Mars Exploration Rovers

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MN Teachers of Physical Sciences Conference

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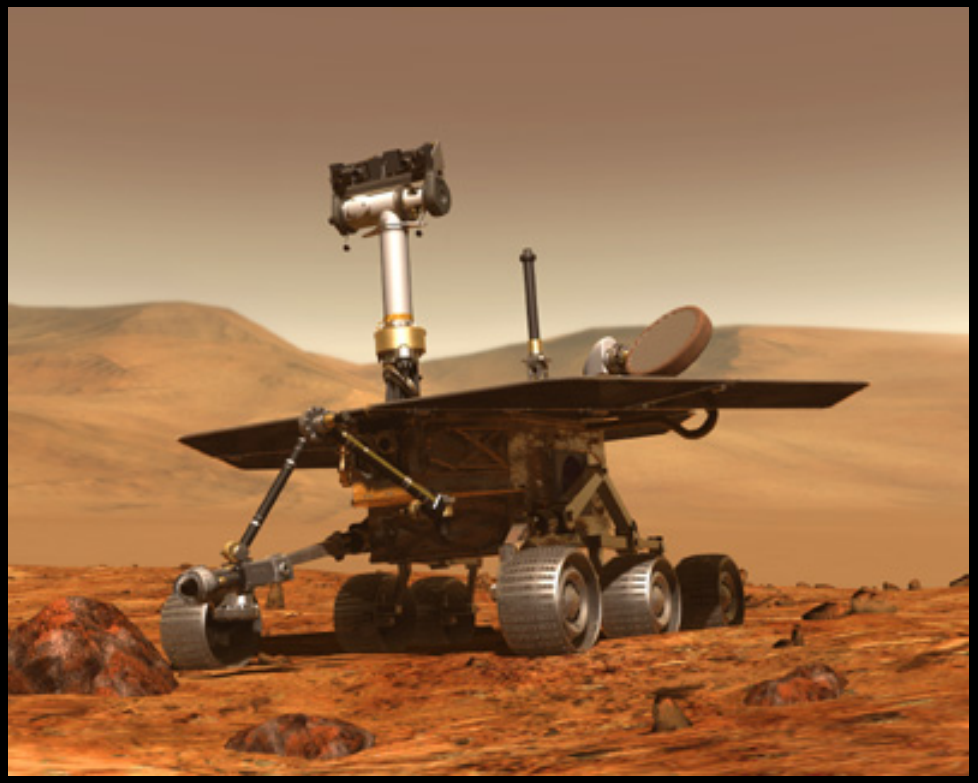
- Mission Objectives
- Robotics Overview
- Getting to the Surface of Mars
- Daily Operations
- Preliminary Science Results
- Mars in the Classroom

Video

Mission Overview

Two robotic geologists are currently exploring two distinct sites on the Martian Surface. Each rover carries a suite of science instruments designed to search for evidence of water.



...Why search for water?

MARS SCIENCE STRATEGY: Follow the Water!

Common Thread

W A T E R

When? Where? Form? Amount?

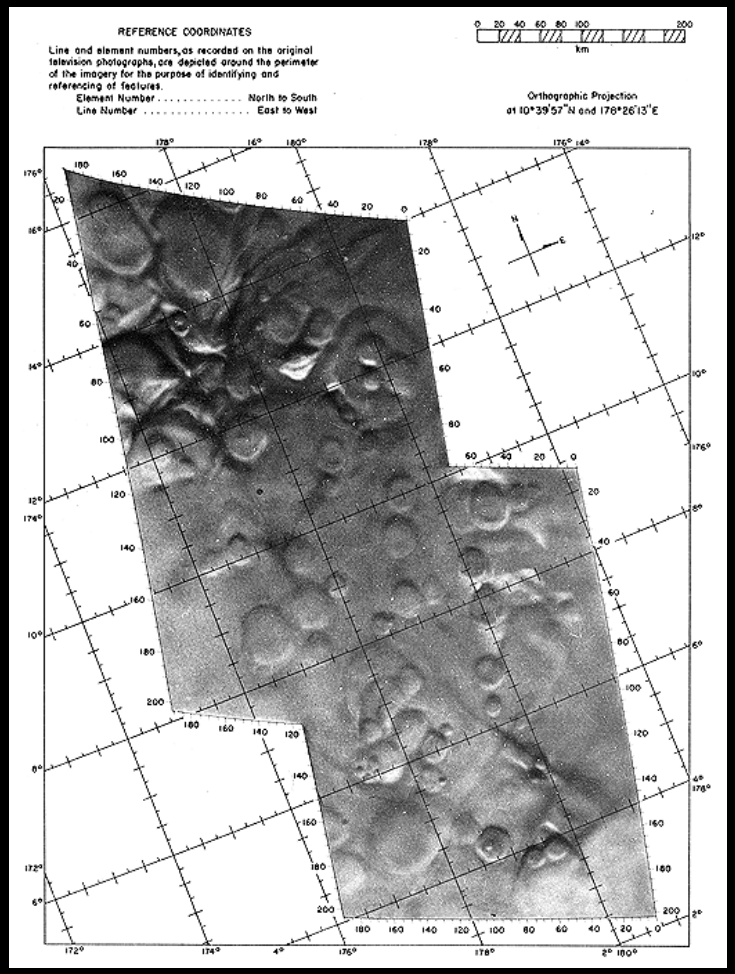
Determine if Life Ever Arose on Mars — LIFE

Characterize the Climate — CLIMATE

Characterize the Geology — GEOLOGY

Prepare for Human Exploration — HUMAN

First close-up views

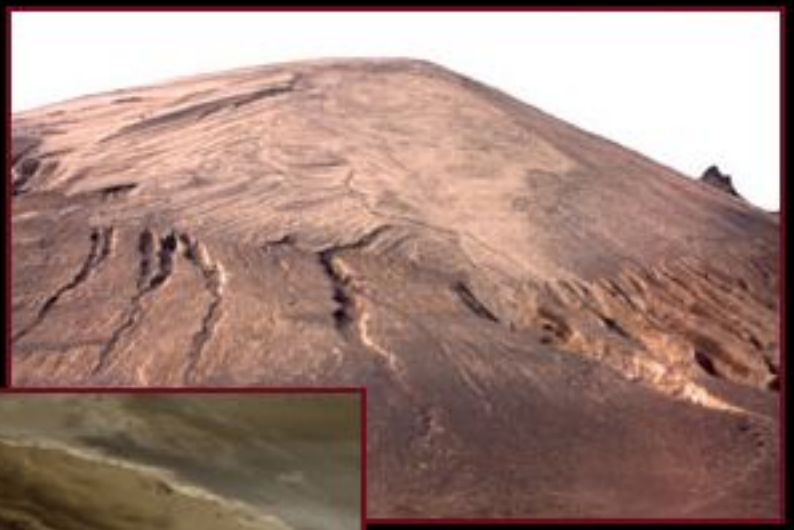


Mariner 4

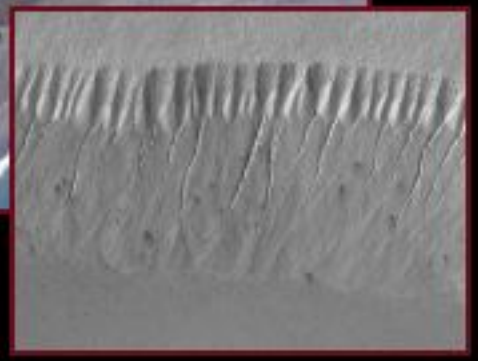
Viking 1

Mars: a close cousin of Earth

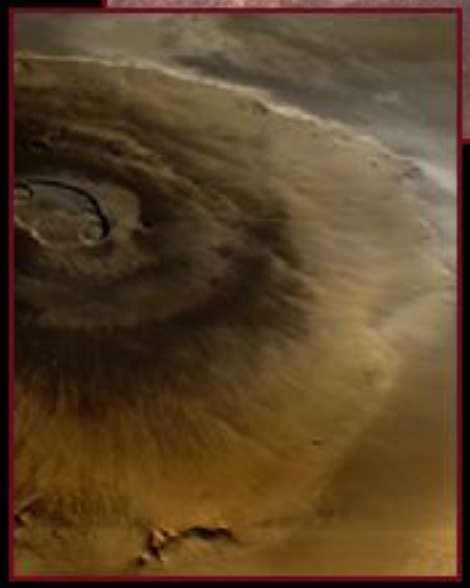
Volcanoes, Canyons, and Layered Terrain in Iceland



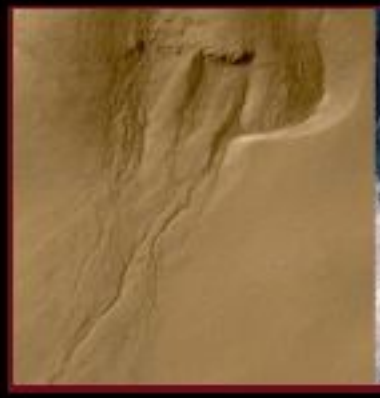
Volcano on Earth



Gullies on Mars



Olympus Mons on Mars

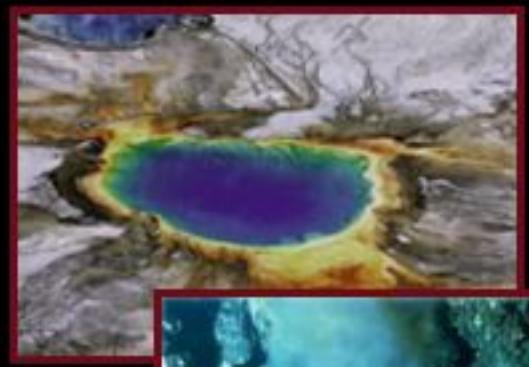


Crater, Noachis Terra

Mount St. Helens

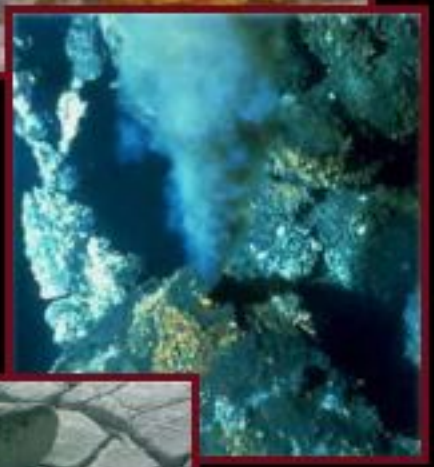
Mars is hostile, but we find life in extreme environments everywhere we look on Earth.

