by investigating any organic and inorganic compounds and the processes that might preserve them.

• Characterizing geology and geochemistry, including chemical, mineralogical, and isotopic composition, and geological processes.

• Investigating the role of water, atmospheric evolution, and modern weather/climate.

• Characterizing the spectrum of surface radiation.
My Role on MSL

- Work with science team to define and verify requirements for science instruments.
- Collaborate with instrument builders and rover team to develop and execute procedures for mechanical and electrical integration with the rover and functional testing of those instruments.
- After everything is integrated - What’s next?
  - Scenario/Day-in-the-life testing
  - Environmental Testing
    - Vibration
    - Electromagnetic Compatibility
    - Surface & Vacuum Thermal Testing
  - Preparation for Launch
  - Launch/Cruise/EDL
  - Operations on Mars!
Mission and Rover Overview
MSL Mission Overview

ENTRY, DESCENT, LANDING
- Guided entry and powered “sky crane” descent
- 20 × 25-km landing ellipse
- Access to landing sites ±30° latitude, <0 km elevation
- 900-kg rover

SURFACE MISSION
- Prime mission is one Mars year (687 days)
- Latitude-independent and long-lived power source
- Ability to drive out of landing ellipse
- 72 kg of science payload
- Direct (uplink) and relayed (downlink) communication
- Fast CPU and large data storage

CRUISE/APPROACH
- 8 to 9-month cruise
- Arrive August 6-20, 2012

LAUNCH
- Window is Nov. 25 to Dec. 18, 2011
- Atlas V (541)
Guided entry corrects for atmospheric variability and improves landing accuracy.

“Sky Crane” design places the rover directly on Martian soil while keeping the rockets away from the ground.
**MSL Science Payload**

**REMOTE SENSING**

- **Mastcam** (M. Malin, MSSS) - Color and telephoto imaging, video, atmospheric opacity
- **ChemCam** (R. Wiens, LANL/CNES) – Chemical composition; remote micro-imaging

**CONTACT INSTRUMENTS (ARM)**

- **MAHLI** (K. Edgett, MSSS) – Hand-lens color imaging
- **APXS** (R. Gellert, U. Guelph, Canada) - Chemical composition

**ANALYTICAL LABORATORY (ROVER BODY)**

- **SAM** (P. Mahaffy, GSFC/CNES) - Chemical and isotopic composition, including organics
- **CheMin** (D. Blake, ARC) - Mineralogy

**ENVIRONMENTAL CHARACTERIZATION**

- **MARDI** (M. Malin, MSSS) - Descent imaging
- **REMS** (J. Gómez-Elvira, CAB, Spain) - Meteorology / UV
- **RAD** (D. Hassler, SwRI) - High-energy radiation
- **DAN** (I. Mitrofanov, IKI, Russia) - Subsurface hydrogen

<table>
<thead>
<tr>
<th>Wheel Base</th>
<th>2.8 m</th>
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<tr>
<td>Height of Deck</td>
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<tr>
<td>Ground Clearance</td>
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<tr>
<td>Height of Mast</td>
<td>2.2 m</td>
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MSL Sampling System

- Cleans rock surfaces with a brush
- Places and holds the APXS and MAHLI instruments
- Acquires samples of rock or soil with a powdering drill or scoop
- Sieves the samples (to 150 μm or 1 mm) and delivers them to instruments or an observation tray
- Exchanges spare drill bits
1. **REMOTE SENSING**
- Landscape imaging
- Sampling of rock and soil chemistry

2. **TRAVERSE/APPROACH**
- Driving up to 100 m per sol
- Imaging and profiling chemistry along the drive
- Locating sampling targets

3. **CONTACT SCIENCE**
- Removal of surface dust
- Chemical and hand-lens observations of a specific target

4. **SAMPLE ACQUISITION/ANALYSIS**
- Drilling, processing, and delivering sample material to the rover’s lab instruments
- Analyzing for mineralogy, organics, elemental and isotopic chemistry

Each activity may require multiple sols. Results are reviewed on Earth before moving on to the next activity. Weather and radiation monitoring occur on all sols.
MSL Science Investigations
Alpha-Particle X-ray Spectrometer

