Astrobiology in the Field: Expeditions, Analog Studies, Technology Demonstrations

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How can we make Star Trek real?

Why do we explore?

What is the value of exploration?

What is the value of analog exploration?

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NASA's 2011 Mars Science Laboratory

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Scientific Objectives for MSL

Explore and quantitatively assess a local region on Mars' surface as a potential habitat for life, past or present.

A. Assess the biological potential of at least one target environment.

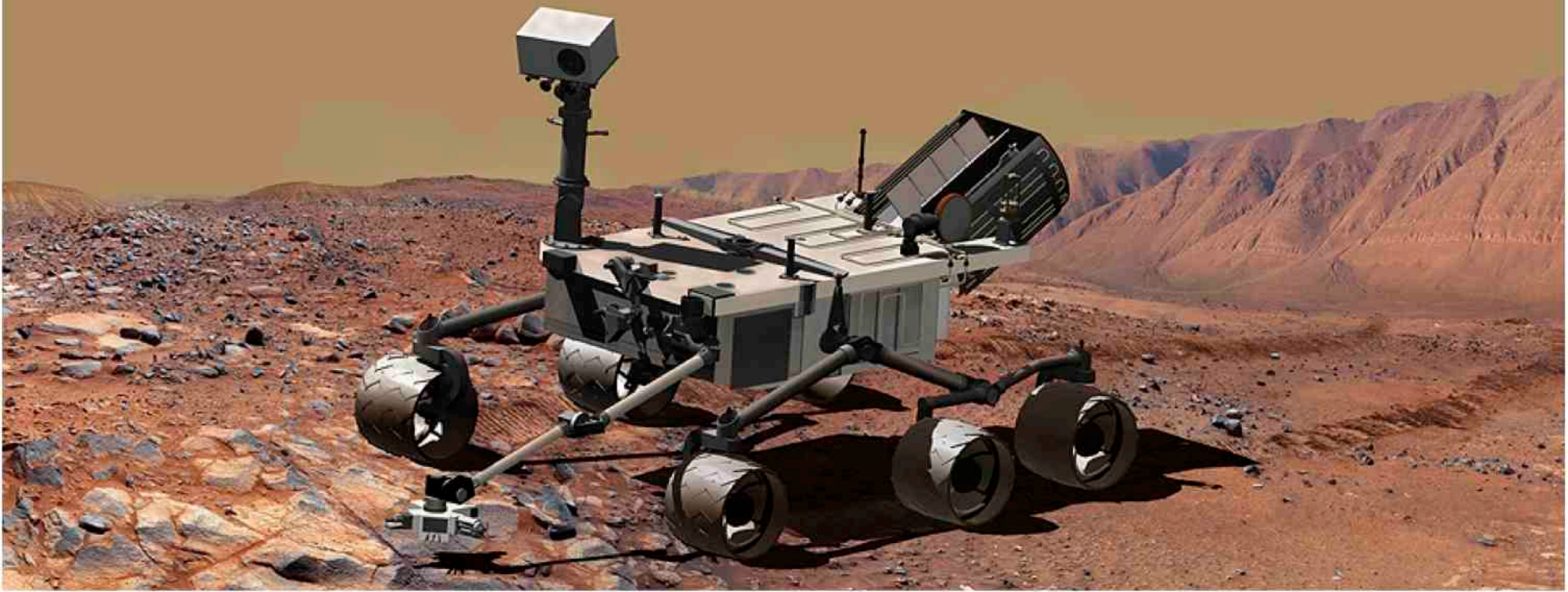
B. Characterize the geology and geochemistry of the landing region at all appropriate spatial scales (i.e., ranging from micrometers to meters).