Mount St. Helens



Thermal Springs

Too Hot to Handle

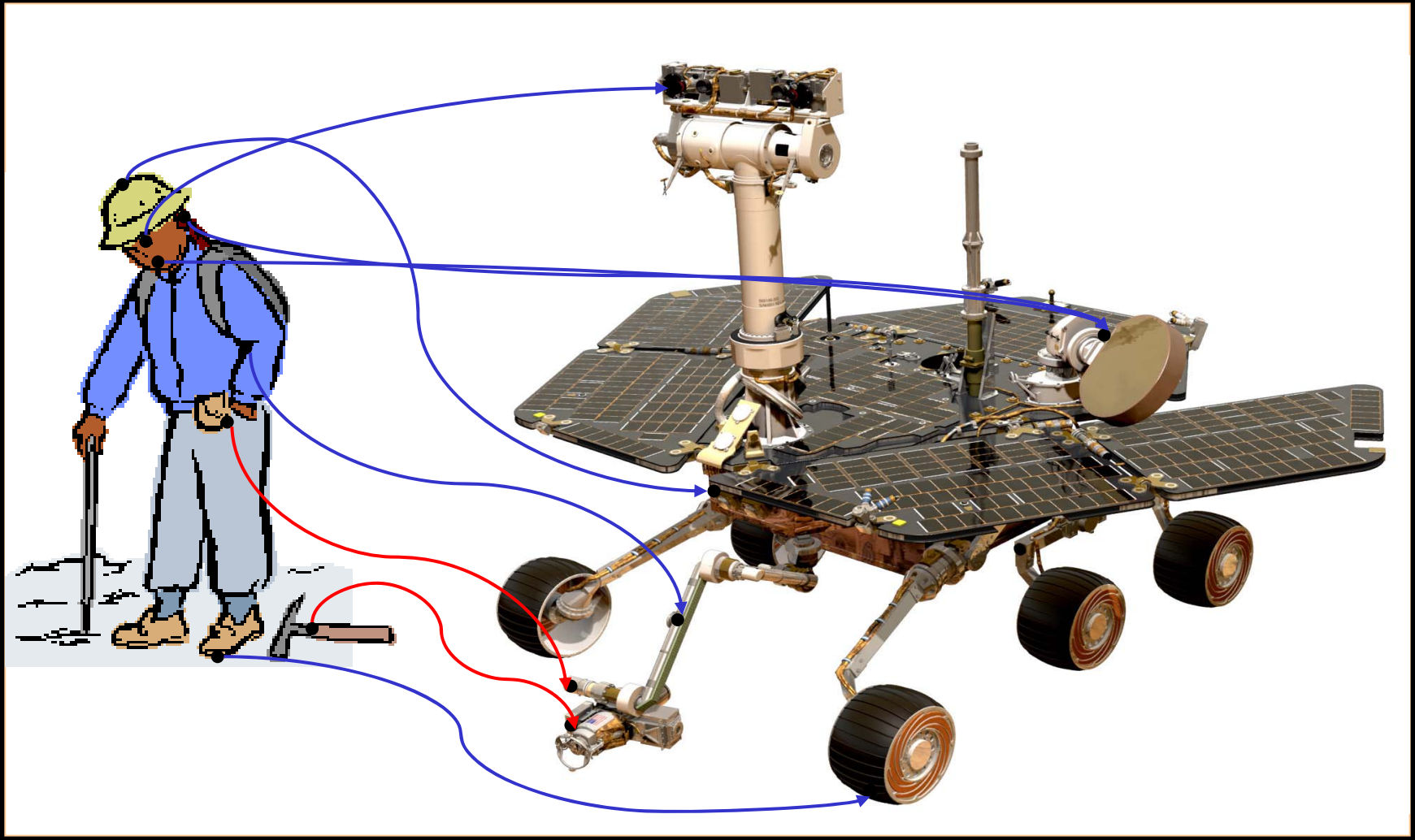


Underwater Vent

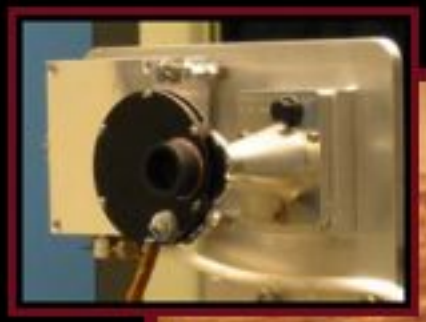
Living Organisms

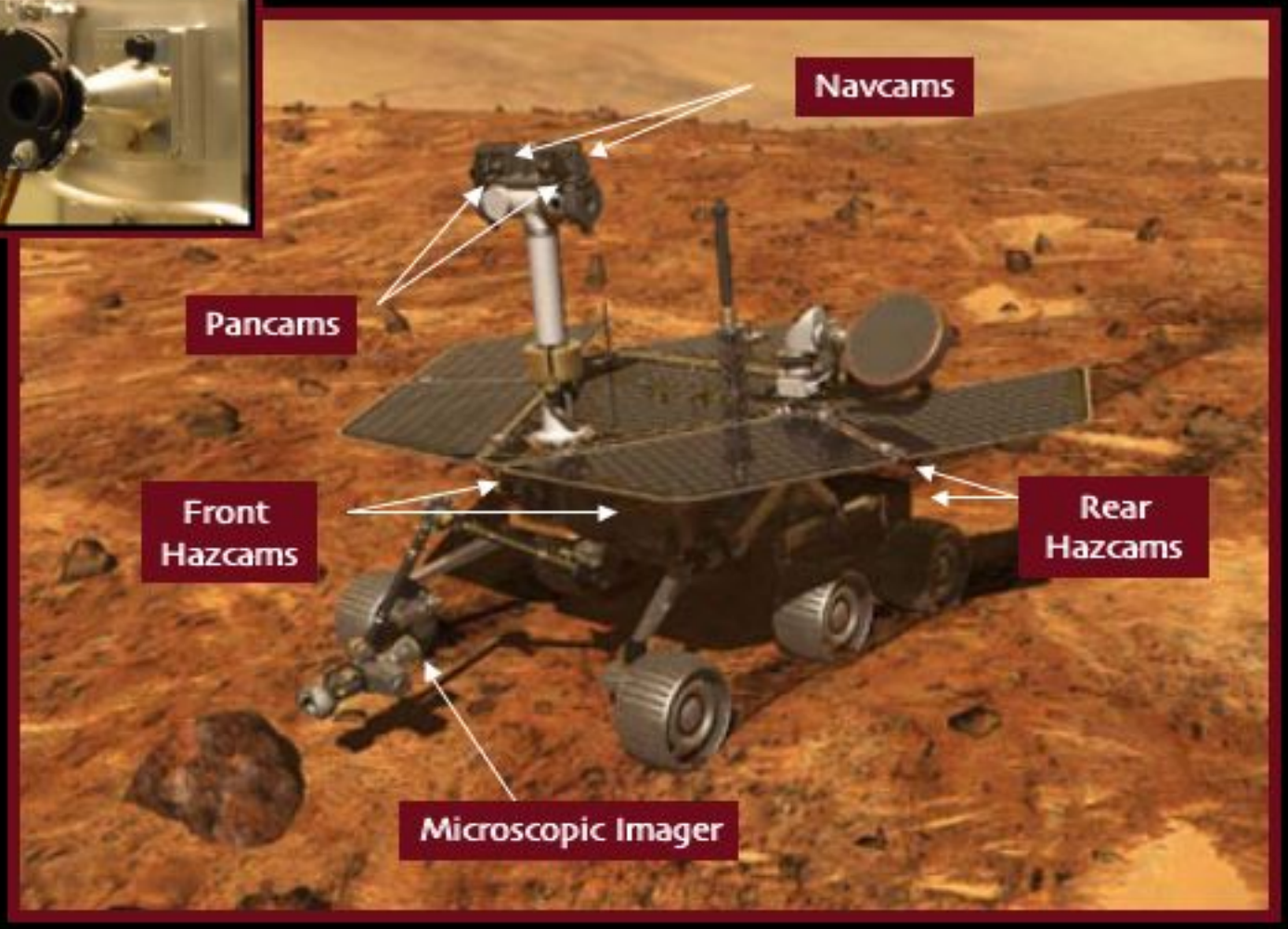
Desolate Deserts

Robotics: How to build a geologist

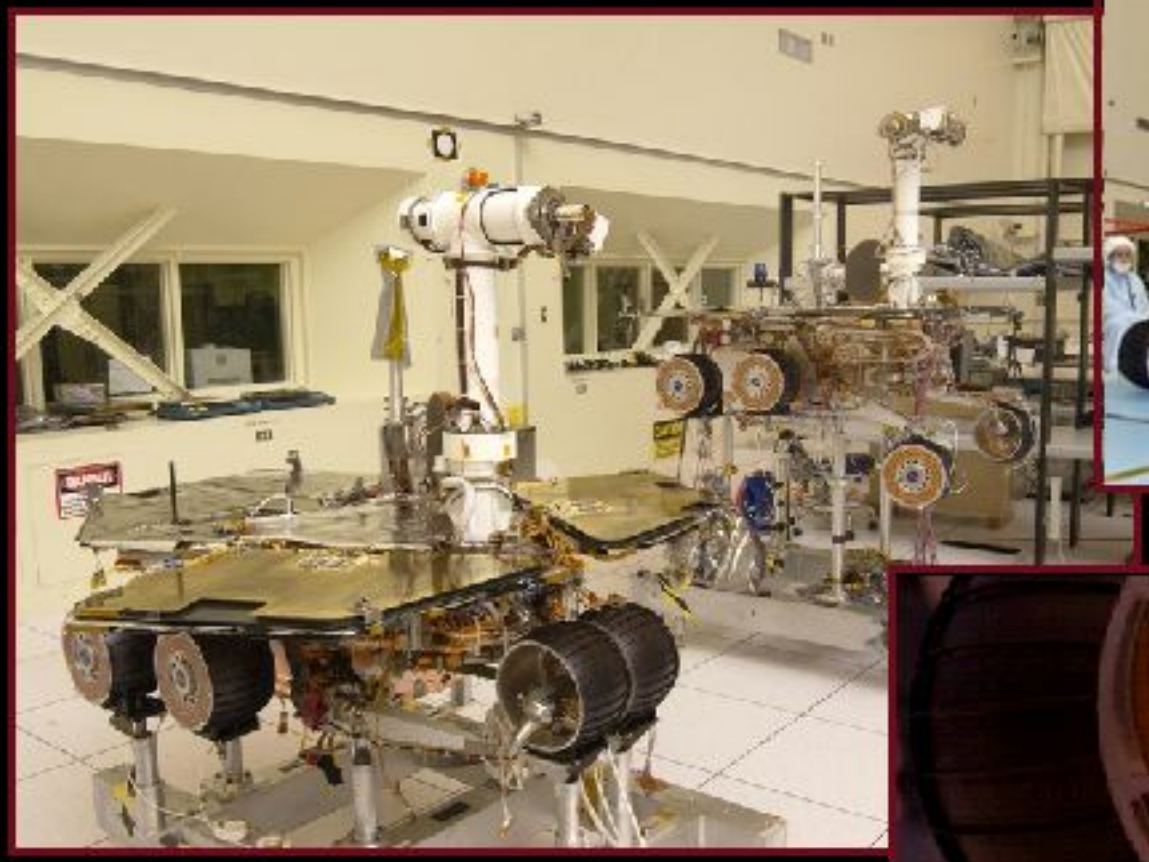


The rover's "eyes" are its cameras. Each rover has 9 "eyes."





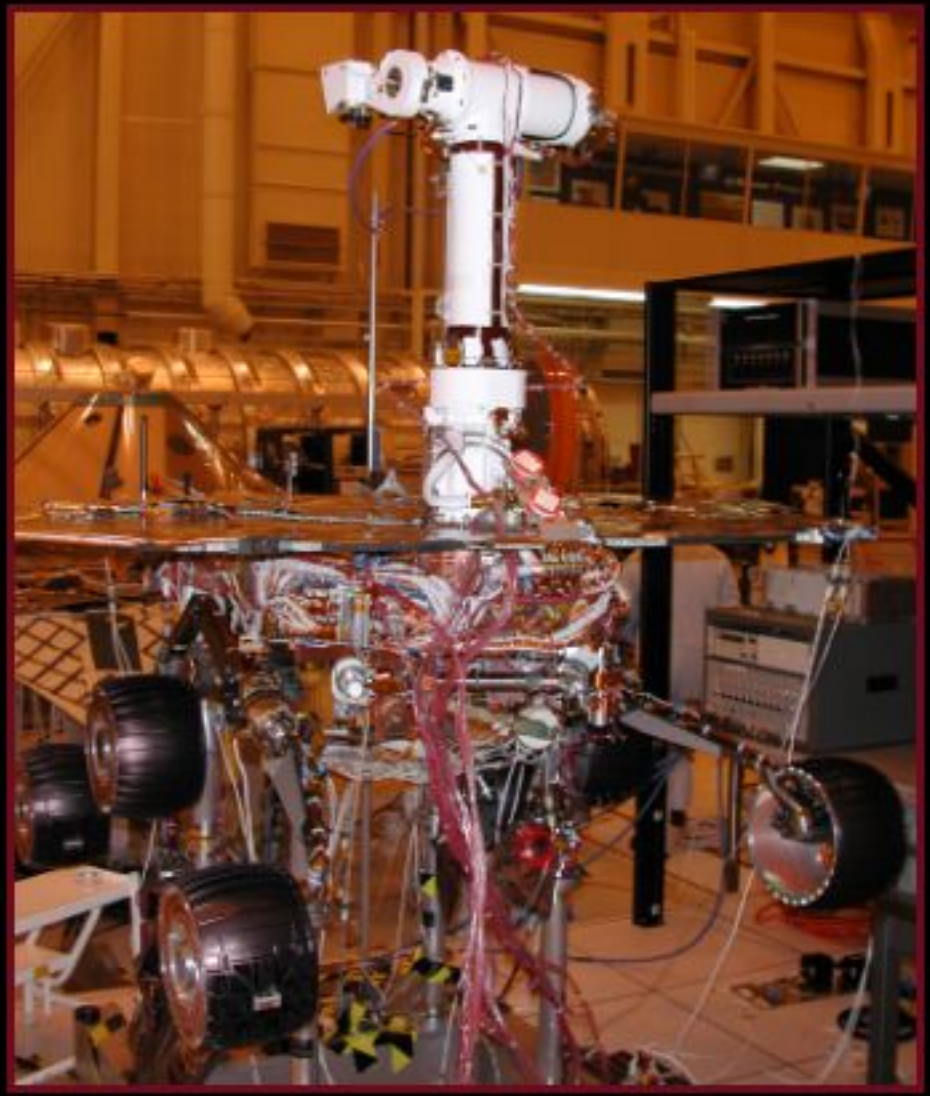
The rovers have "legs" with wheels to get around on Mars.



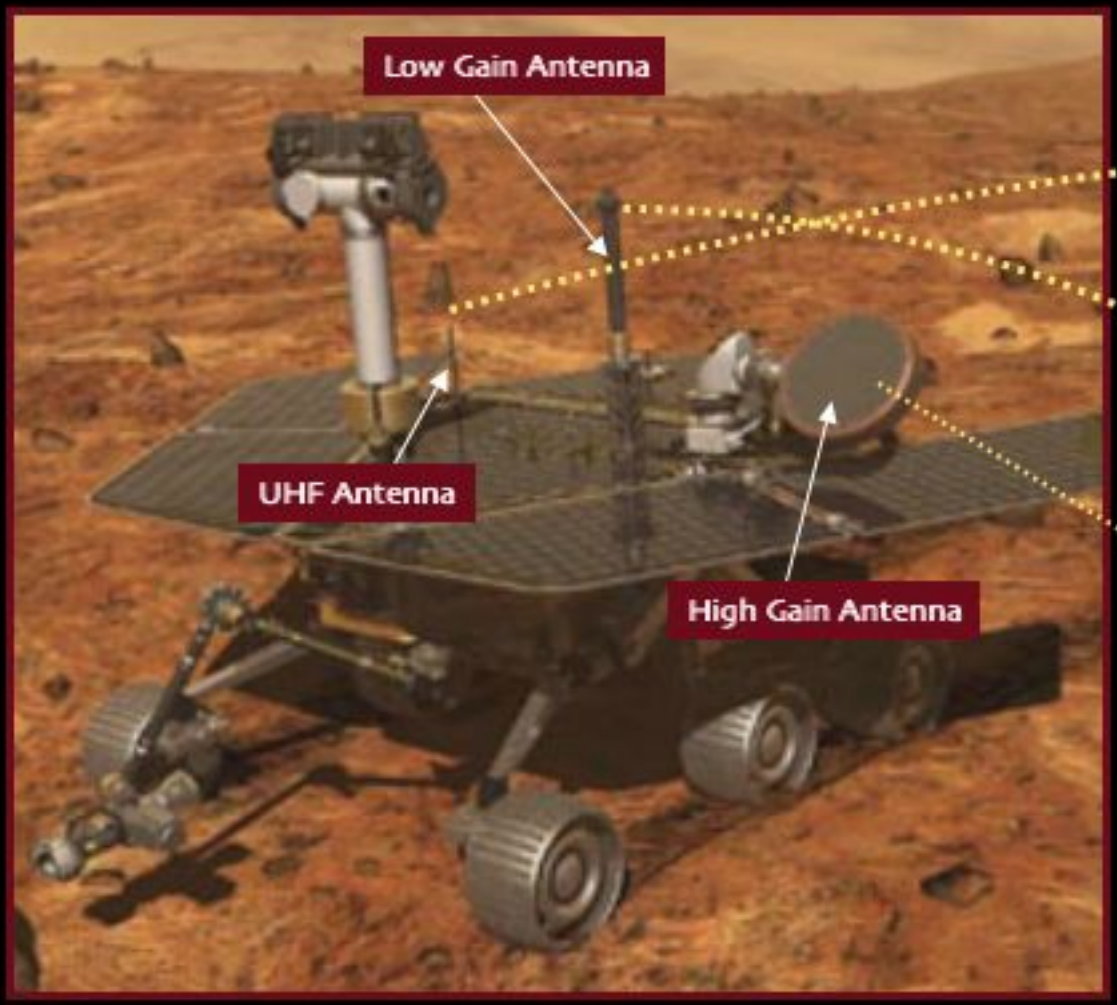
The rovers have an arm and a scraping tool that perform the same function as a geologist's rock hammer.

Microscopic Image

The rovers have brains -- but they're located in their bodies!



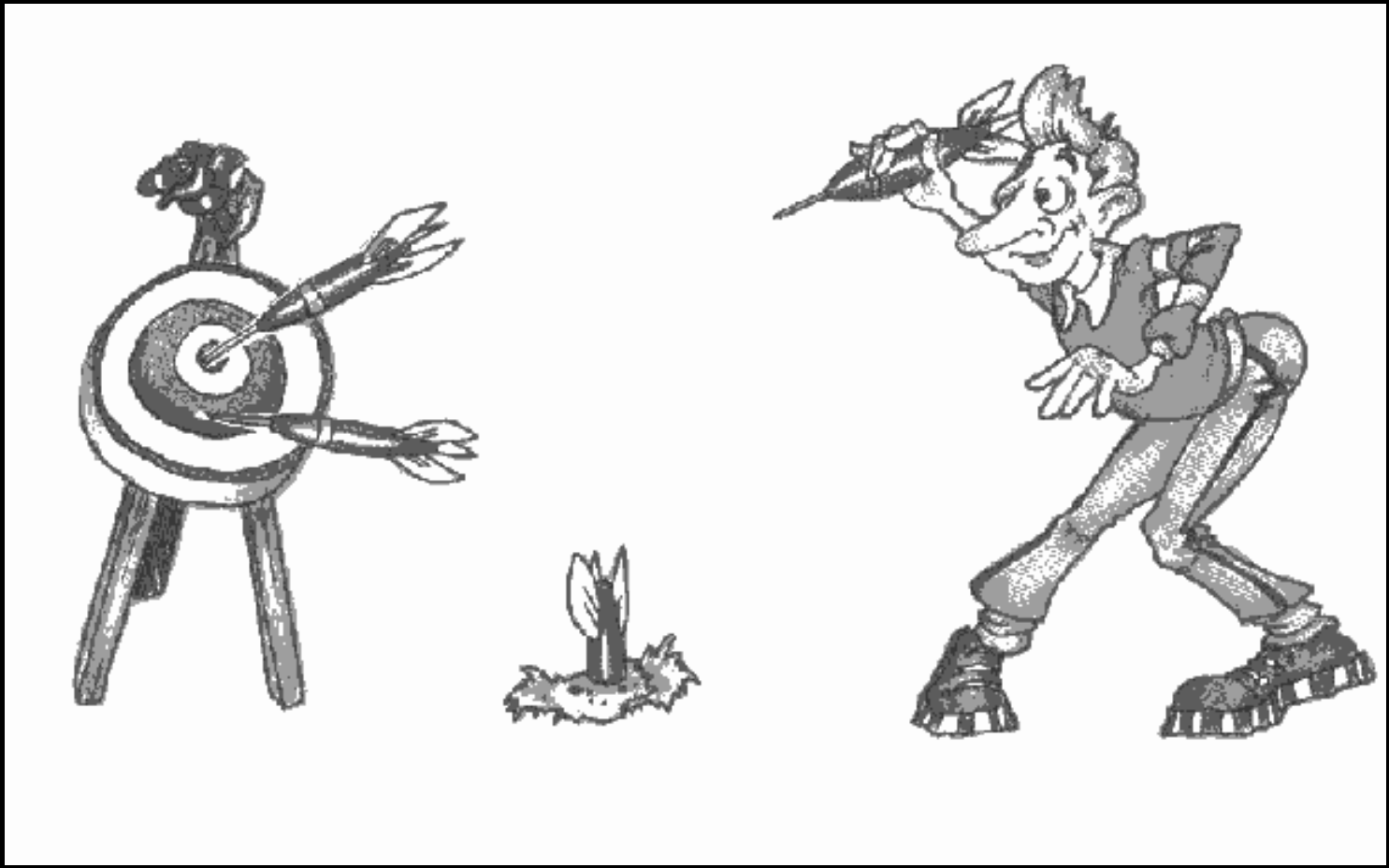
The rovers listen and speak to Earth with their communications antennas.



