The Mars Curiosity Rover Mission: Remotely operating a science laboratory on the surface of another planet

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SPACE TECHNOLOGY AND TELE-REACH: BENEFITING HUMANITY ON EARTH AND BEYOND
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At 2.1 m high, 1.5 m wide, and nearly 900 kg, Curiosity dwarfs Spirit and Opportunity (2004) and Sojourner (1997).

3rd Generation of Remotely Operated Rovers

Pathfinder/Sojourner
1997

Opportunity 2004-today

Curiosity 2012-?

175 kg

25 kg

900 kg

NASA/JPL Caltech
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

- Biological potential
- Geology and geochemistry
- Role of water
- Surface radiation
**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
- 84 kg of science payload
- Direct (uplink) and relayed (downlink) communication
- Fast CPU and large data storage

**CRUISE/APPROACH**
- 8-month cruise
- Arrived August 5, 2012

**LAUNCH**
- Nov. 24, 2011
- Atlas V (541)
Gale Crater and Mount Sharp

NASA/JPL-Caltech/ESA/DLR/FU Berlin/MSSS
Curiosity overview

**Environmental Science:**
- REMS - temperature, pressure, UV and wind sensors
- RAD - full spectrum radiation detection

**Robotics Arm & Sampling Subsystem**
- 5 DOF 2m long robotic arm
- Actuated brush to clean rocks
- Rotary percussive drill
- Sample processing with sieve + portioning/delivery
- Sample observation tray
- 2 spare drill bits + 5 reference samples

**Remote Science:**
- MASTCAMS - stereo color science cameras w/ filters
- CHEMCAM - remote laser induced breakdown chemical analysis

**Contact Science:**
- MAHLI - focusable microscopic color imager with LEDs
- APXS - chemical analysis

**Analytic Sample Science:**
- SAM - chemical analysis of rock/soil or atmospheric samples
- CHEMIN - mineralogy assessment

**Telecom:**
- Relay to orbiters
- Direct to earth communication

**Power:**
- Continuous power source
- Re-chargeable Li-Ion Batteries

**Avionics Subsystem:**
- Redundant computer and power distribution

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**Mobility Subsystem:**
- Rocker-bogie suspension with 6 wheel drive, 4 wheel steering
- Front and rear stereo cameras
Communication Paths

Mars Odyssey

Mars Reconnaissance Orbiter

Mars Express

Deep Space Network

NASA/JPL-Caltech
Horizon masks and terrain tilt considerations
Curiosity’s trek from the landing site captured by HiRISE on the Mars Reconnaissance Orbiter

NASA/JPL-Caltech/Univ. of Arizona
Tactical Operations Process

Deep Space Network - COMMAND

- Radiate Cmd/Seq (Direct or via Relay)

Ground Activity Planning and Commanding

- Activity Planning, Resource Modeling & Verification, Sequence Generation, Validation, and Translation

Science


Engineering

- Monitor and Analyze S/C Safety, Health, and Performance. Provide go forward assessment,

Deep Space Network - TELEMETRY

- Acquire, Process, Store, Distribute Telemetry and Radiometric Data

Ground Assessment

- Data Product Processing (Image and Science data), Report Generation
Integrated Planning/Commanding Tool
Mars Operations Process

STEP 1: TARGET SELECTION & TRIAGE via REMOTE SENSING

- +/-181 deg azimuth and +91/-87 elevation range of motion
- Laser Induced Breakdown Spectroscopy
- Redundant Stereo Vision Cameras for target designation, tool placement and autonomous navigation
- Near and far field adjustable focus color cameras capable of video

NASA/JPL-Caltech/MSSS
Mars Operations Process
STEP 2: APPROACH OR TRAVERSE

- Autonomous navigation allows the vehicle to operate up to 20m (currently) without the real time feedback of a ground operations team.
Can also use mobility system as a diagnostic tool to assess soil properties.
Mars Operations Process

STEP 3: CONTACT SCIENCE

NASA/JPL-Caltech/MSSS
Mars Operations Process

STEP 3: SAMPLE DIAGNOSTICS AND ACQUISITION

Scooping

Dusting

Drilling
Mars Operations Process

STEP 4: SAMPLE DELIVERY AND ANALYSIS

Chemin Inlet Cover - Closed

Chemin Inlet Cover – Open

SAM Instrument Inlet Covers

Inlets for 1mm and 150µ particle sizes

Mineral X-ray, tune-able laser spectroscopy, mass spectrometry...
Managing Marstime

1 Sol (Martian Day) = 1.02 Earth Day, ~24h, 39min

Sols 0-90:
7 day/wk, sliding Marstime for 16 hr/day. All teams co-located.

Sols 90-180:
7 day/wk, Earth time, 12-10 hr/day. Timeline. All teams at respective locations.

Sols 180+:
5 day/wk, 10 hr/dy.

Integrated scheduling tool with all time formats.
Looking ahead!

Foothills of Mt. Sharp

NASA/JPL-Caltech/Univ. of Arizona

NASA/JPL-Caltech/MSSS

Landing Site
Glenelg

Base of Mount Sharp

Lower Reaches of Mount Sharp
Layers, Canyons, and Buttes of Mount Sharp

This boulder is the size of Curiosity

NASA/JPL-Caltech/MSSS