JPL Advisory Council

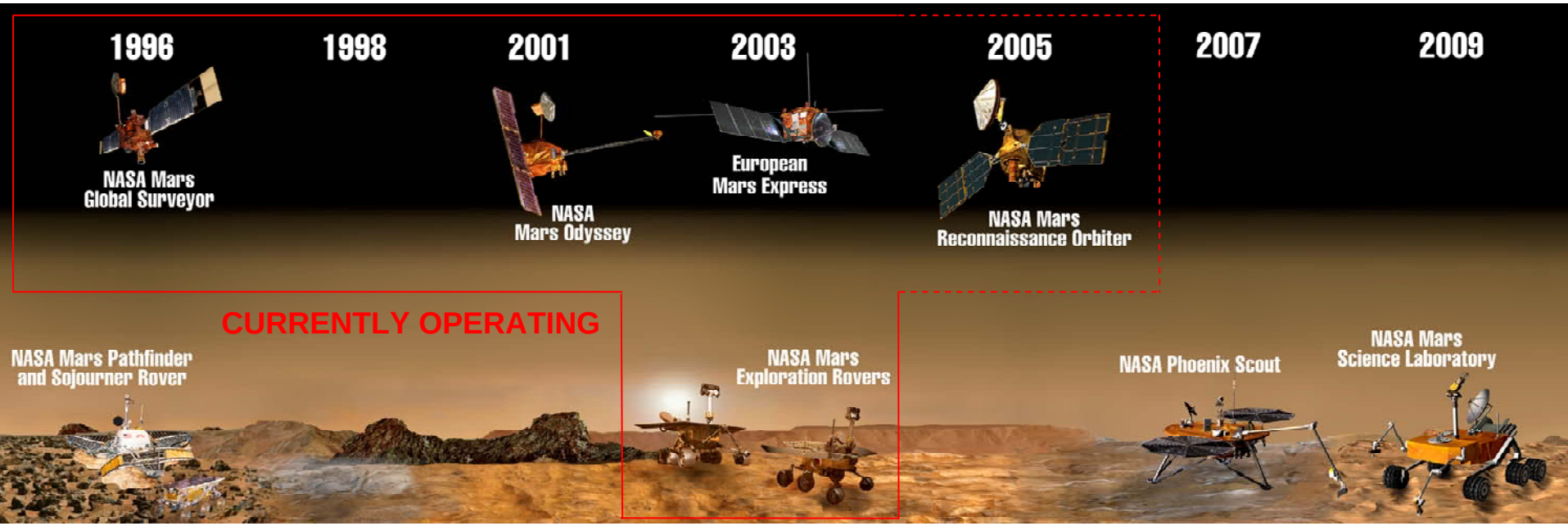
Mars Exploration Program

March 9, 2006

National Aeronautics and
Space Administration

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