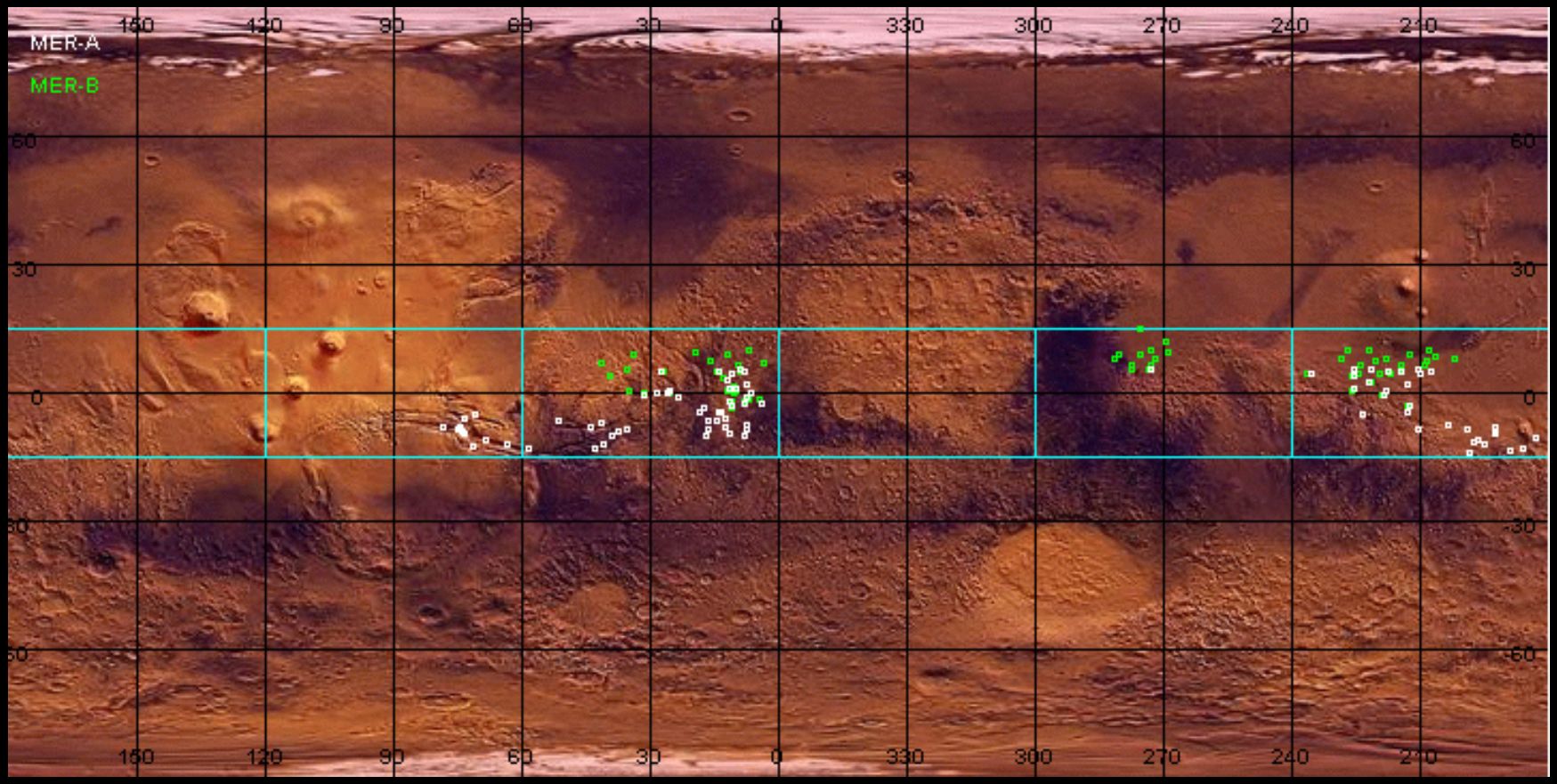
The rovers get their energy from the sun, which warms their "backs."

Solar panels take in the sun's energy; batteries store power and provide it to the rover during the night.

Landing Site Selection

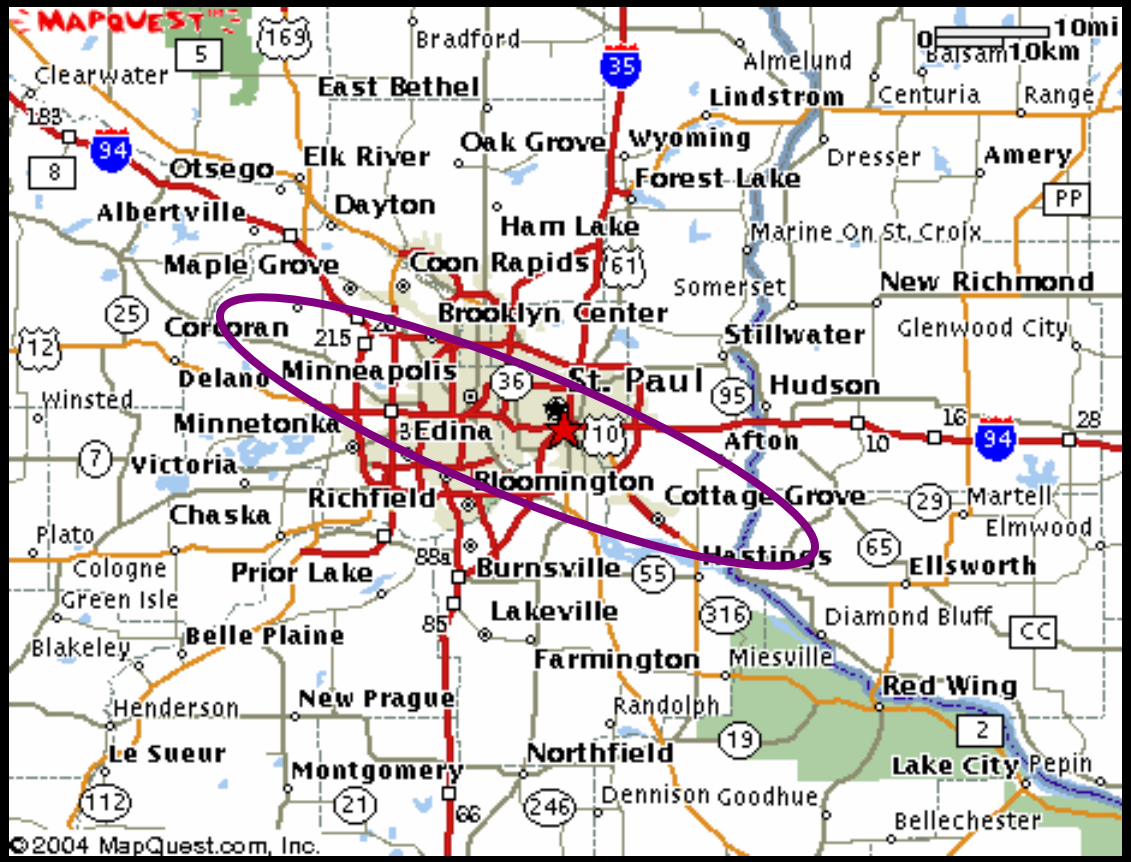


Candidate Landing Sites



A) ±15° Latitude Band, <-1.3 km Elevation; ~5% of Surface
B) Smooth, Flat Over Ellipse, ~155 Possible Landing Sites
C) 25 of these sites were selected by the Scientific Community for further consideration

The Landing Ellipse



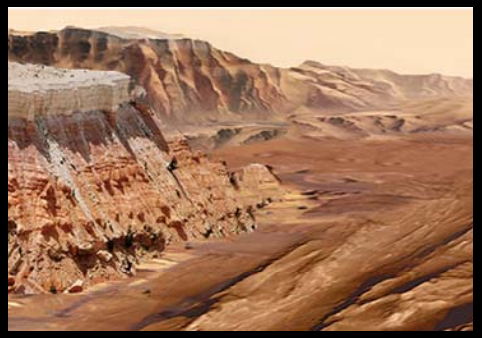
about 50 miles long by 6 miles wide

And the winners are…

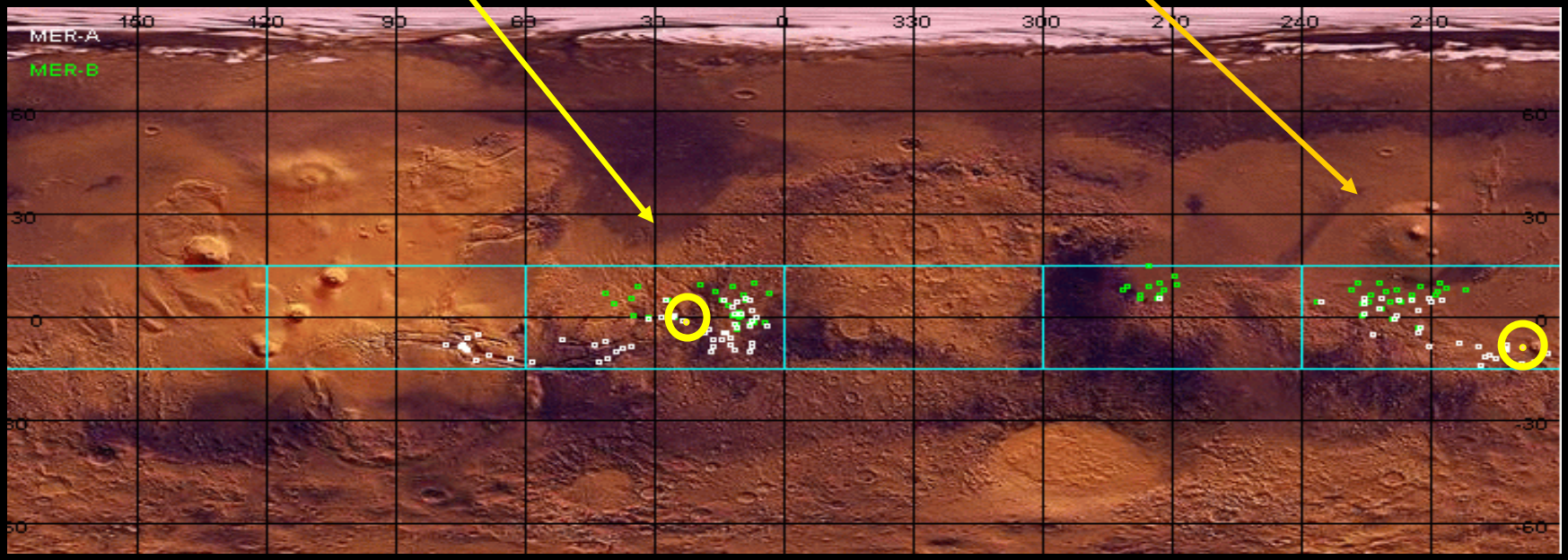
Meridiani

Water-formed hematite?

Gusev Crater



Ancient lake sediments?



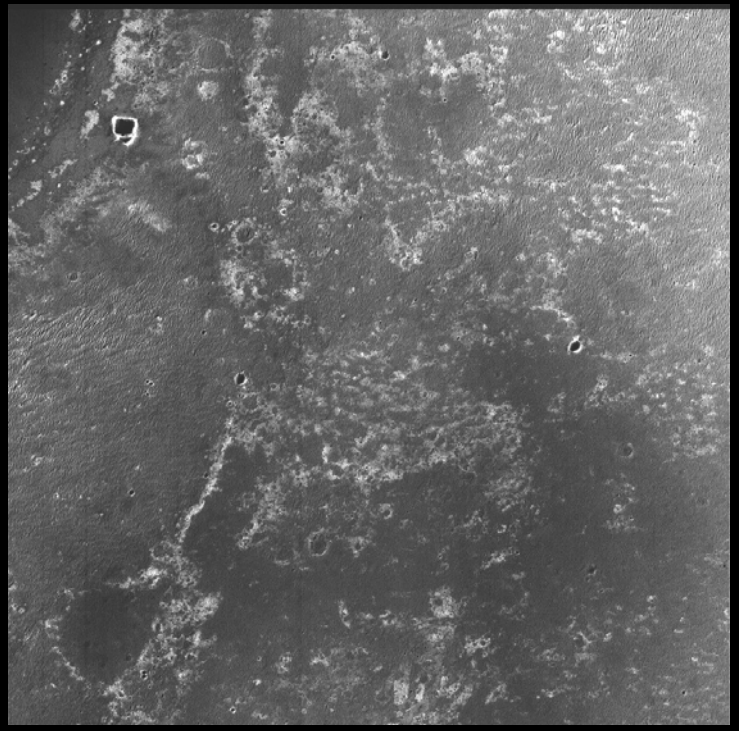
Gusev Crater

- Compelling evidence that water pooled in the crater
- Lakebed deposits can preserve substantial evidence of past water-related processes, environmental conditions, and habitability
- Ice-covered lake? Short-lived playa lakes? Muddy debris flows? Ancient highland rocks deposited in the crater?

Meridiani Planum

<u>Gray hematite</u>: Precipitate from large standing body of water? Precipitate from warm percolating water? Cold ground water? Surface weathering coatings on rocks? High-temperature oxidation of volcanic rock?

119 km x 17 km landing ellipse (75 miles x 11 miles)



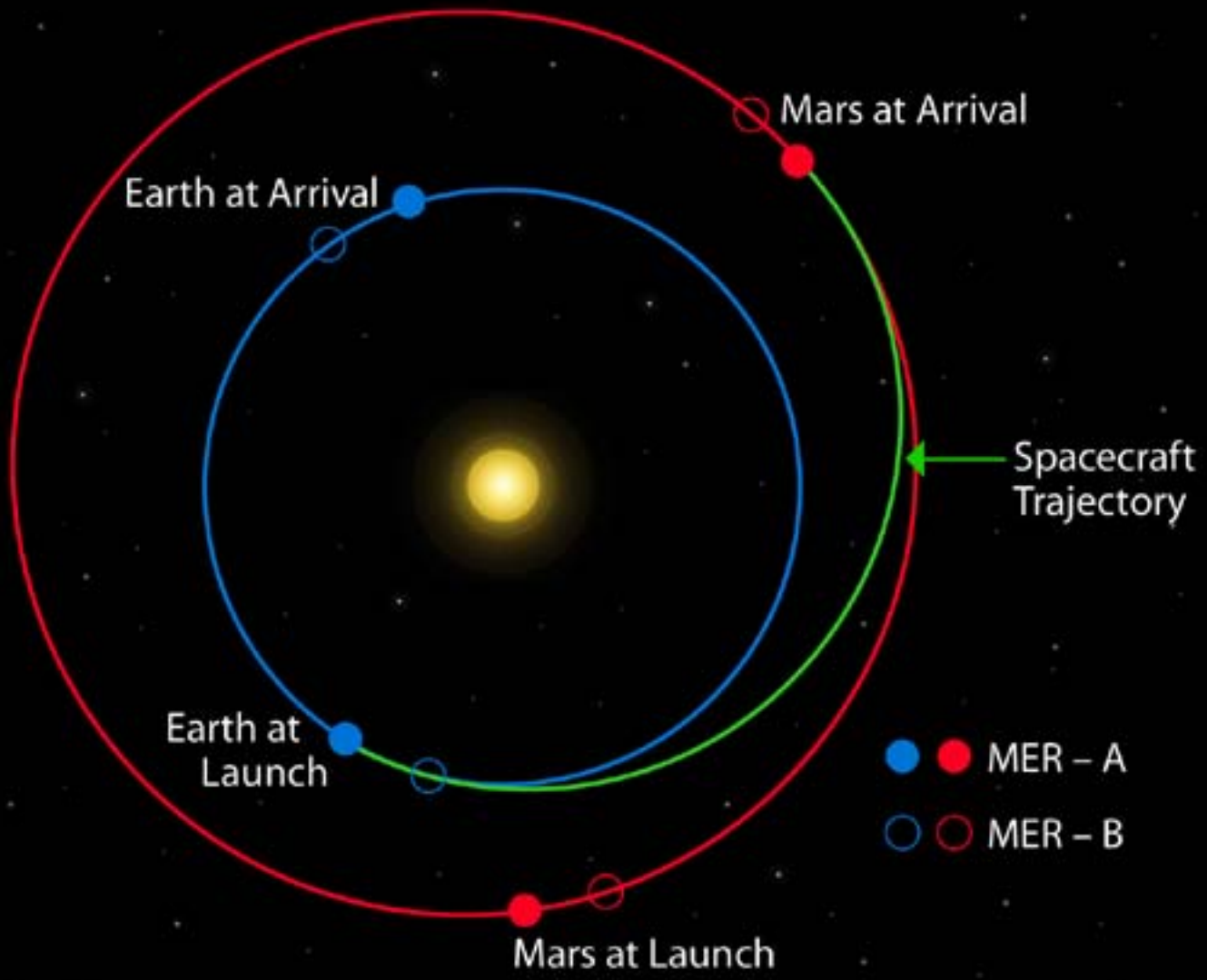
MOC image 3 km across, 3 m/pixel (2 miles across, 10 feet/pixel)

