6 Minutes of Terror Landing On Mars Enables Years of Discoveries

Richard Rainen
Manager Rover Mechanical
Jet Propulsion Laboratory
California Institute of Technology
MSL’s primary scientific goal is to explore a landing site as a potential habitat for life, and assess its potential for preservation of biosignatures

Objectives include:

• Assessing the biological potential of the site by investigating organic compounds, other relevant elements, and biomarkers

• 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
Gale Crater

landing site

notional traverse

landing site
Sedimentary rocks are records of environmental change
Curiosity The Rover
Enabling Capabilities

A Robotic Field Geologist
- Access to a site mapped from orbit
- Long life, mobility, capability to explore a local region
- Remote sensing and contact science

A Mobile Geochemical Laboratory
- A broad and flexible payload including analytical laboratory instruments
- Ability to acquire and process dozens of rock and soil samples
- An integrated science team and operations strategy
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
The Challenge of Entry, Descent and Landing
The 6 Minute Challenge

Entry
Energy Dissipation Via: Aerodynamic Drag / Aerothermodynamic heating
Velocity Range: 12,000 mph → 1,000 mph
Peak Temperature: 1447° C
% of Total Energy Dissipated: 99.0%

Parachute Descent
Energy Dissipation via: Aerodynamic Drag
Velocity Range: 1,000 mph → 200 mph
% of Total Energy Dissipated: 0.98%

Powered Descent
Energy Dissipation Via: Rocket Thrust
Velocity Range: 200 mph → 4-40 mph
% of Total Energy Dissipated: 0.002%

Landing
Energy Dissipation Via: Viscous Damping or Plastically Crushed Material
Velocity Range: 4 – 40 mph → 0.0 mph
% of Total Energy Dissipated: 0.0009%
Cruise Stage

MSL Spacecraft Major Elements

- Cruise Stage
- Backshell
- Descent Stage
- Rover
- Heatshield
Heatshield
Parachute Test
Landing Radar Test in California Desert
Descent Stage

Powered Descent Vehicle
(Descent Stage + Rover)

Descent Stage
Powered Descent Vehicle Stowed in Backshell
Curiosity Suspended Below the Descent Stage
“Building Curiosity” Video – YouTube
Full Motion Drop Test

Curiosity

Our Mobile Field Geologist/Analytical Laboratory
Remote Sensing Mast Deployed
Flexing Her Muscles!
Turret – Sample Collection and Portioning
System Test Bed Drills
Flight Unit Traverse Tests
Torque: A Perspective

- **Current torque capability**
  - ~80% the torque output of an M1 Abrams Main Battle Tank

\[ \tau = r \times F \]

\[ \text{power} = \frac{\text{work}}{\text{time}} = \frac{\text{force} \times \text{distance}}{\text{time}} \]

- Mini-Cooper S: Torque ~162 ft-lbf, Curb Weight 2,700 lbs
- Wrangler: Torque ~235 ft-lbf, Curb Weight 3,500 lbs
- HMVM: Torque ~190 ft-lbf, Curb Weight 6,820 lbs
- MSL-M3: Torque ~2965 ft-lbf, Curb Weight ~1200 lbs
- M1 Abrams Battle Tank: Torque 3800 ft-lbf, Curb Weight 120,000 lbs
Verification of Operations on Slope
Surface System Environmental Test
Aeroshell “Fit Check”
YouTube Video

“Ready For Mars!”
Liftoff In 7 Days!

http://mars.jpl.nasa.gov/msl/
and Beyond!