Mars Exploration Program



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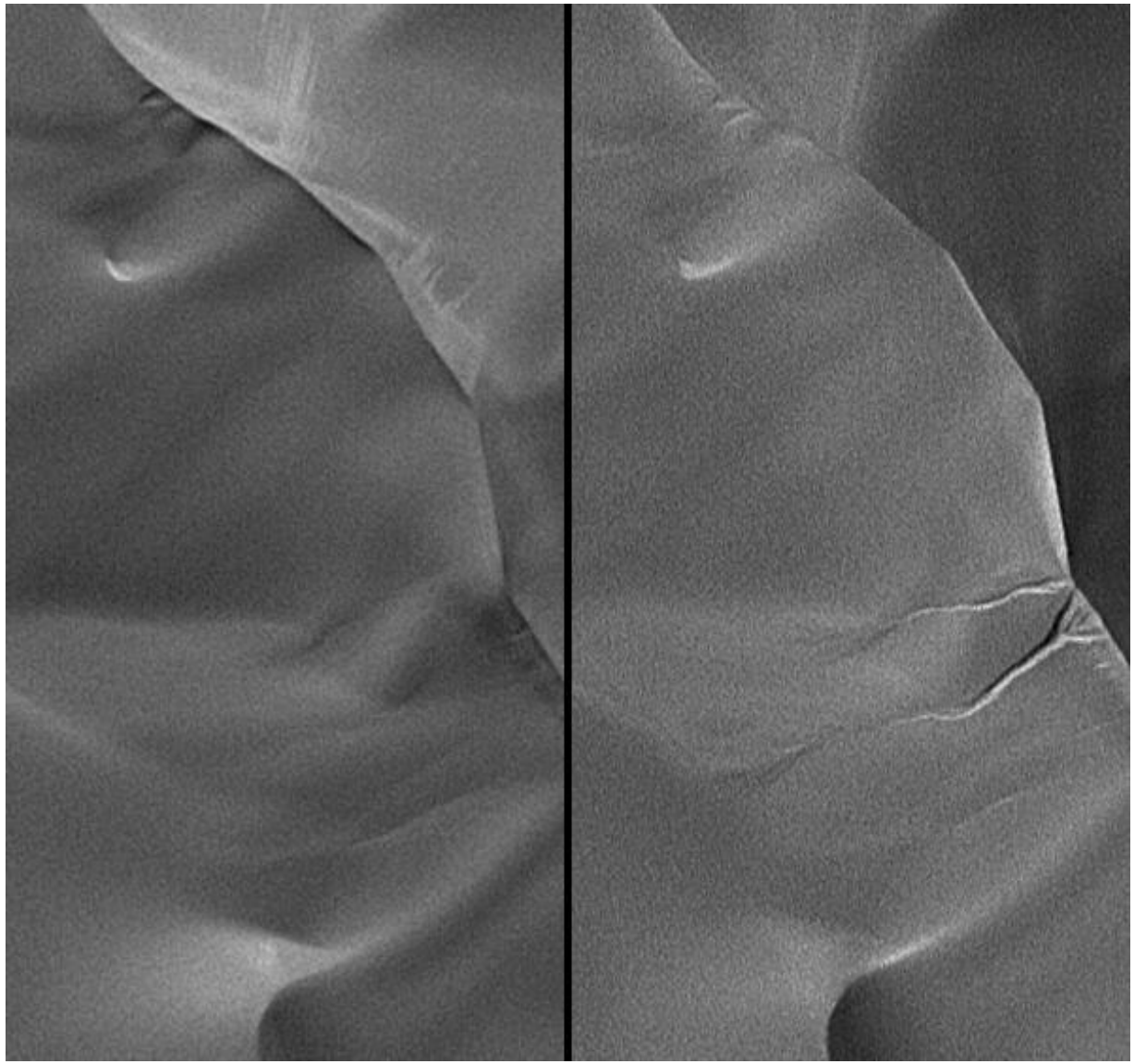
Mars Global Surveyor
Recent Formation of Gullies