NASA/JPL/MSSS

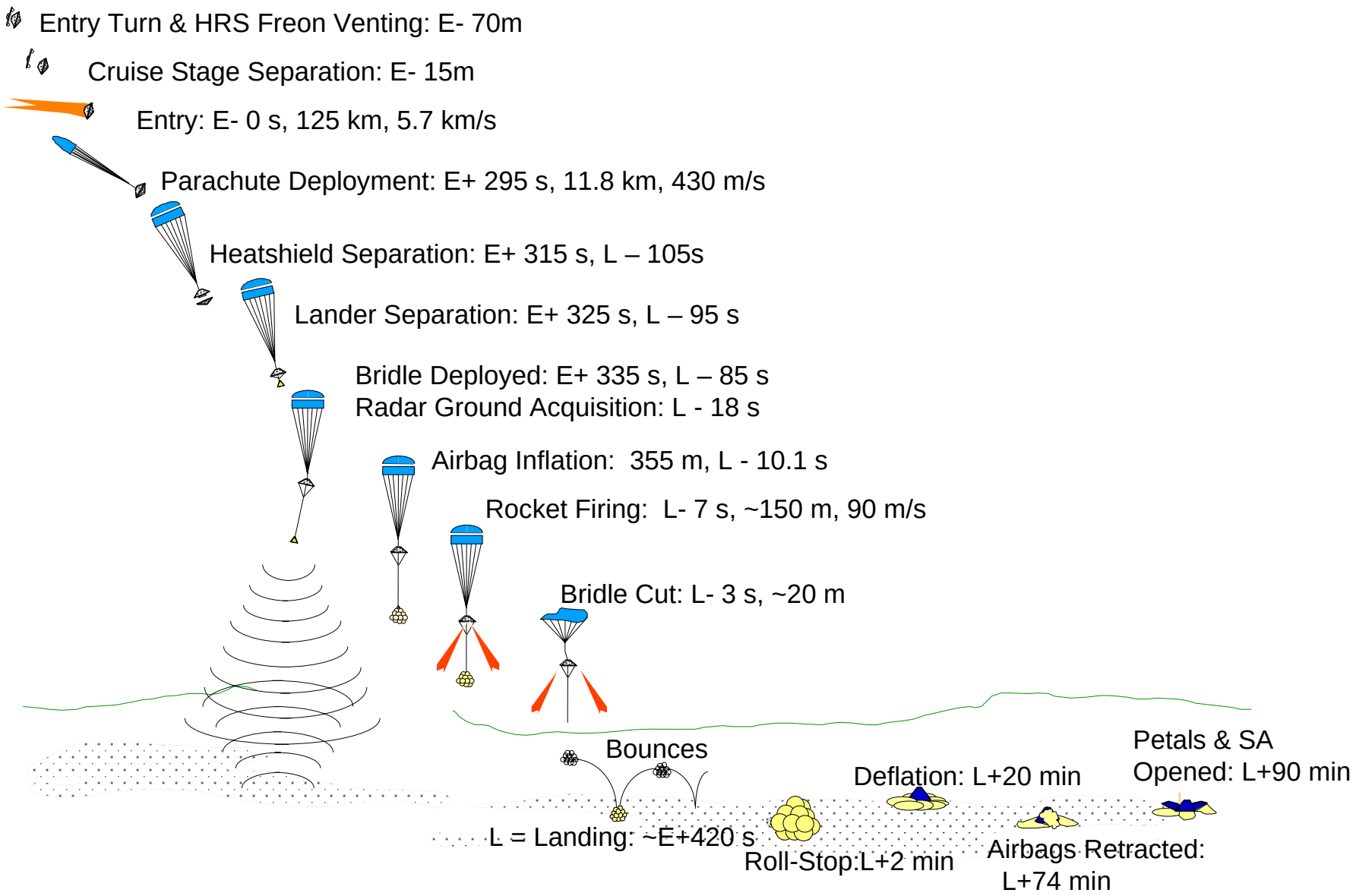
Spirit
DELTA

Opportunity
USAF
MDA
JCI
DELTA
MPF
NASA

The Cruise Trajectory



Entry, Descent, & Landing Timeline



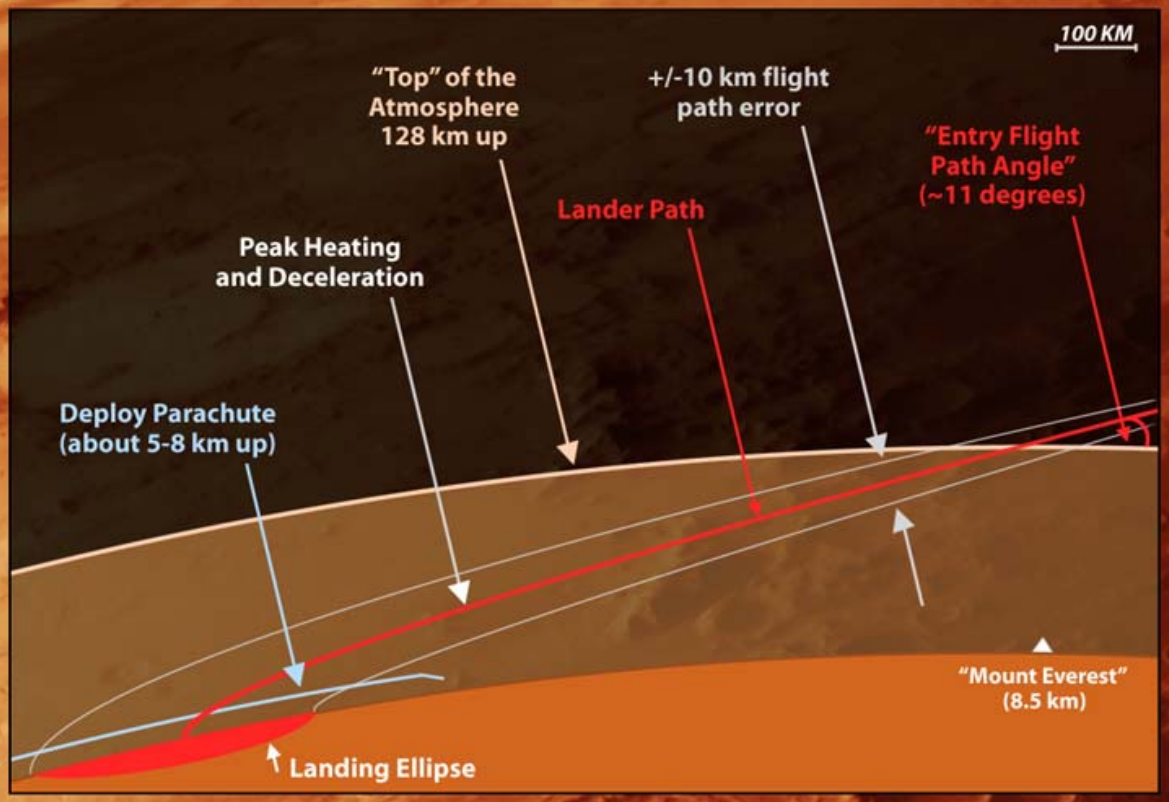
Opportunity EDL

Entry, Descent and Landing

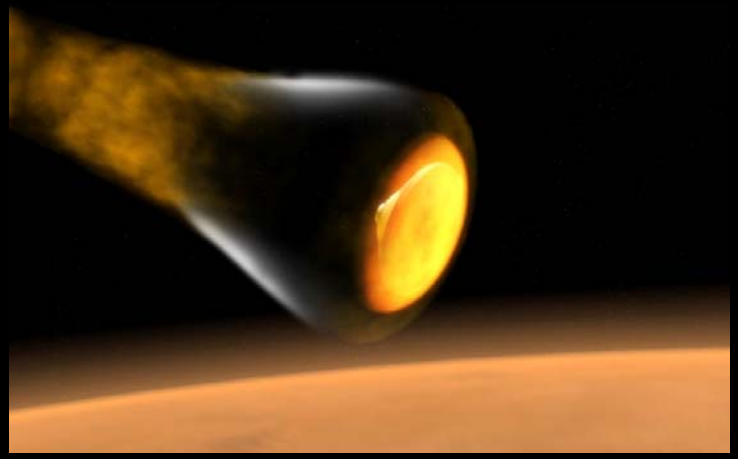
Entry: 11 Degree Angle

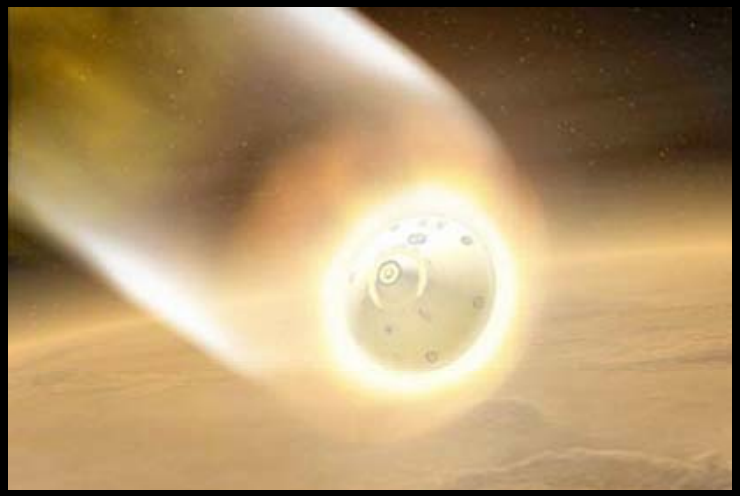
Any steeper and you get to the ground too fast!

Any shallower and you "skip out" back into space!