C. Investigate planetary processes of relevance to past habitability, including the role of water.

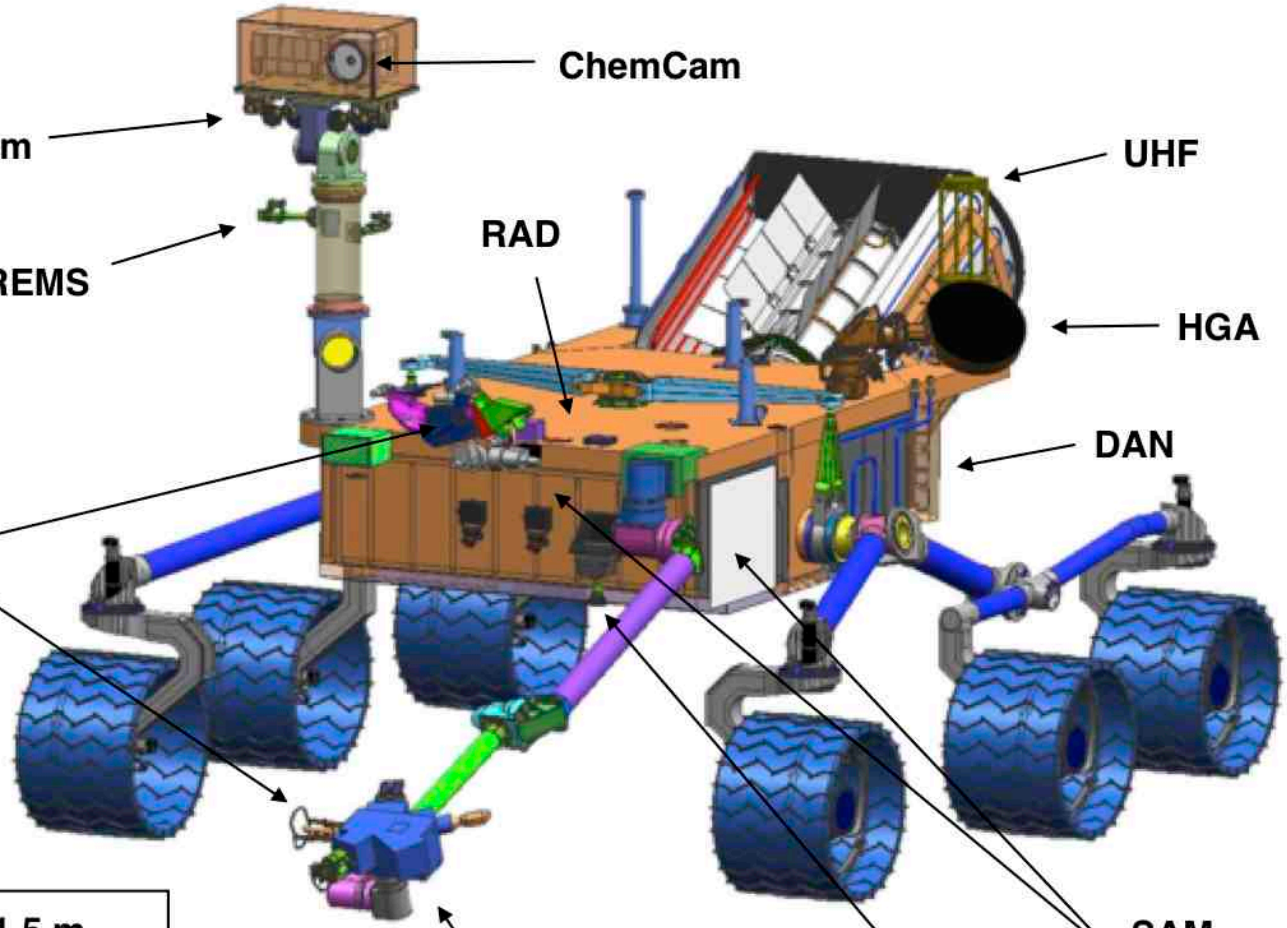
D. Characterize the broad spectrum of surface radiation, including galactic cosmic radiation, solar proton events, and secondary neutrons.

Capabilities of MSL

- A long-lived, roving, robotic laboratory capable of visiting many sites
- Access to a wide range of candidate landing sites assessed by orbiting spacecraft
- A broad and flexible payload including advanced geochemical instruments used in Earth labs
- A system to acquire and process dozens of rock and soil samples
- An integrated science team



Current Rover Configuration



Wheel Base:	1.5 m
Height of Deck:	1.1 m
Height of Mast:	2.1 m
Wheel Diameter:	0.5 m
Clearance:	0.66 m

Habitability assessment ≠ life detection!

Habitability

- Reference to the **potential** of an environment (past or present) to support life of any kind

Habitat

- An environment (defined in time and space) that is or was occupied by life

Life detection

- The process of investigating the presence of biosignatures (including potential biosignatures). Life detection can apply to either past or present life.

Biosignature

- Any phenomenon produced by life (either modern or ancient).

How does habitability assessment differ from life detection?

Habitability

- Is there any water around?
- What potential energy sources are present?
- What raw materials are available on the planetary surface?
- Habitable for whom?
- Is the environment *inhabited* ?

How can you tell if a planet has ever been inhabited?

Does a planet's surface weather differently with the presence of a biosphere than it does without having had one?

If it does, what observable chemical differences distinguish geo-*biological* processes from abiotic geochemical processes?

What structural features of a planetary surface might be distinct when produced by biological processes?