July 2002 April 2005

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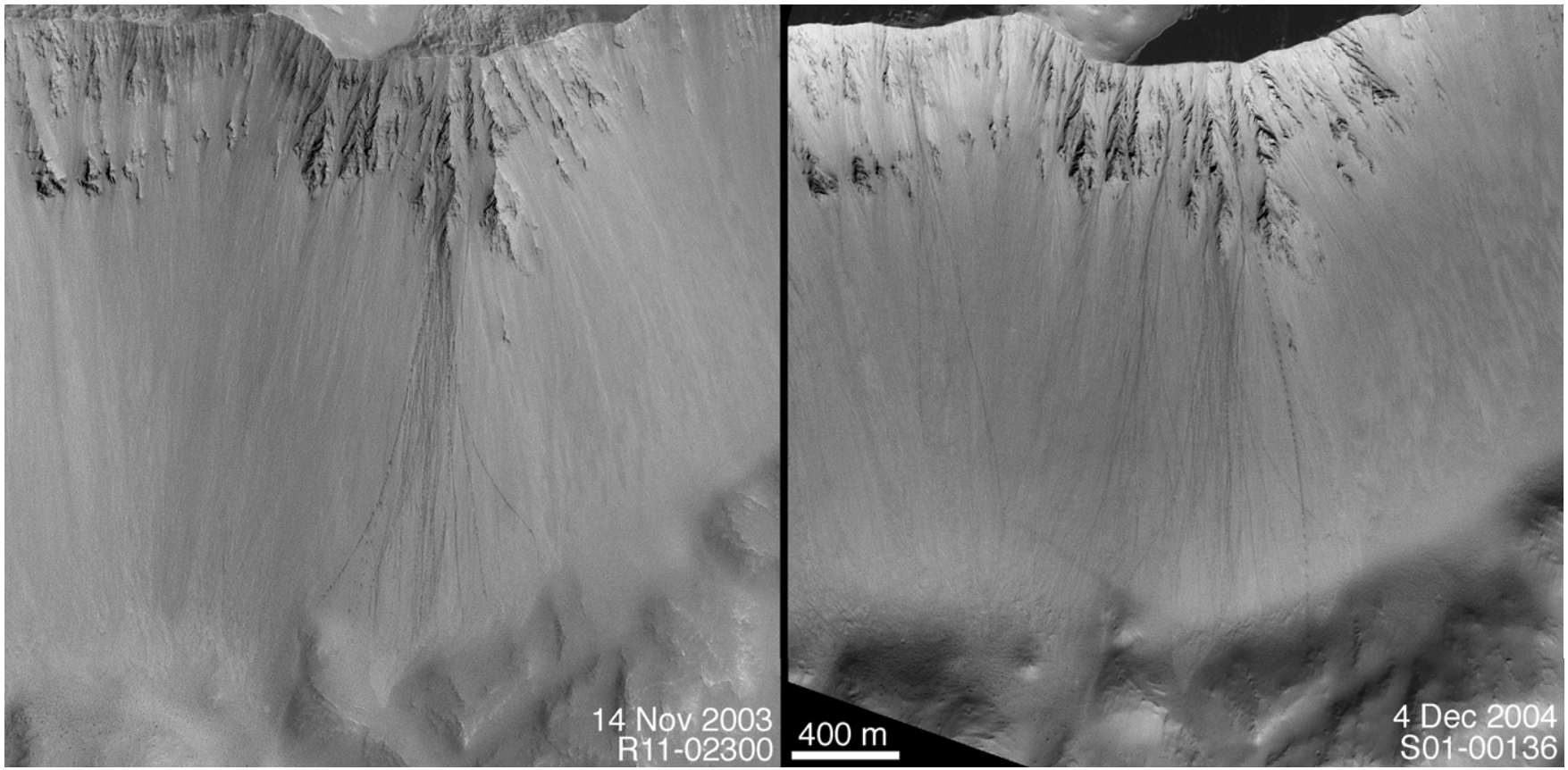
Mars Global Surveyor
Recent Formation of Boulder Tracks