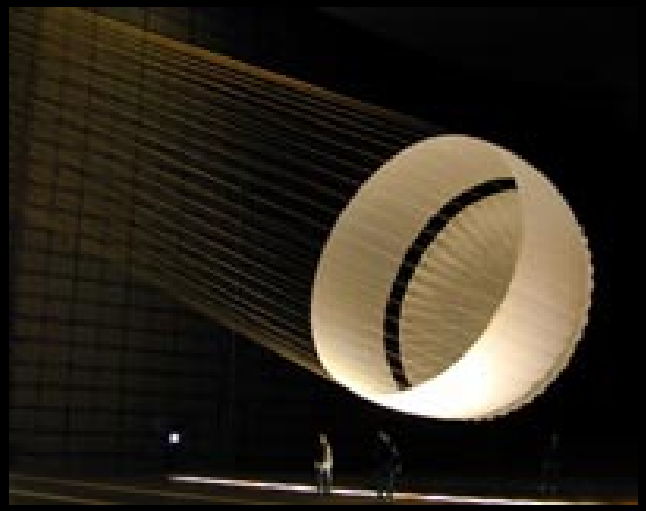


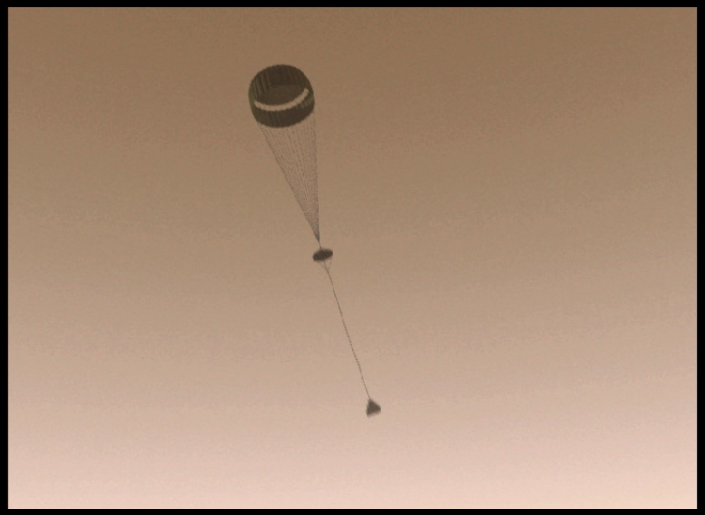
Heatshield takes out 90% of the energy

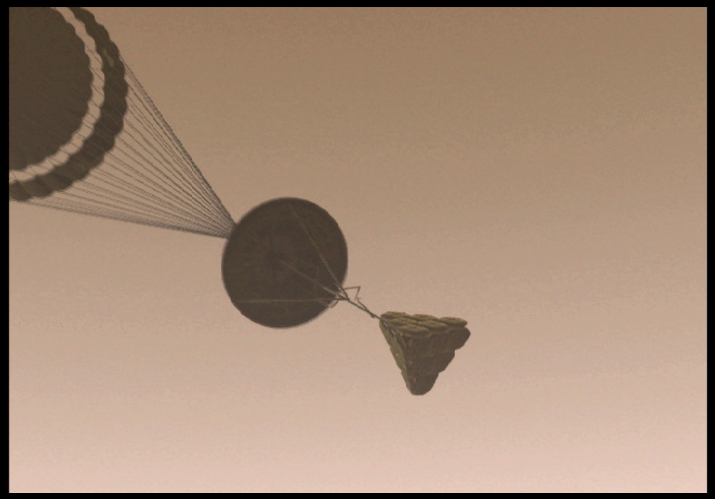


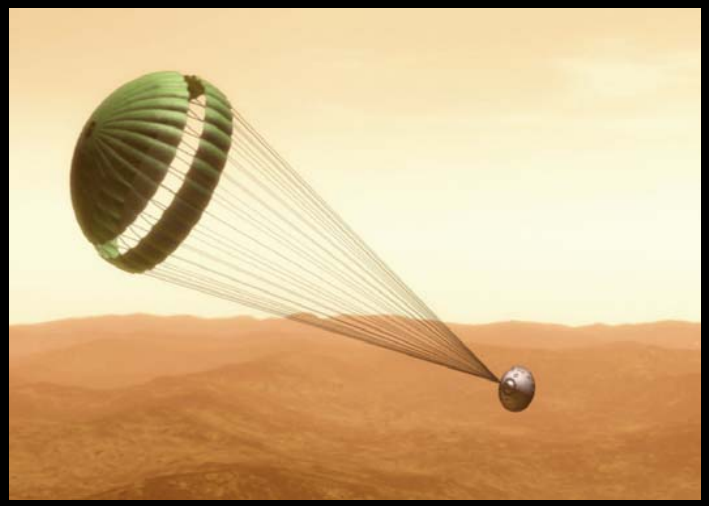


Parachutes open at Mach 1.3 and slow the lander to 200 mph

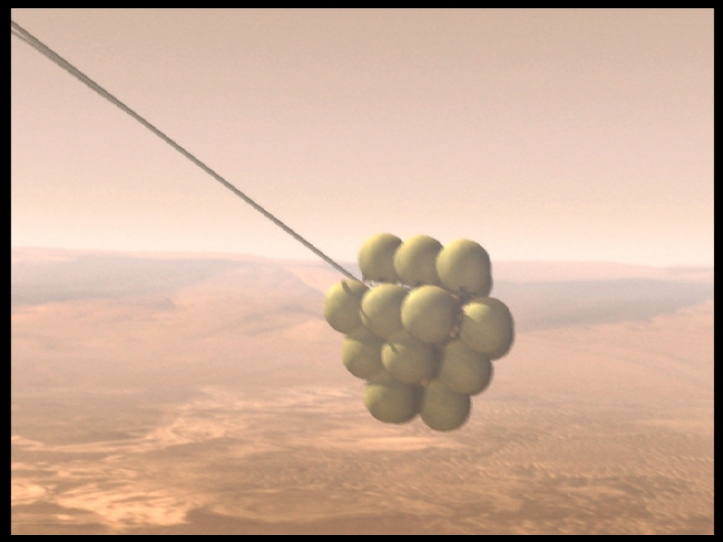


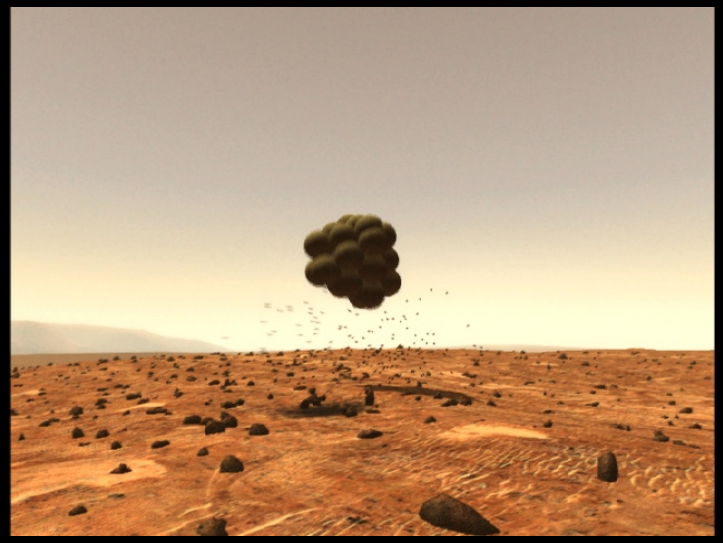






Rockets and airbags do the rest

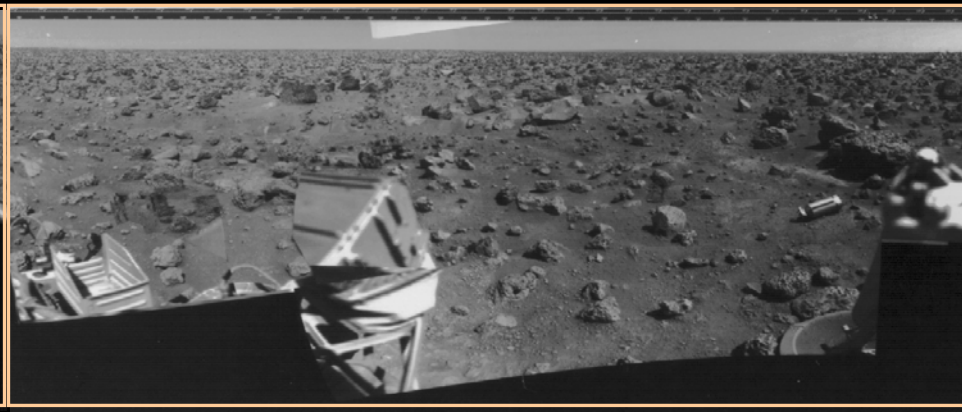




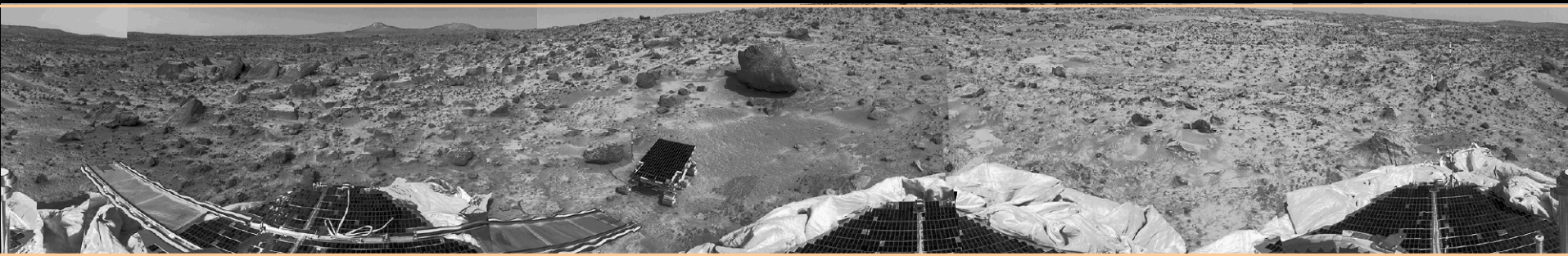
Another Successful Landing!

Martian Landscapes

Viking 1



Viking 2

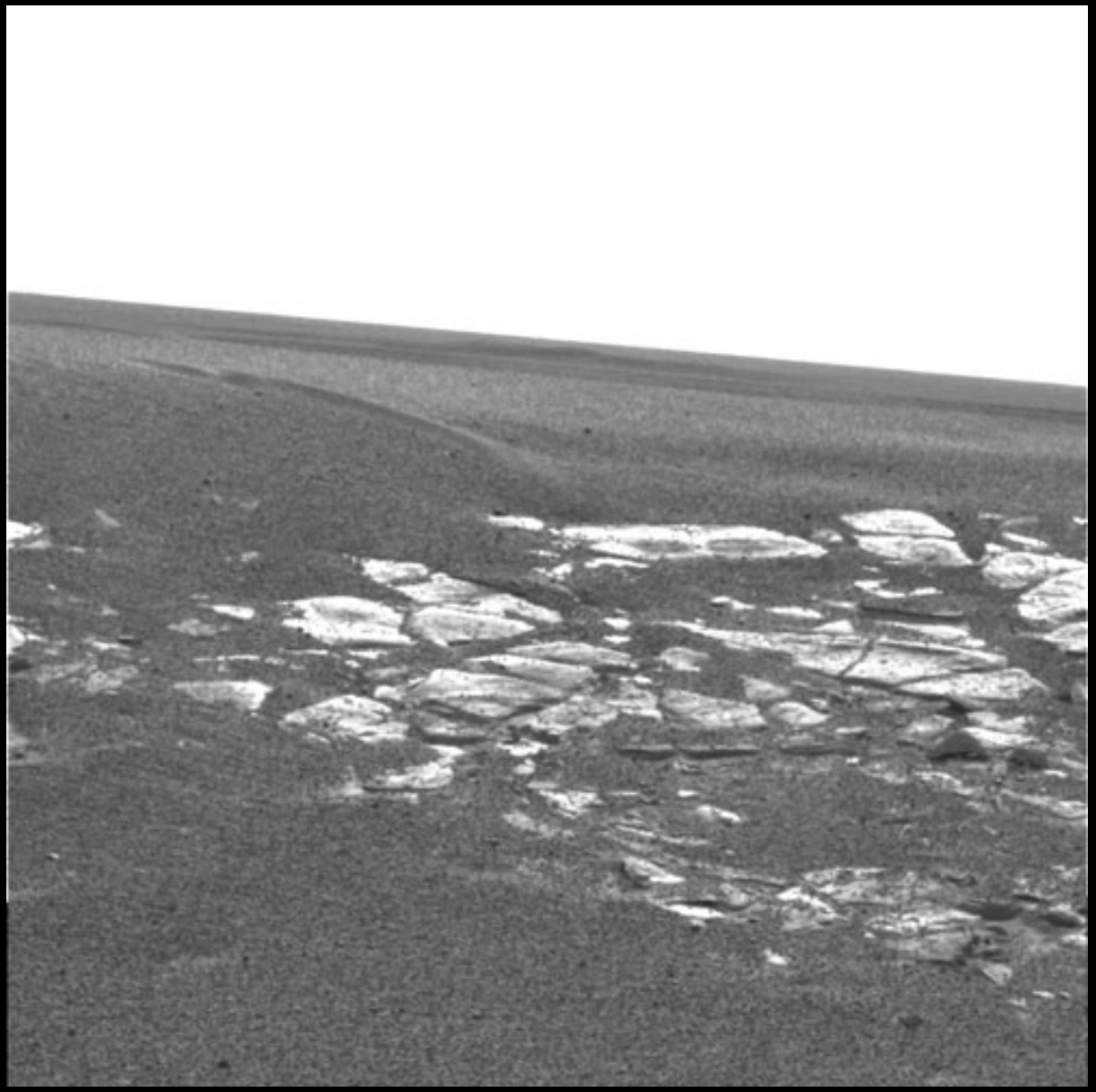


Pathfinder ↑

↓ Spirit

A new view

A new view

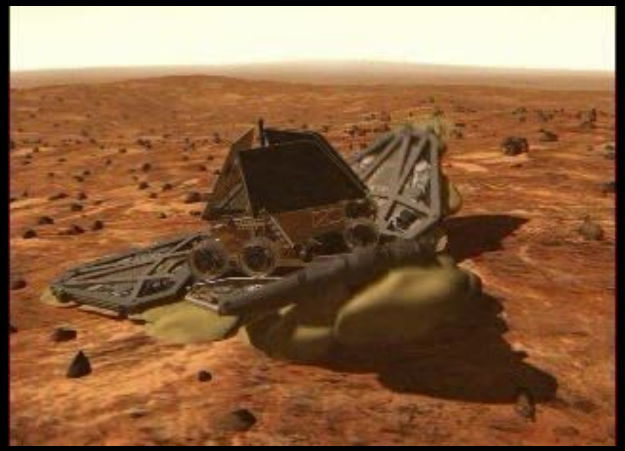
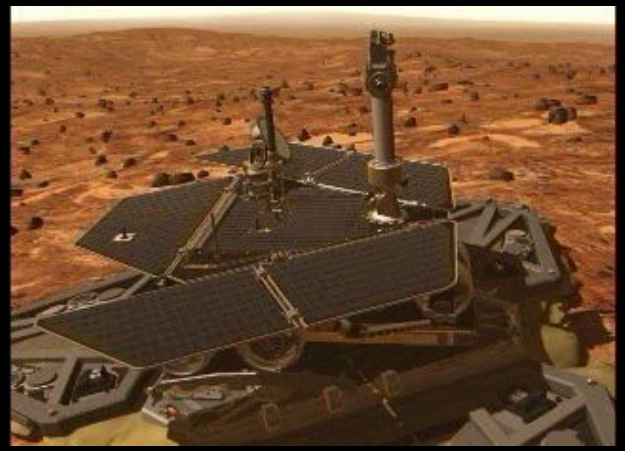
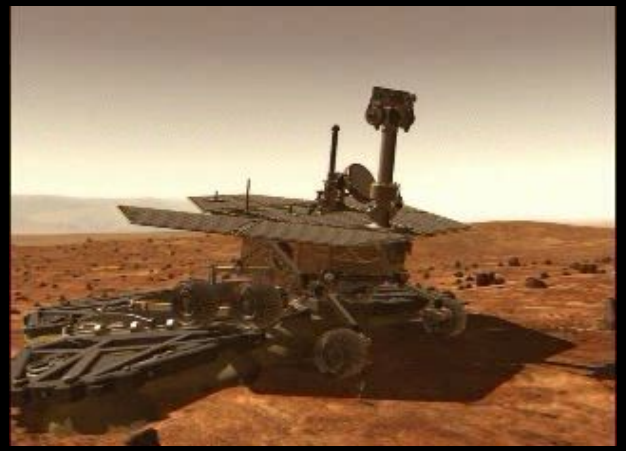


Once safe on the surface, it’s time to:

Open up the lander and unfold the rover,

Call home,
Look around,

Get moving and explore!

Operations Timeline

Surface Operations

Operate

Uplink

Downlink

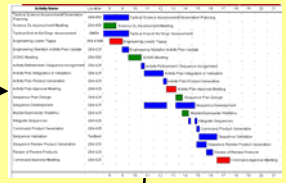
Activity Planning

Science D/L Mtg

Engineering Tag-up

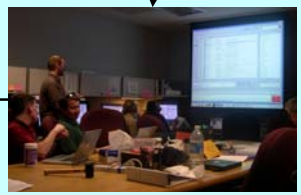
Science Planning

Activity Plan

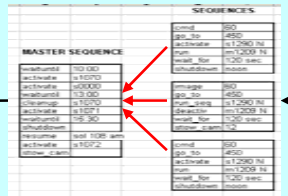


Sequencing

Master Sequence



Integration & Validation



Uplink & Review Products

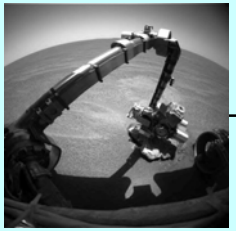
FLIGHT RULES	
do not shutdown during comm	✓
earth in control after resume	✓
stow camera before shutdown	✓
don't use ground flagged cmds	✓
do not operate science during UHF	
do not drive during comm	
do not deactivate IDD seqs	

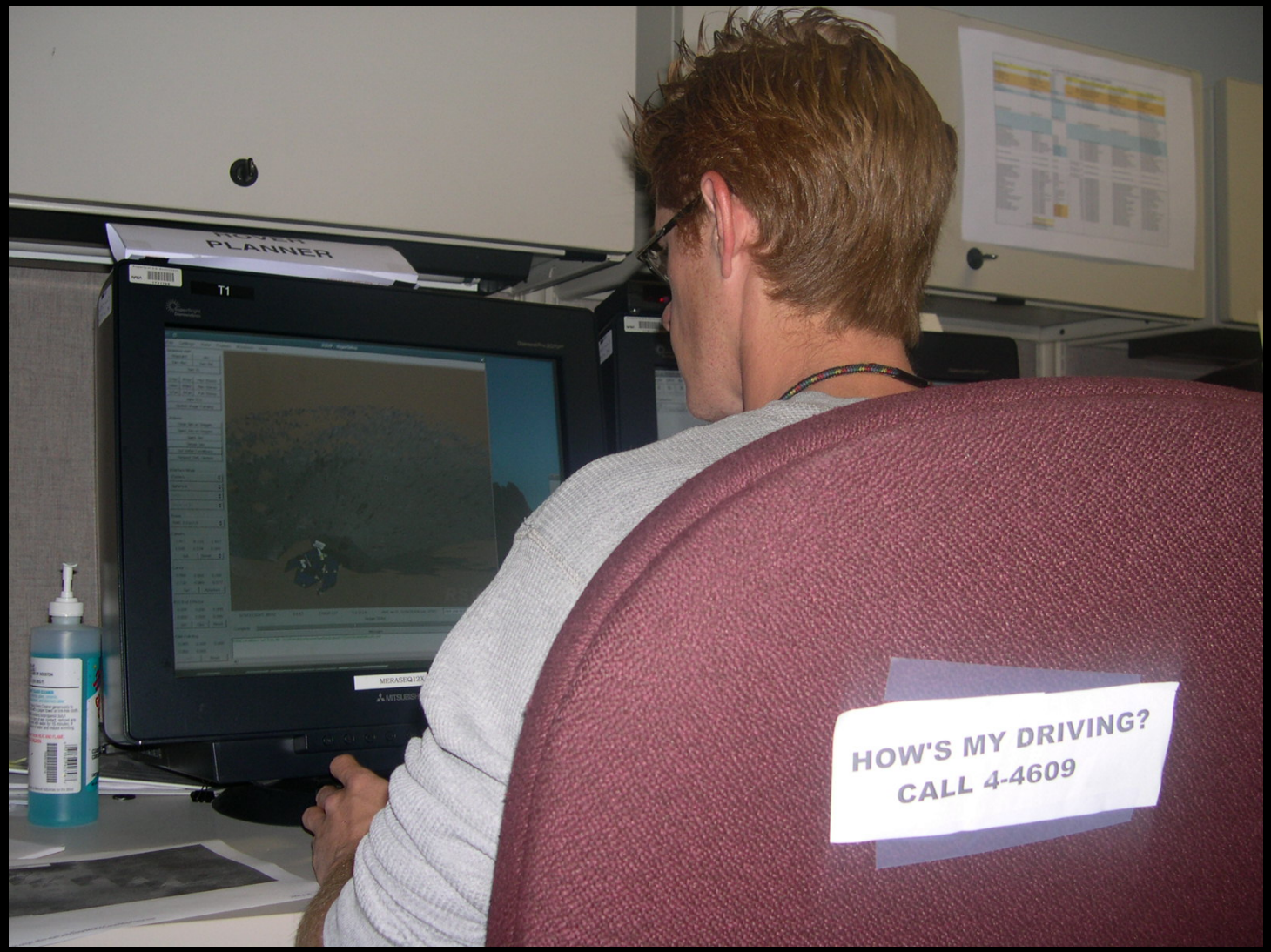
Command Approval Meeting

Engineering Sequences

Final sequences

Science Sequences

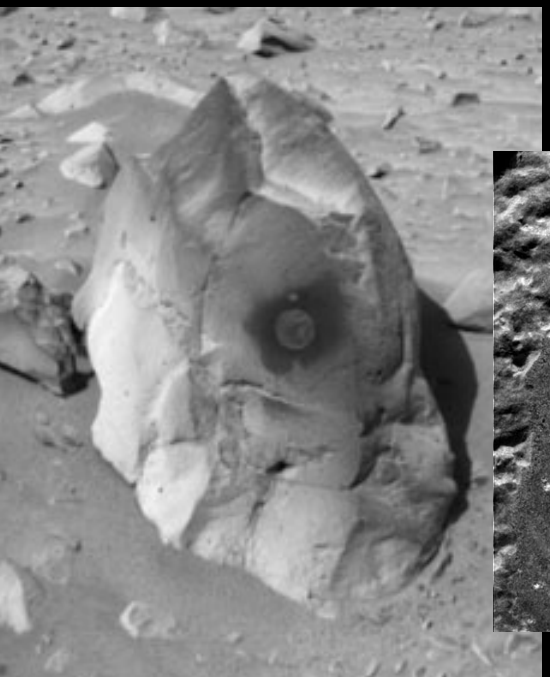


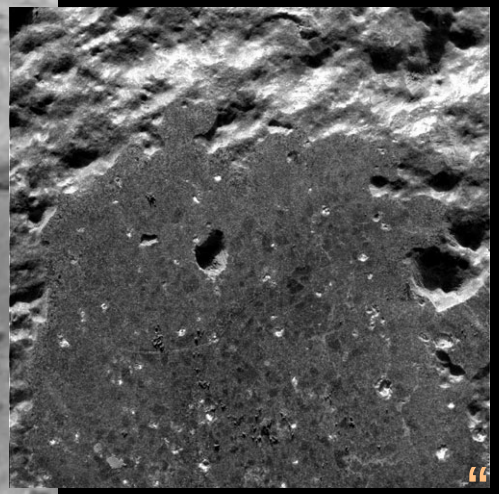

PLANNER
T1
HOW'S MY DRIVING?
CALL 4-4609

Science Results

Preliminary Hints of Water @ Gusev

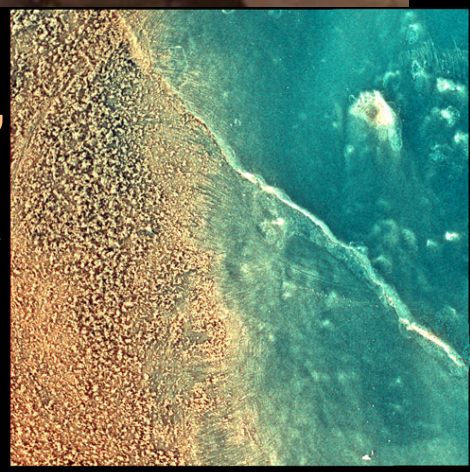
- Fractures filled with alteration material indicate rocks may have been altered by a small amount of water