Principal Investigator: Ralf Gellert
University of Guelph, Ontario, Canada
Canadian Space Agency

APXS determines the chemical composition of rocks, soils, and processed samples

- Combination of particle-induced X-ray emission and X-ray fluorescence using $^{244}$Cm sources
- Rock-forming elements from Na to Br and beyond
- Useful for lateral / vertical variability, surface alteration, detection of salt-forming elements
- Factor of $\sim$3 increased sensitivity; better daytime performance compared with MER
ChemCam

Principal Investigator: Roger Wiens
Los Alamos National Laboratory
L'Institut de Recherche en Astro. et Planétologies

ChemCam performs elemental analyses through laser-induced breakdown spectroscopy (LIBS)

- Rapid characterization of rocks and soils up to seven meters away
- Will identify and classify rocks, soils, pebbles, hydrated minerals, weathering layers, and ices
- Analysis spot size < 0.5 mm
- 240-850 nm spectral range
- Dust removal; depth profiling to > 0.5 mm
- High-resolution context imaging (resolves ~1 mm at 10 m)
Chemistry and Mineralogy (CheMin)

Principal Investigator: David Blake
NASA Ames Research Center

CheMin derives definitive mineralogy

- X-ray diffraction (XRD); standard technique for laboratory analysis

- Identification and quantification of minerals in geologic materials (e.g., basalts, evaporites, soils)

- Will assess role of water in formation, deposition, alteration

- Accuracy of ±15% in concentration for major mineral components
Dynamic Albedo of Neutrons (DAN)

Principal Investigator: Igor Mitrofanov
Space Research Institute (IKI), Russia

DAN measures the abundance of H and OH bearing materials (e.g., adsorbed water or hydrated minerals)

- Active neutron spectroscopy with pulsed 14 MeV neutrons or passive
- Creates profiles along traverses and with depth to 1 m
- Resolves time decay curve and energy spectrum of returned pulse
- Accuracy of 0.1-1% by weight of water (or water-equivalent hydrogen) depending on observation type
Mars Hand-Lens Imager (MAHLI)

Principal Investigator: Ken Edgett
Malin Space Science Systems

MAHLI characterizes the history and processes recorded in geologic materials

- Examines the structure and texture of rocks, fines, and frost/ice at micron to cm scale
- Returns 1600 × 1200-pixel color images and video; synthesizes best-focus images and depth-of-field range maps
- Highest possible spatial resolution is 14 μm/pixel
- Can focus at distances suitable for landscape and engineering support/diagnostic imaging
- White light and UV LEDs for controlled illumination, fluorescence
Mars Descent Imager (MARDI)

Principal Investigator: Michael Malin
Malin Space Science Systems

MARDI provides detailed imagery of the MSL landing region

- Acquires images during powered descent ranging from 1.5 m/pixel to 1 mm/pixel at the surface. Ties post-landing surface images to pre-landing orbital images.
- Bayer pattern filter for natural color
- High-definition, video-like data acquisition (1600×1200 pixels, 4.5 frames per second)
- Large internal storage: 256 MByte SRAM, 8 GByte flash
Mast Camera (Mastcam)

Principal Investigator: Michael Malin
Malin Space Science Systems

Mastcam provides color and stereo imaging of the landscape, rocks, fines, frost/ice, and atmospheric features

- Narrow-angle (5.1° FOV) and medium-angle (15° FOV) cameras
- Bayer pattern filter design for natural color plus narrow-band filters for scientific color
- High spatial resolution: 1200×1200 pixels (0.2 mm/pixel at 2 m, 8 cm/pixel at 1 km)
- High-definition video at 5 frames/second, 1280×720 pixels
- Large internal storage: 256 MByte SRAM, 8 GByte flash
Sample Analysis at Mars (SAM)

Principal Investigator: Paul Mahaffy
NASA Goddard Space Flight Center

SAM Suite Instruments

Quadrupole Mass Spectrometer (QMS)
Gas Chromatograph (GC)
Tunable Laser Spectrometer (TLS)

- Explore sources and destruction paths for carbon compounds, and search for organic compounds of biotic and prebiotic relevance
- Reveal chemical and isotopic state of other light elements that are important for life as we know it on Earth
- Study atmospheric/surface interactions expressed in trace species compositions
- Investigate atmospheric and climate evolution through isotope measurements of noble gases and light elements