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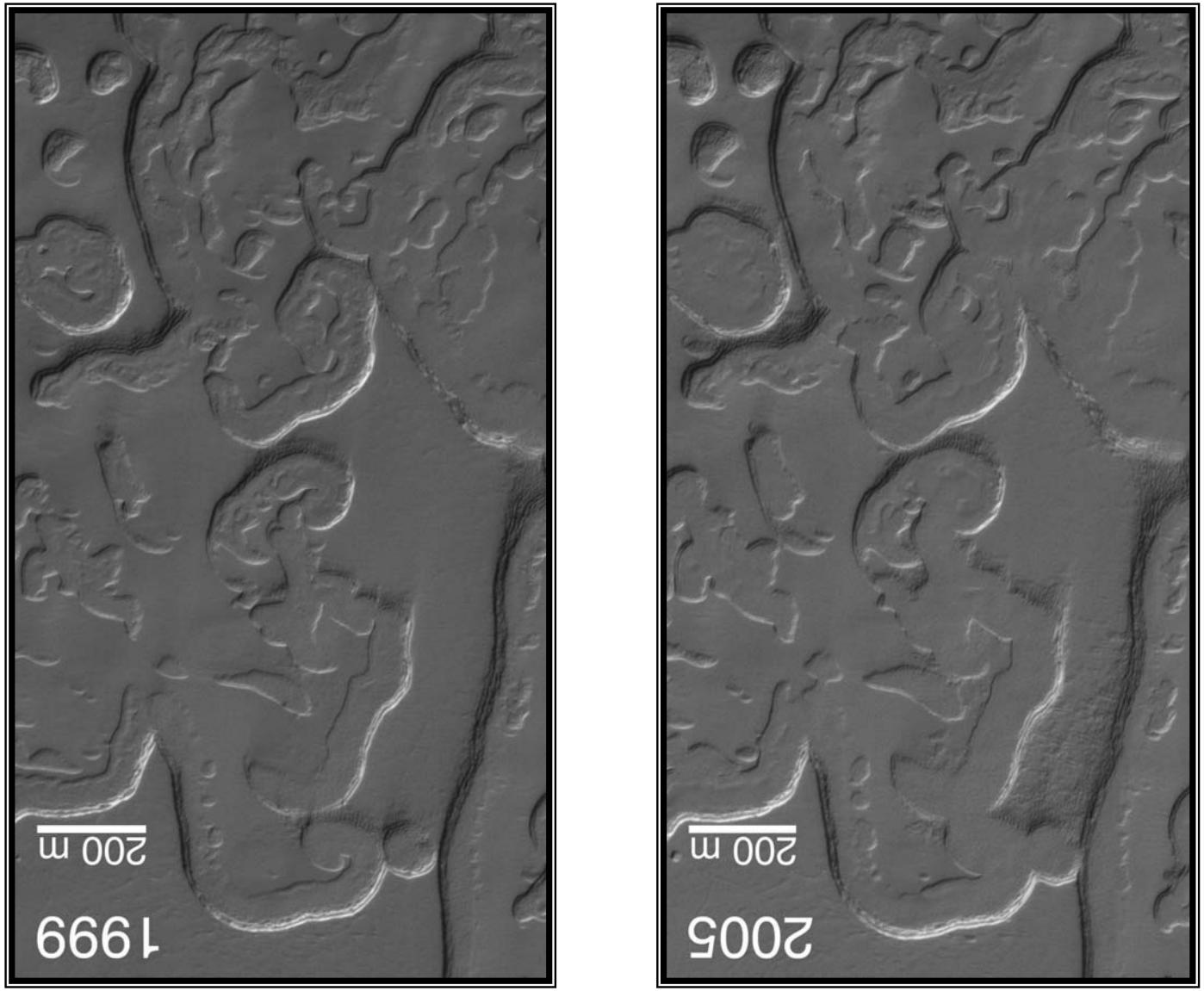
Mars Global Surveyor
Vanishing South Polar CO2 Cap



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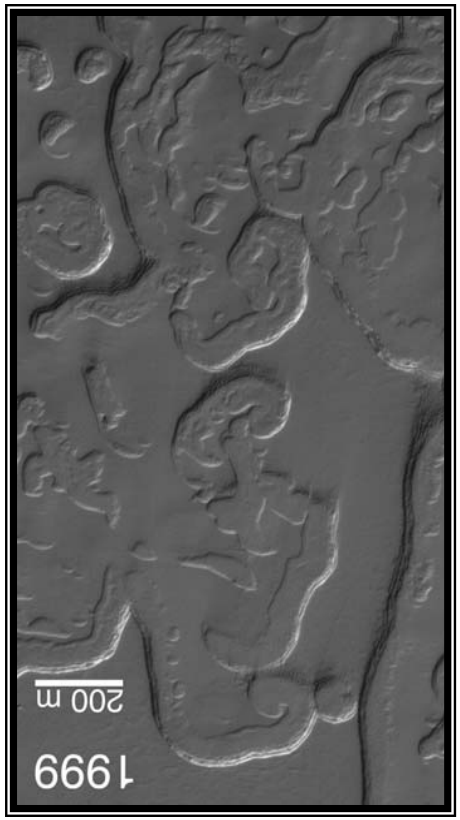
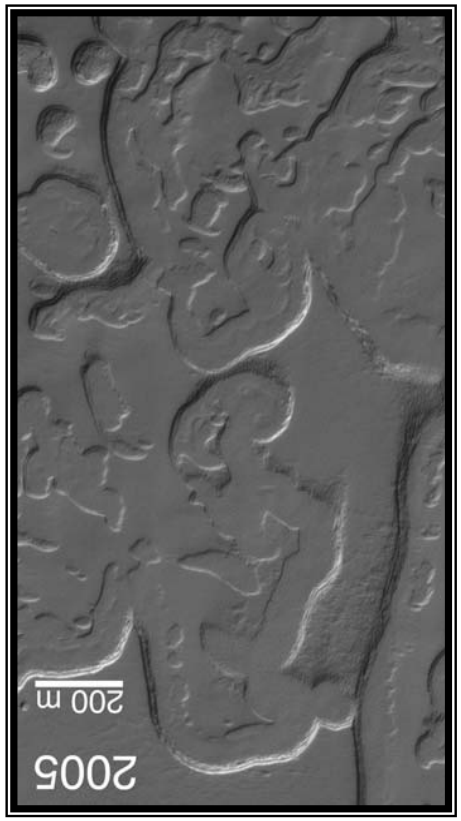
Mars Global Surveyor
Vanishing South Polar CO2 Cap





Leno quote: "Oh, did you see this? I'm not sure I understood this. Scientists this week said that Mars is now experiencing global warming. How does this happen? We only have 2 vehicles on Mars."