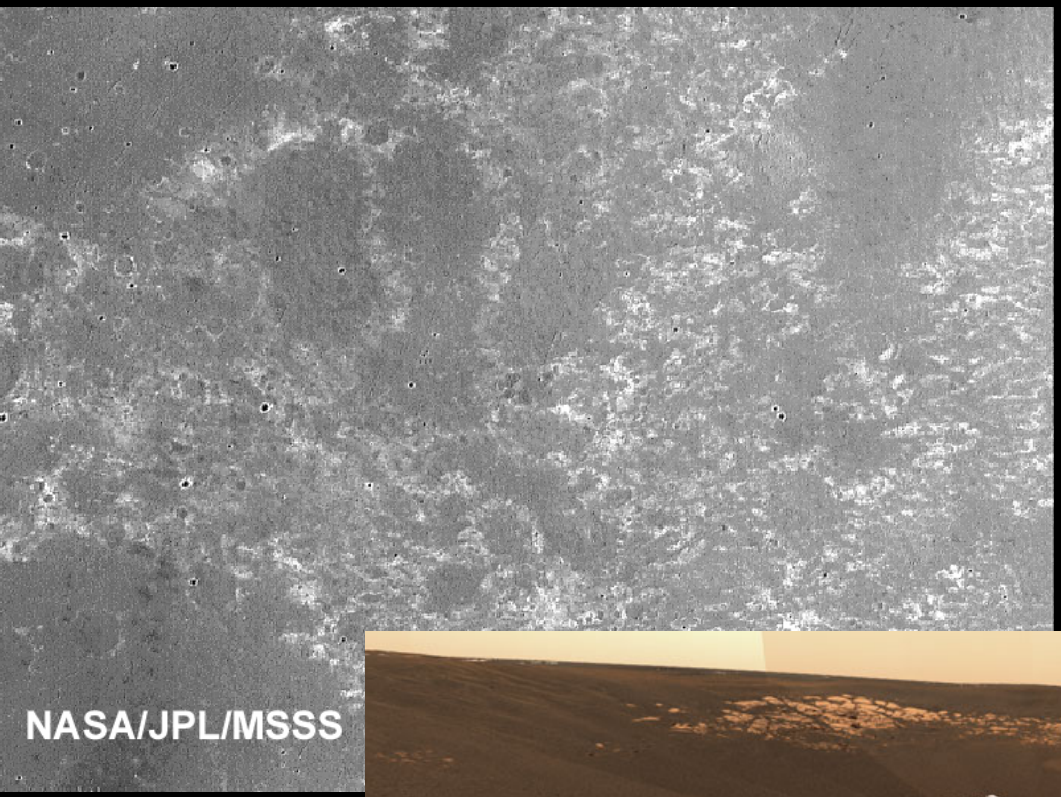
"Humphrey"

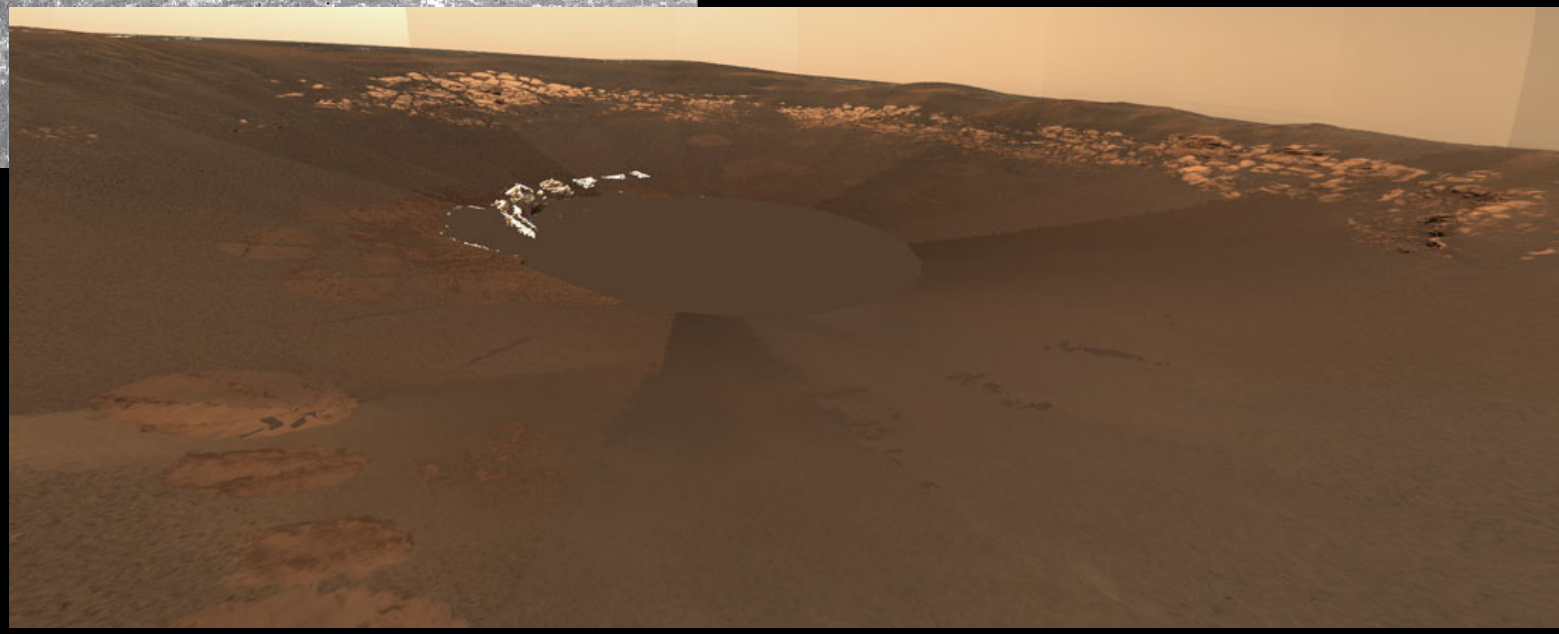
"Mazatzal"



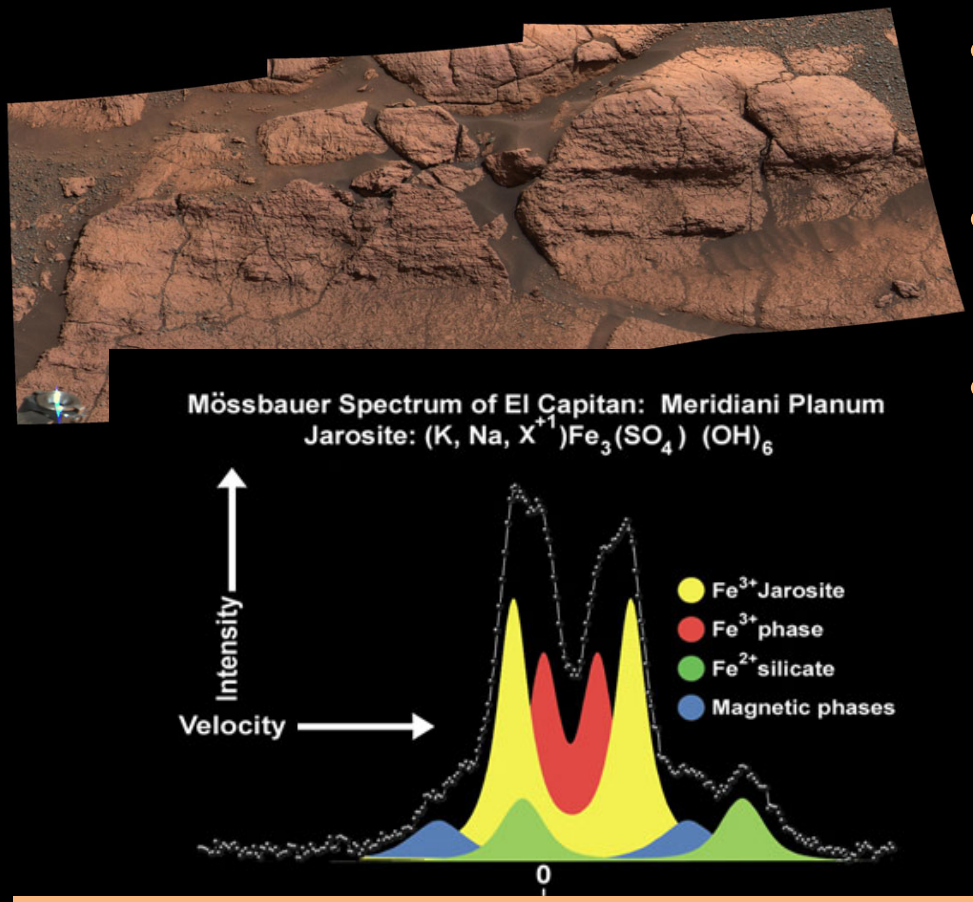
By Steve Kelley, *The Times-Picayune*, New Orleans, Creators Syndicate

Evidence of Water @ Meridiani





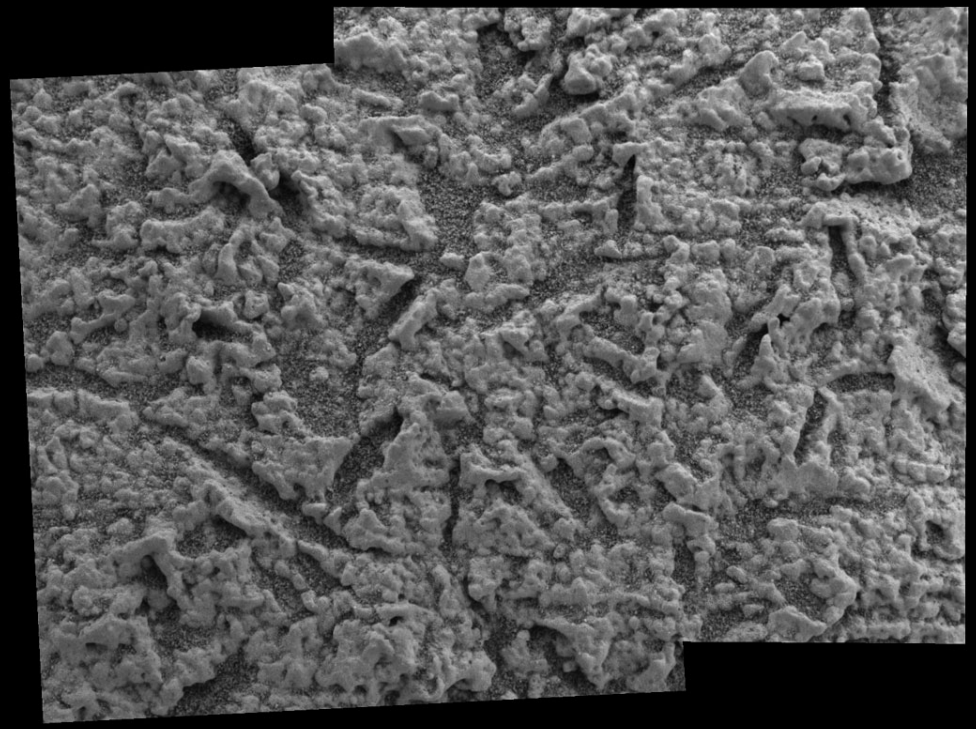
Chemical Evidence

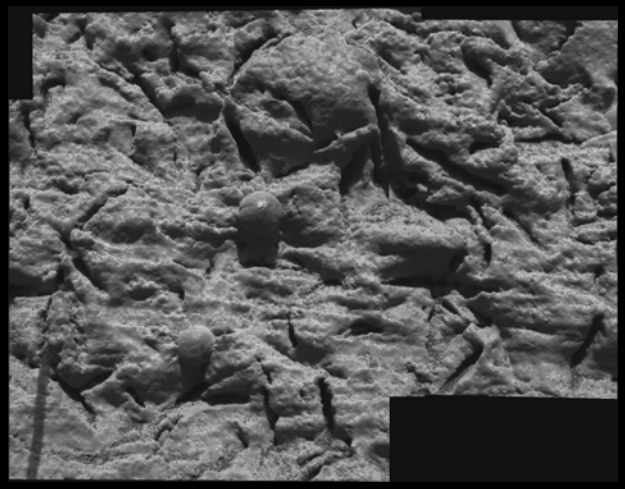


- High concentrations of sulfate salts
- Jarosite (hydrated iron sulfate)
- On Earth, rocks with as much salt as this mars rock either have formed in water or, after formation, have been altered by long exposures to water.

Geological Evidence: Vugs

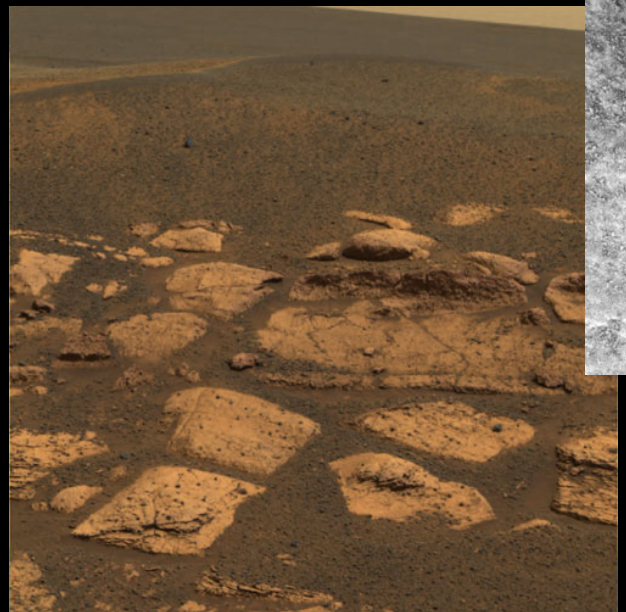
- Crystals of salt minerals form within rocks that sit in briny water.
- Crystals disappear by erosion, or by dissolving in less-salty water
- Voids, called ‘Vugs’ are left behind.
- Vugs shown are about 1 cm long