Life Detection

Detection of Life must be based upon ***measurable*** parameters which imply four possible states:

- Alive
- Dead
- Preserved
- Non-life

How do we avoid Earth-centric bias?
What should we measure?
What are the scales of observation?
How do we interpret the results?
What tools might we use?

Defining Life in Measurable Terms

… what life is:

Unique Chemistry

Structure

… what life does:

Energy Uptake/Conversion

Replication

Evolution

Meaningful Movement

Measurement of Habitability

1. First, study remote sensing data, maps, etc.
2. Decide how big an area to measure.
   - Science driven
   - Technology, safety, finance and time constrained
3. Determine the spatial sampling rate.
   - Science driven
   - Technology, finance and time constrained
4. Determine the temporal sampling rate.
   - Science driven
   - technology, safety, finance and time constrained
5. Determine the order of measurements
   - Primarily technology constrained, but also by safety and time
6. Decide where to begin measurements
7. Randomly select locations and proceed

Habitability Assessment

Candidate Habitability Indicators

Physical	Chemical	Biological
Altitude	Elemental abundance	Vegetation Survey
Latitude/longitude coordinates	Organic inventory	Biodiversity and spatial distribution (by PCR)
Solar radiation (λ and intensity)	Stable isotopes of C and O	Functional diversity (by PCR)
Temperature of rock or soil and air	Abundance and state of water	ATP/LAL
Mechanical stability (slope, etc.)	Mineral content (and rock type)	
Electrical/magnetic environment	Total Nitrogen	
Wind speed, direction & variability	Volatile inventory (air)	
Humidity	Volatile Inventory (in rock & soil)	
General geomorphology		
Geophysical environment (volcanism, seismicity, impact evidence, etc)		
Sedimentary structures		

Habitability Assessment:

Environmental Physics Measurements

- *Ionizing radiation environment*
- *Mechanical environment (impacts, mass transport). This requires the big picture (literally), as well as smaller spatial scale clues.*
- *Electromagnetic environment*
- *Thermal history*
- *Solar environment*

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The Physics of Habitable Environments

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Habitability Assessment: Sverefjell Volcano

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Rover Operations in Analog Exploration

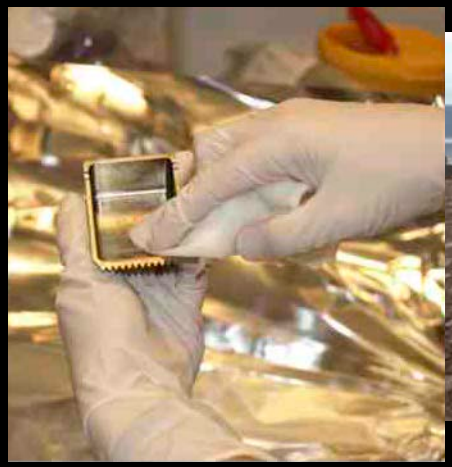
Systems Level Development

Level one requirements, as well as functional requirements and mission success criteria
Operational readiness test procedures
Field test procedures
Test biological cleanliness
Implement field deployments

Mechanical Design and Implementation

Software Development

Electrical System Development



Mission Operations in Analog Exploration

Payload

- Remote sensing instruments:
  - Hazcams (monochrome, ~100 deg FOV, front and rear)
  - Navcam (monochrome, ~45 deg FOV)
  - Pancam (color, ~15 deg FOV)
  - Remote Raman
- Contact instruments:
  - Microscopic imager
  - LINF
- Analytical instruments:
  - CheMin
  - SAM
  - Life marker chip

Mission Scenario

- Landing took place on a rolling plateau of impact-shattered basaltic lava flows that are interpreted to be ~3 Gyr old.
- The rover drove for 180 sols to reach a range of rugged hills that predate the lavas (approximate age 4 Gyr). It has been exploring these hills for 120 sols.
- The hills to date have been found to consist primarily of a complex sequence of interbedded impact ejecta deposits. The target materials were basaltic in origin, and the ejecta deposits underwent post-impact aqueous alteration that was spatially variable in its intensity.
- 4 sols ago, Pancam images revealed a relatively small local outcrop of a geologic unit with textural and vis/NIR spectral properties distinct from any investigated to date. The rover has been driving toward that outcrop since then.
- The field test will begin with receipt of the downlink for Sol 300.
  - 3x2 Navcam mosaic from end-of-drive position, targeted toward the outcrop.
  - Front Hazcams from end-of-drive position.
- The first uplink will be for Sol 301.
- We will perform as many uplink and downlink cycles as time allows.

Simulated Navcam Mosaic

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