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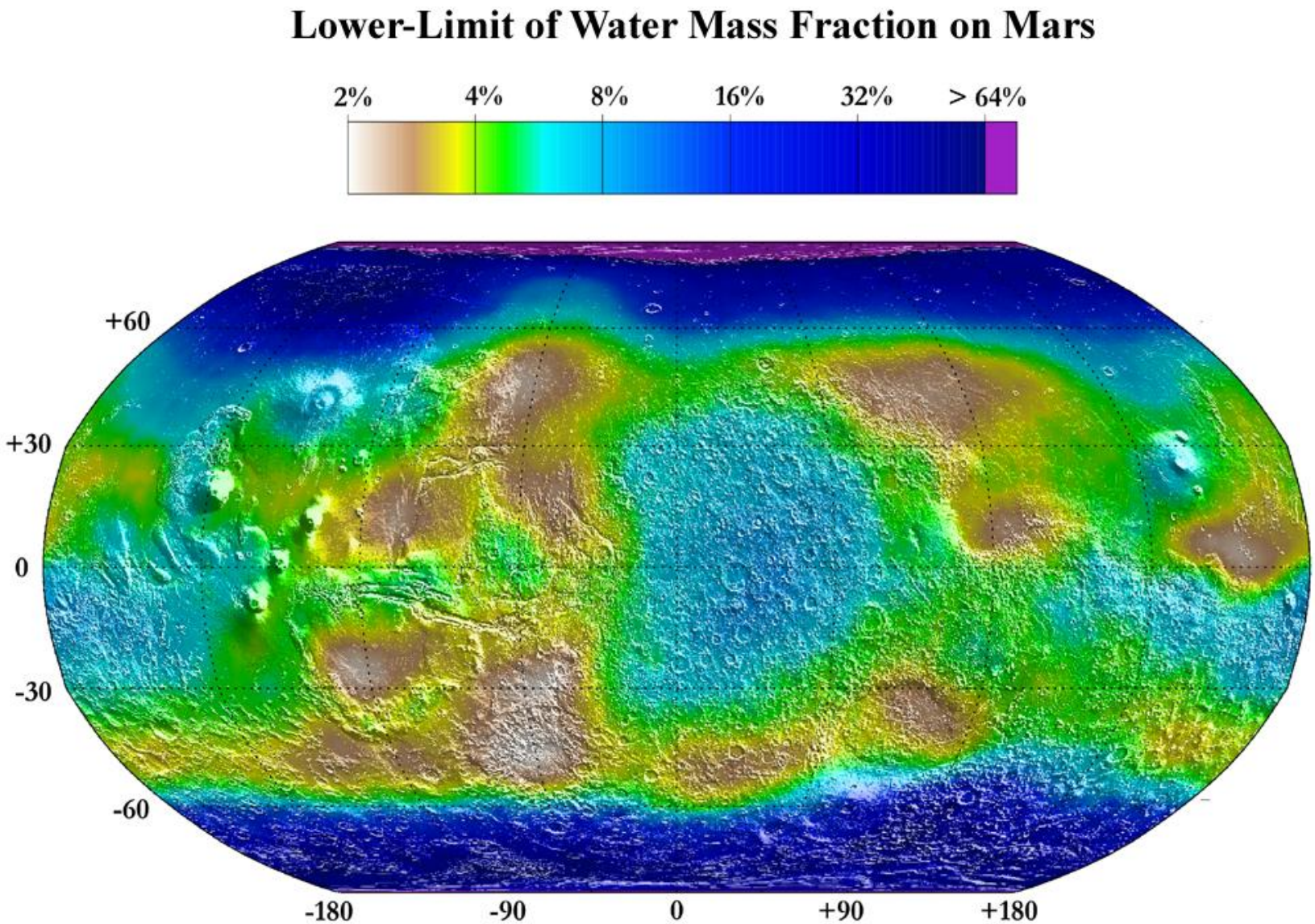
Mars Odyssey Neutron Spectrometer
H Detection