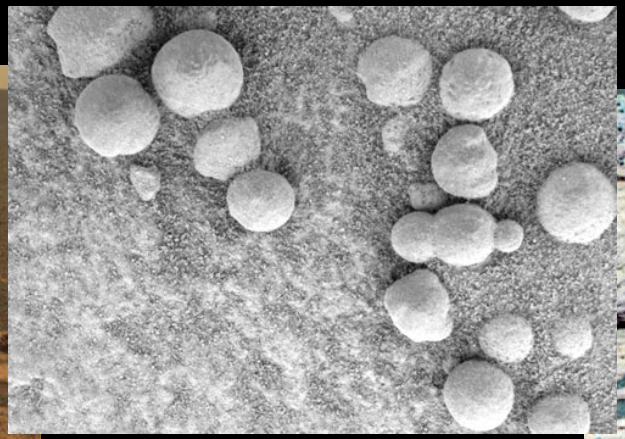


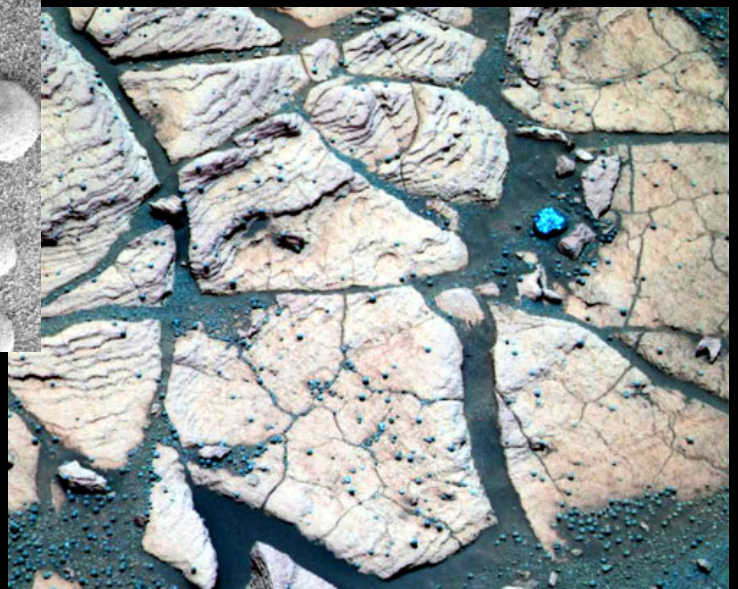


Geological Evidence: Spherules

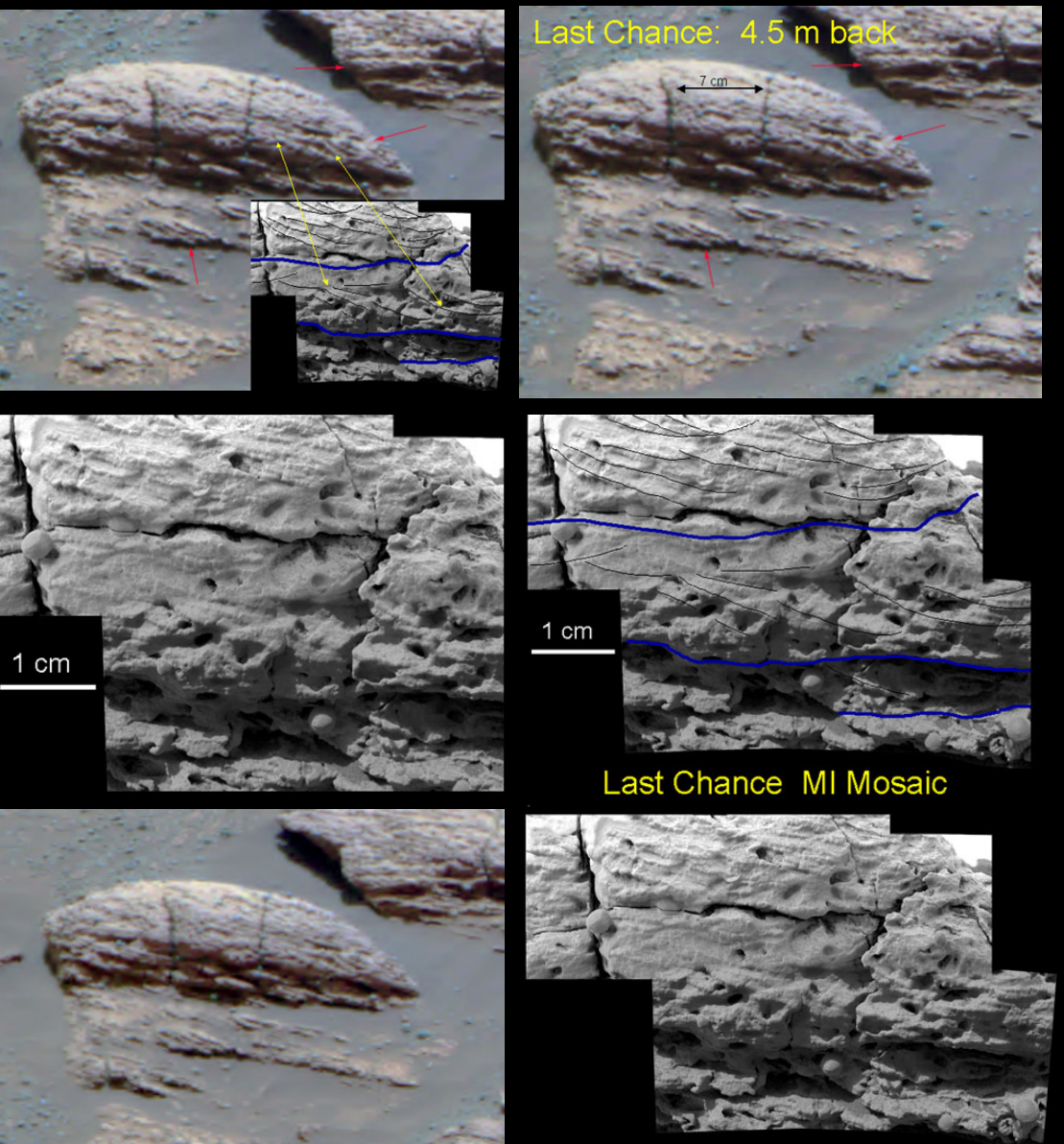
- "Blueberries" could be formed by:
  - Volcanic Eruption
  - Molten rock ejected during impact
  - Accumulation of minerals coming out of a solution inside a porous, water soaked rock
- Hematite
- Grain Size consistent with hematite formed in a wet environment.
- Interlocking spherules, random distribution support a wet past





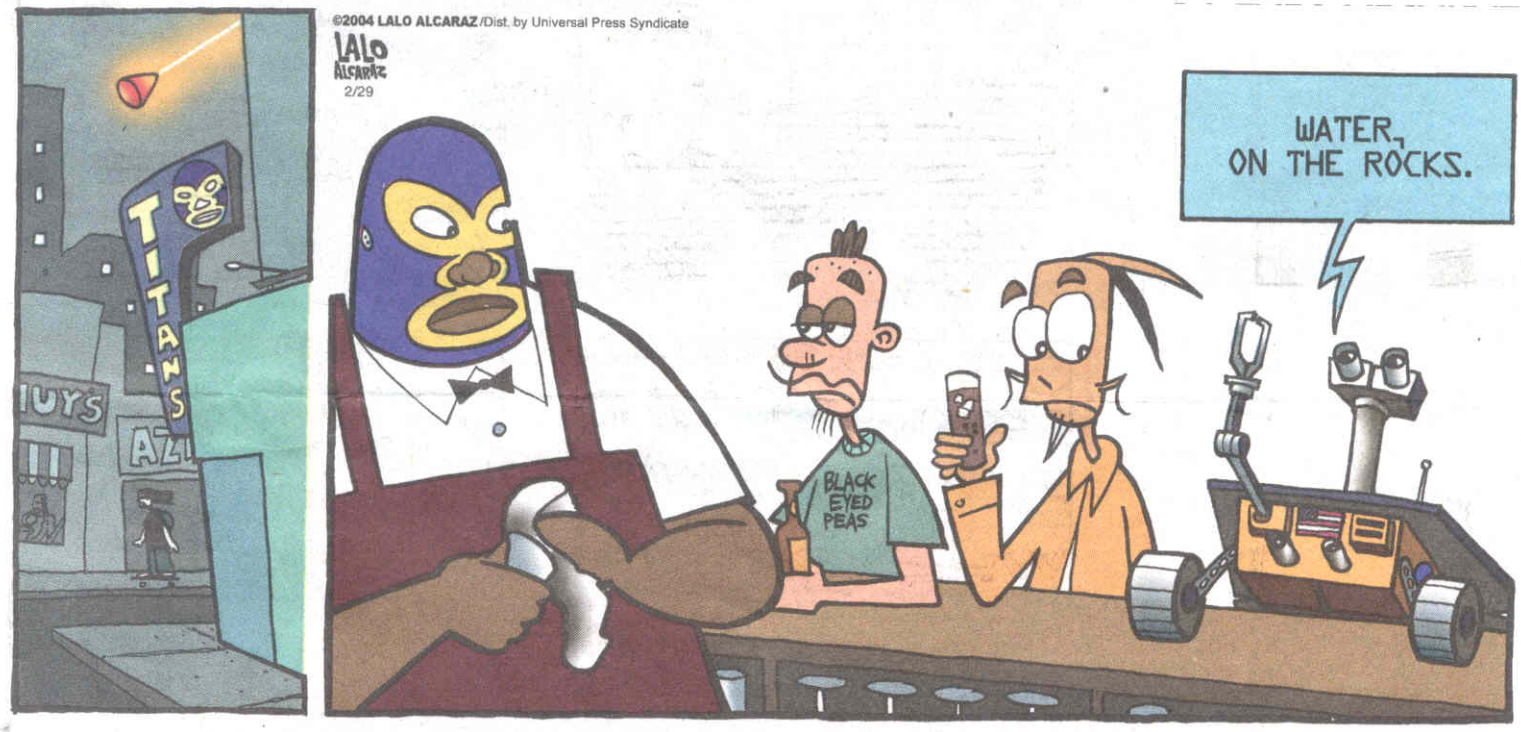


Geological Evidence: Cross-Bedding



- Layers that lie at an angle to main layers can result from the action of wind or water
- The small scale and concave patterns shown here hint at water.

LA CUCARACHA By Lalo Alcaraz



Mars in the classroom

- http://marsrovers.jpl.nasa.gov/classroom/

- Classroom Activity Guide
  - Rover Races
  - Martian Candy Core Samples

Before and After

image credit: NASA/JPL/Malin Space Science Systems.

Before and After

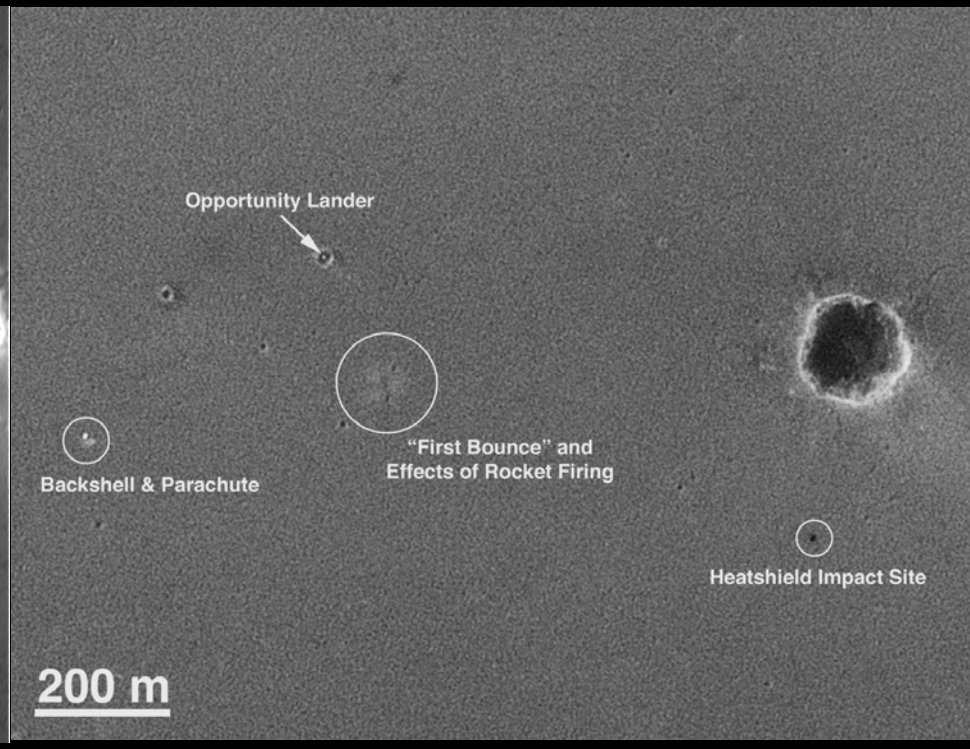
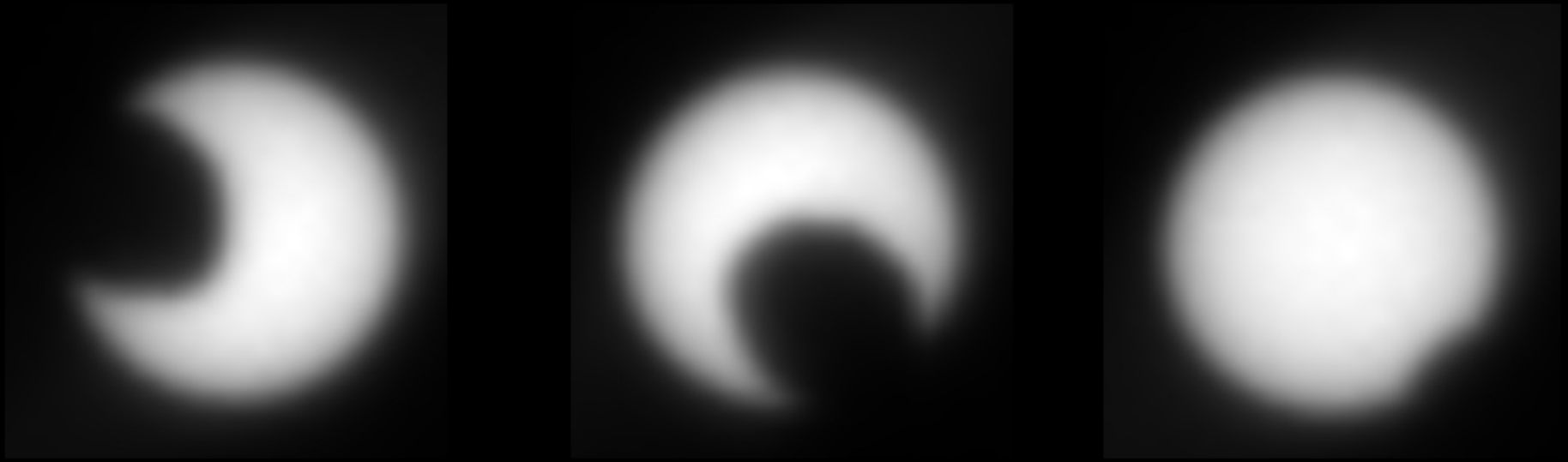
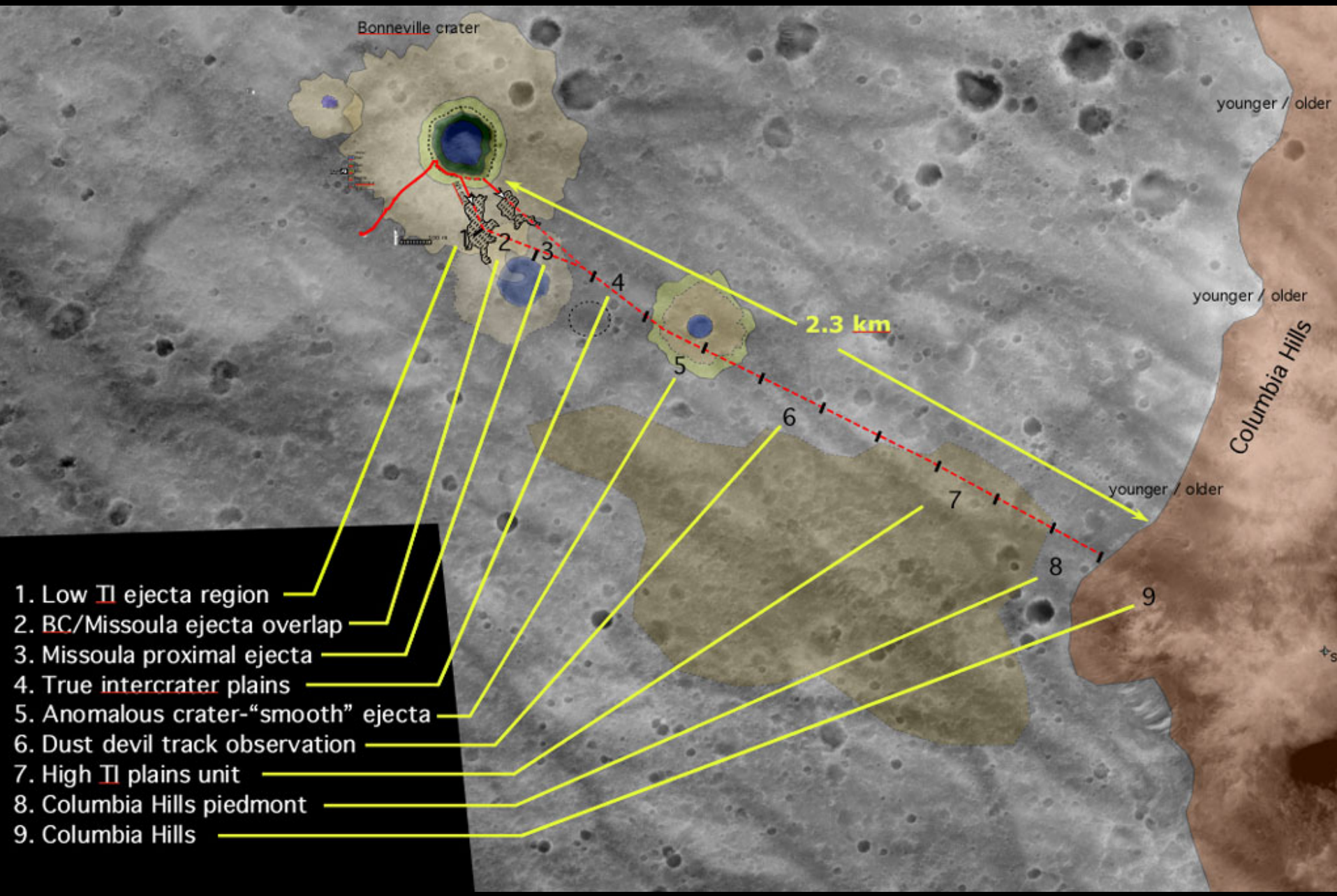


image credit: NASA/JPL/Malin Space Science Systems.