• QMS: molecular and isotopic composition in the 2-535 Dalton mass range for atmospheric and evolved gas samples
• GC: resolves complex mixtures of organics into separate components
• TLS: abundance and isotopic composition of CH₄, CO₂, and H₂O
Radiation Assessment Detector (RAD)

Principal Investigator: Donald M. Hassler
Southwest Research Institute

RAD characterizes the radiation environment on the surface of Mars

- Measures galactic cosmic ray and solar energetic particle radiation, including secondary neutrons and other particles created in the atmosphere and regolith
- Determines human dose rate, validates transmission/transport codes, assesses hazard to life, studies the chemical and isotopic effects on Mars’ surface and atmosphere
- Solid state detector telescope and CsI calorimeter. Zenith pointed with 65° FOV
- Detects energetic charged particles (Z=1-26), neutrons, gamma rays, and electrons
Rover Environmental Monitoring Station (REMS)

Principal Investigator: Javier Gómez-Elvira
Centro de Astrobiología (CAB), Spain

REMS measures the meteorological and UV radiation environments

- Two 3-D wind sensors
- Air temperature sensors
- IR ground temperature sensors
- Pressure sensor
- Relative humidity sensor
- UV radiation detector (200 to 400 nm)
- 1-Hz sampling for 5 minutes each hour
Candidate Landing Sites
Mars Landing Sites
(Previous Missions and MSL Candidates)
**Candidate Landing Sites**

**Eberswalde Crater** (24° S, 327° E, -1.5 km) contains a clay-bearing delta formed when an ancient river deposited sediment, possibly into a lake.

**Gale Crater** (4.5° S, 137° E, -4.5 km) contains a 5-km sequence of layers that vary from clay-rich materials near the bottom to sulfates at higher elevation.

**Holden Crater** (26° S, 325° E, -1.9 km) has alluvial fans, flood deposits, possible lake beds, and clay-rich sediment.

**Mawrth Vallis** (24° N, 341° E, -2.2 km) exposes layers within Mars’ surface with differing mineralogy, including at least two kinds of clays.
Eberswalde Delta:

Clay-Bearing Deltaic and Paleolake Deposits along a Major Martian Drainage
Eberswalde Delta

- Best evidence for a delta anywhere on Mars.
- Lighter-toned layers have phyllosilicate signatures in CRISM observations.
- Evidence for a much larger, paleodeltaic complex exists across all the crater floor, including the ellipse location to the east.
- HiRISE images (bottom) show layers exposed at the margin of the deposit.
Gale Crater:

A 5-km Sequence of Layered Materials Recording Major Compositional Changes
Gale Crater

CTX image overlain on DEM by Larry Edwards from CTX stereo pairs, looking toward southwest.
Mawrth Vallis:

Ancient Phyllosilicate-Bearing Layered Materials near an Outflow Channel
Mawrth Vallis

- Exposure of stratified Noachian bedrock near the dichotomy boundary
- Cycles of deposition and erosion
- Strong signature of phyllosilicates from near-infrared spectroscopy
- Phyllo-bearing units are thick, flat-lying, and widespread
- Deposition occurred gradually, but very early in Mars’ history
Holden Crater: 

Paleolake and Flood Deposits along a Major Martian Drainage System
Holden Crater

- Offers opportunity to explore 80-m thick section of light-toned layered deposits (phyllosilicate-bearing), paleolake, fan, and flood deposits, and basal materials.
Rover and Spacecraft Pictures
Rover Driving Test
Cruise Stage
Parachute Test
Assembled Spacecraft
Learn More about Curiosity

Mars Science Laboratory
http://mars.jpl.nasa.gov/msl

MSL for Scientists
http://msl-scicorner.jpl.nasa.gov

Mars Exploration Program
http://mars.jpl.nasa.gov

MSL Candidate Landing Sites
http://marsoweb.nas.nasa.gov/landingsites
http://webgis.wr.usgs.gov/msl

Mission Video
http://www.jpl.nasa.gov/video/index.cfm?id=979