You are here

Additional Images




Bonneville crater
younger / older
younger / older
younger / older
Columbia Hills
2.3 km
2
3
4
5
6
7
8
9
1. Low TI ejecta region
2. BC/Missoula ejecta overlap
3. Missoula proximal ejecta
4. True intercrater plains
5. Anomalous crater-"smooth" ejecta
6. Dust devil track observation
7. High TI plains unit
8. Columbia Hills piedmont
9. Columbia Hills

Extras

- Spirit's Drive to Bonneville
- Spirit Launch
- Fun Stuff
- Extra Images

Cocktail Contest Winner
Spirit of Mars
A galactic blend of SKYY Vodka, Kahlua, Hiram Walker Butterscotch Schnapps and fresh milk, perfectly shaken and topped with chocolate sprinkles and whipped cream.
SKYY
SKYY
Created By
James Cummings
James Cummings, Vancouver International Airport
Grand Prize Winner
2003 Airport Mixology Contest
SKYY VODKA ©2003 40% Alc./Vol. (80 Proof)
©2003 Kahlua® Liqueur, 26.5% Alc./Vol. (available only in Ohio) Allied Domecq Spirits USA, Westport, CT. Mix Freely. Drink Responsibly.
Drink Responsibly.
Drive Responsibly.

Move over Rover.

MARS IMAGE CREDIT: NASA/JPL/CORNELL

Outlander has arrived.

No matter whether you're 55 million kilometres from Earth or 55 kilometres from anywhere, it pays to invest in reliability.

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PRESS RELEASE

NASA FINDS OCEAN WATER ON MARS!
LONG JOHN SILVER'S GIVES AMERICA FREE GIANT SHRIMP TO CELEBRATE

***

Long John Silver's President Calls Discovery
"One Small Step for Man, One Giant Leap for Giant Shrimp"

LOUISVILLE, KY, March 24, 2004 - NASA's March 23 announcement of evidence of the past presence of "a body of gently flowing saltwater" on Mars is big news for America, and giant news for seafood fans.

LJS President Steve Davis announces America will receive free Giant Shrimp on May 10, to celebrate NASA's discovery of salt water on Mars.

In January, Long John Silver's offered to give America free Giant Shrimp if NASA found conclusive evidence of an ocean on Mars. **To celebrate the success of NASA's Mars Rover project, the company is going to give America free Giant Shrimp on Monday, May 10.**

"This is the big announcement that Long John Silver's has been waiting for since January - that there is evidence of a past salty sea on Mars," said Mike Baker, Chief Marketing Officer for Long John Silver's, Inc. "We can't wait to celebrate NASA's out-of-this-world success, and there's no better way to recognize their giant accomplishments than with free Giant Shrimp for America."

On Monday, May 10, between the hours of 2 p.m. and 5 p.m., customers can stop by any participating Long John Silver's restaurant and enjoy a free Giant Shrimp (one piece per customer).

Long John Silver's President Steve Davis sent a personal letter to NASA Administrator Sean O'Keefe, congratulating NASA on their discovery.

"We've been following the Mars Exploration project since the beginning," Davis wrote, "and we've been anxiously awaiting word of evidence of an ocean on Mars. The rovers have been extremely busy since they arrived on Mars - they've had 'plenty of things on their plate.' Now, with the discovery of ocean water, America can add one more thing to its plate - free Giant Shrimp."

Davis ended the letter by writing, "This is one small step for man, and one giant leap for Giant Shrimp." He also again expressed interest in Long John Silver's becoming the first seafood restaurant on Mars.

Baker added that the Giant Shrimp giveaway is the perfect way to celebrate NASA's historic discovery, which has taken place at the same time Long John Silver's Giant Shrimp introduction has been one of the most successful product launches in company history.

THE Jim Henson COMPANY

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Hollywood, CA 90028
Telephone 323.802.1500
Facsimile 323.802.1825

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New York, NY 10021
Telephone 212.794.2400
Facsimile 212.570.1147

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London NW1 7DE
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Facsimile 171.428.4001

www.henson.com

TO: MARS ROVER MISSION TEAM
Jet Propulsion Laboratory

FR: Dr. Bunsen Honeydew & Beaker, MUPPET LABS

RE: CONGRATULATIONS!

Dear colleagues,

It is with mixed emotions that Muppet Labs offers you a hearty "congratulations" on the recent success of your Mars Rovers, Spirit and Opportunity. While we realize that your remarkable accomplishment is a really nifty thing for the entire scientific community, we at Muppet Labs Mars Exploration Team (MULMET) wanted to get there first! We were so close: a mere three weeks—give or take a 20 year margin of error--from launching our own Mars explorers.

Nonetheless, in the spirit of scientific camaraderie and with a promise that we'll-beat-you-next-time, Muppet Labs sends you and your team an enthusiastic "Well done, bucko!"

Scientifically yours,

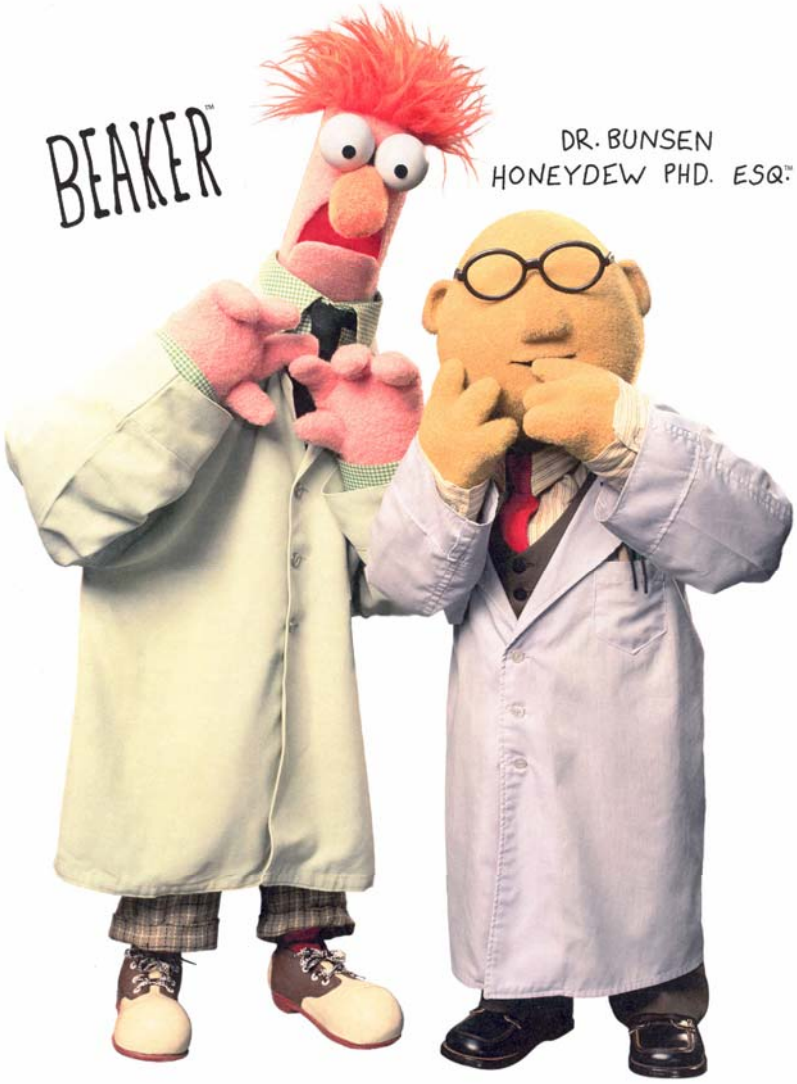
DR. BUNSEN HONEYDEW PHD. ESQ.™

DR. BUNSEN HONEYDEW

PS: If you continue to have difficulties with the Spirit Rover, my assistant Beaker is happy to offer free roadside assistance on Mars, utilizing our new, thoroughly untested Interplanetary Coil-Powered Catapult…or as we at MULMET like to call it "The Spring Fling".

PPS: Meep-meep-meep-meep-MEEP-MEEP-MEEP-MEEP!!!!!! NOT!

BEAKER™



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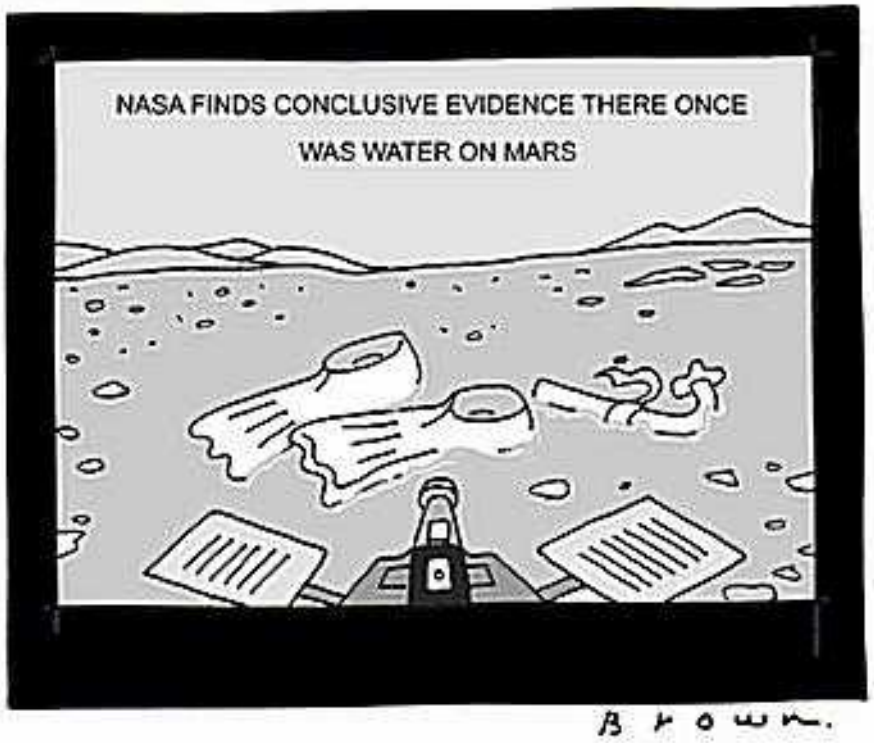


MARS EXPLORATION ROVER - A
1SLS
Red Planet Gladiators
NASA ★ BOEING ★ JPL ★ CORNELL

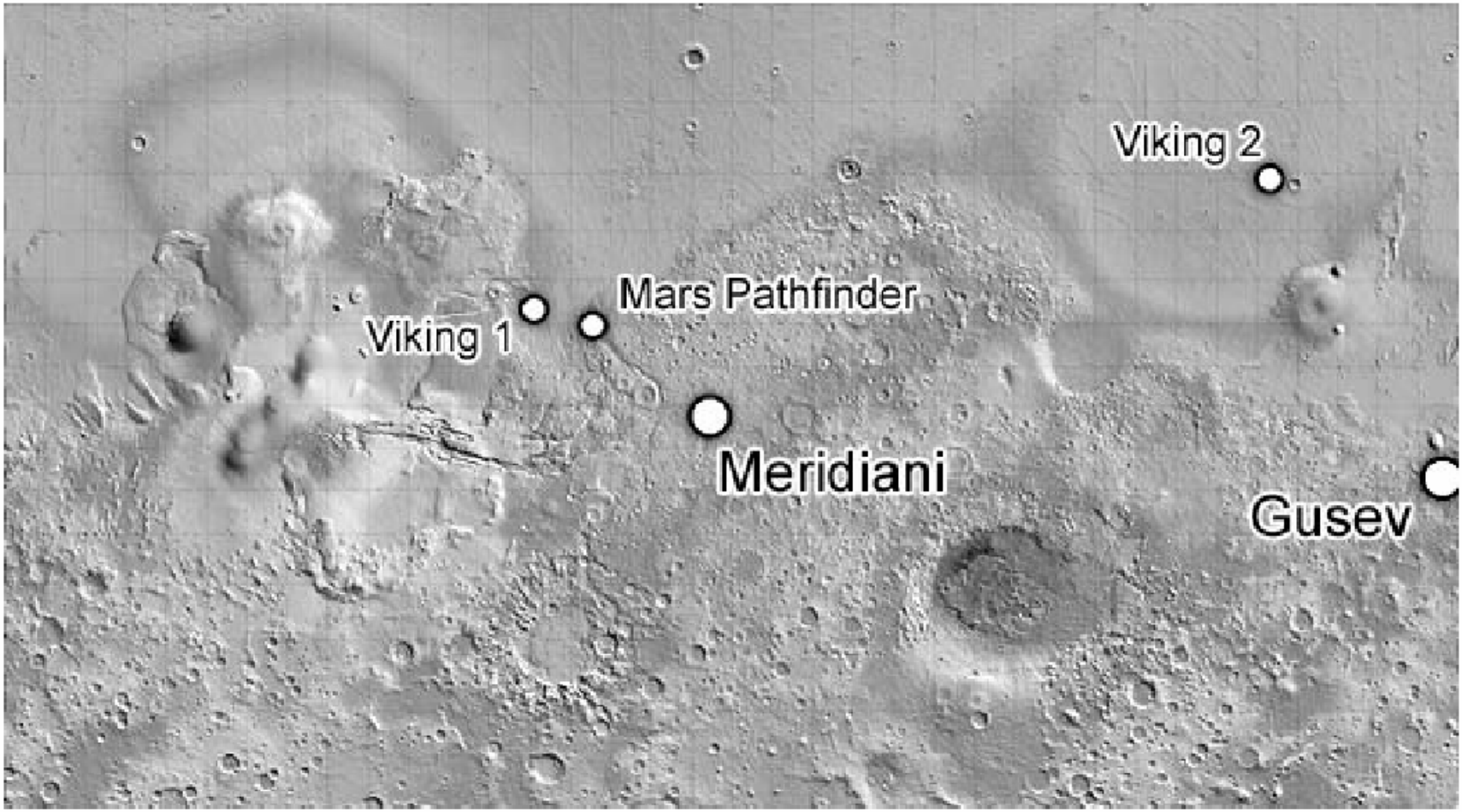
NASA BOEING JPL CORNELL
RED PLANET GLADIATORS
1SLS MERB
TEAM DELTA

Potential Records in 2005 Guinness

- First inspection of a rock interior on another planet: Spirit
- Biggest Science Web Event: MER (4.4 billion hits)
- Heaviest Rover on Mars: Spirit & Opportunity (174 kg each)
- Most bounces on surface of Mars: Spirit, 28
- Highest Resolution Image: Spirit & Opportunity
- Most Images returned by Mars Rover in 1 day: Spirit, 349
- Most Data returned by a Mars Rover: TBD
- Highest number of science instruments on a mobile surface probe: Spirit & Opportunity, 7 ea
- Fastest Rover on Mars, Spirit & Opportunity, 3 meters/minute
- Longest distance traversed in one sol, Opportunity, ~100 meters
- Most Sleep Deprived group, MER team
- Longest Living Rover on Mars, Spirit, 107 sols

Unused Material

Telescopes brought beliefs of canals and the Martians who could have built them.


Viking 2
Mars Pathfinder
Viking 1
Meridiani
Gusev

Mars in the classroom

- http://marsrovers.jpl.nasa.gov/classroom/
- http://origin.mars5.jpl.nasa.gov/classroom/students.html
- http://passporttoknowledge.com/mars/firstlook.html
- http://www.marsquestonline.org/mer/
- http://zipcodemars.jpl.nasa.gov/index.cfm

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