W. Feldman, LANL

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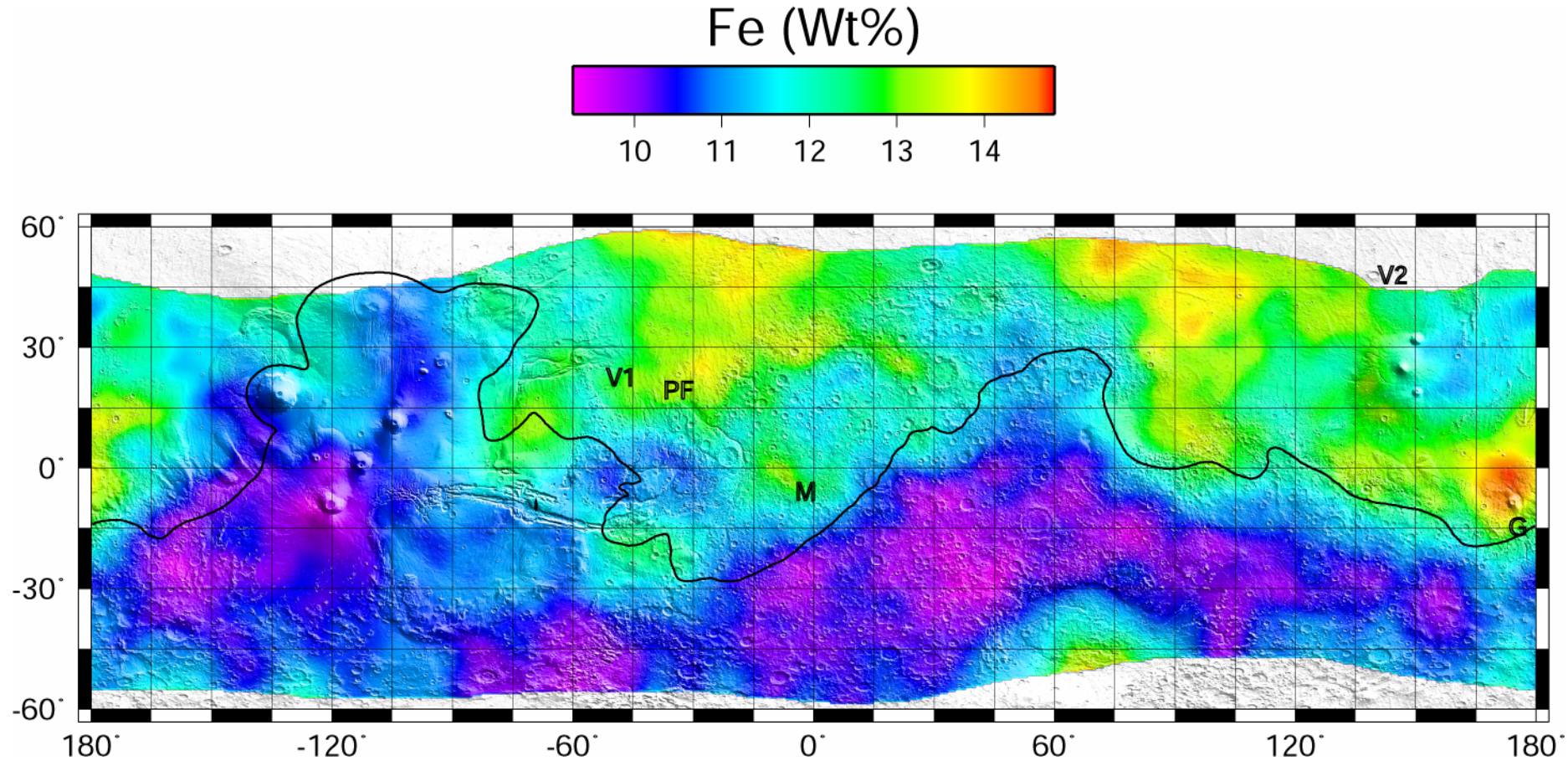
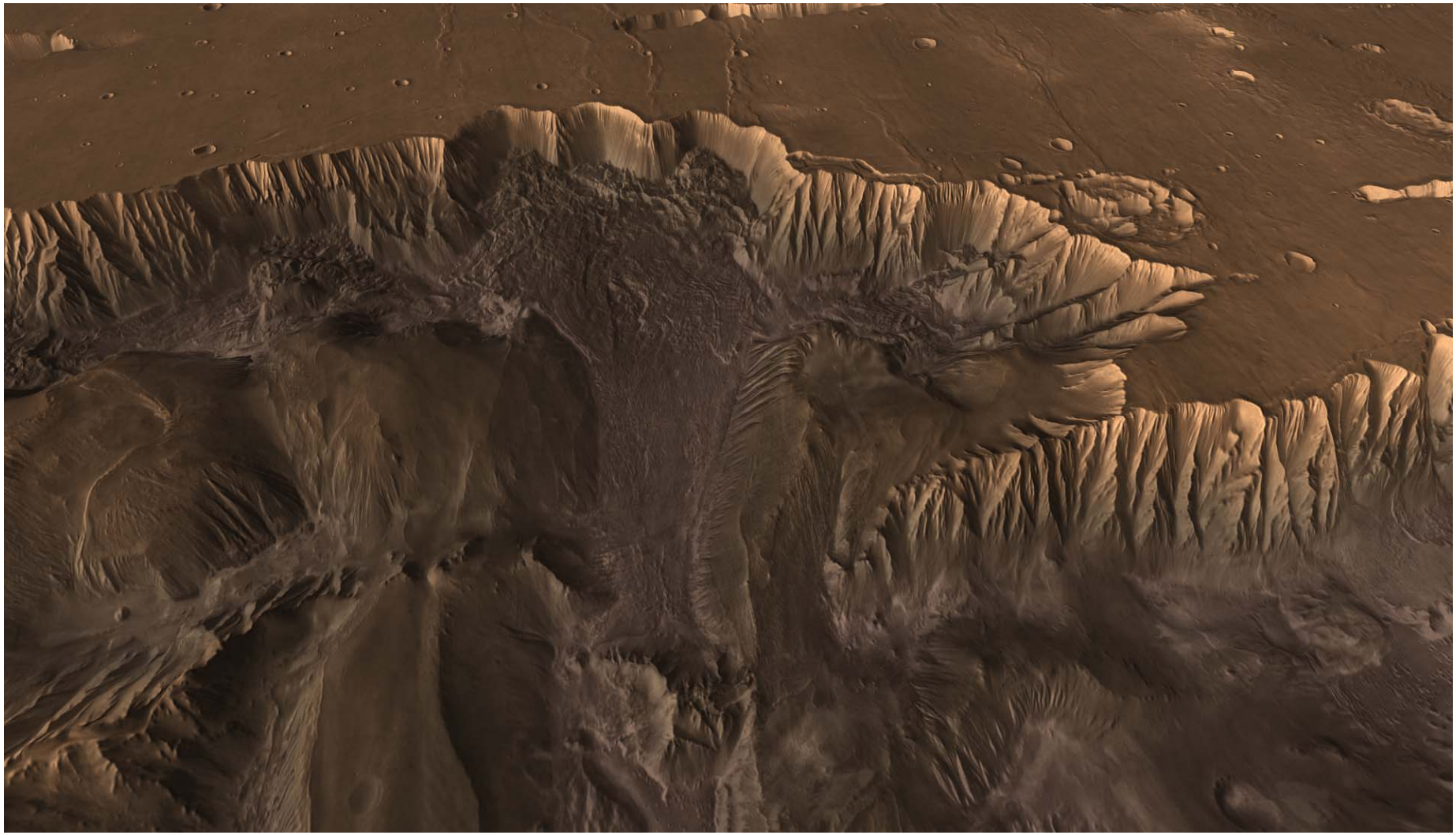
Mars Odyssey GRS Element Maps - Iron



- Iron abundance follows the global topographic dichotomy boundary (zero elevation contour shown).
- May indicate leaching of ancient highlands' iron by acid rain during early warm/wet period.

Mars Odyssey THEMIS Science Update

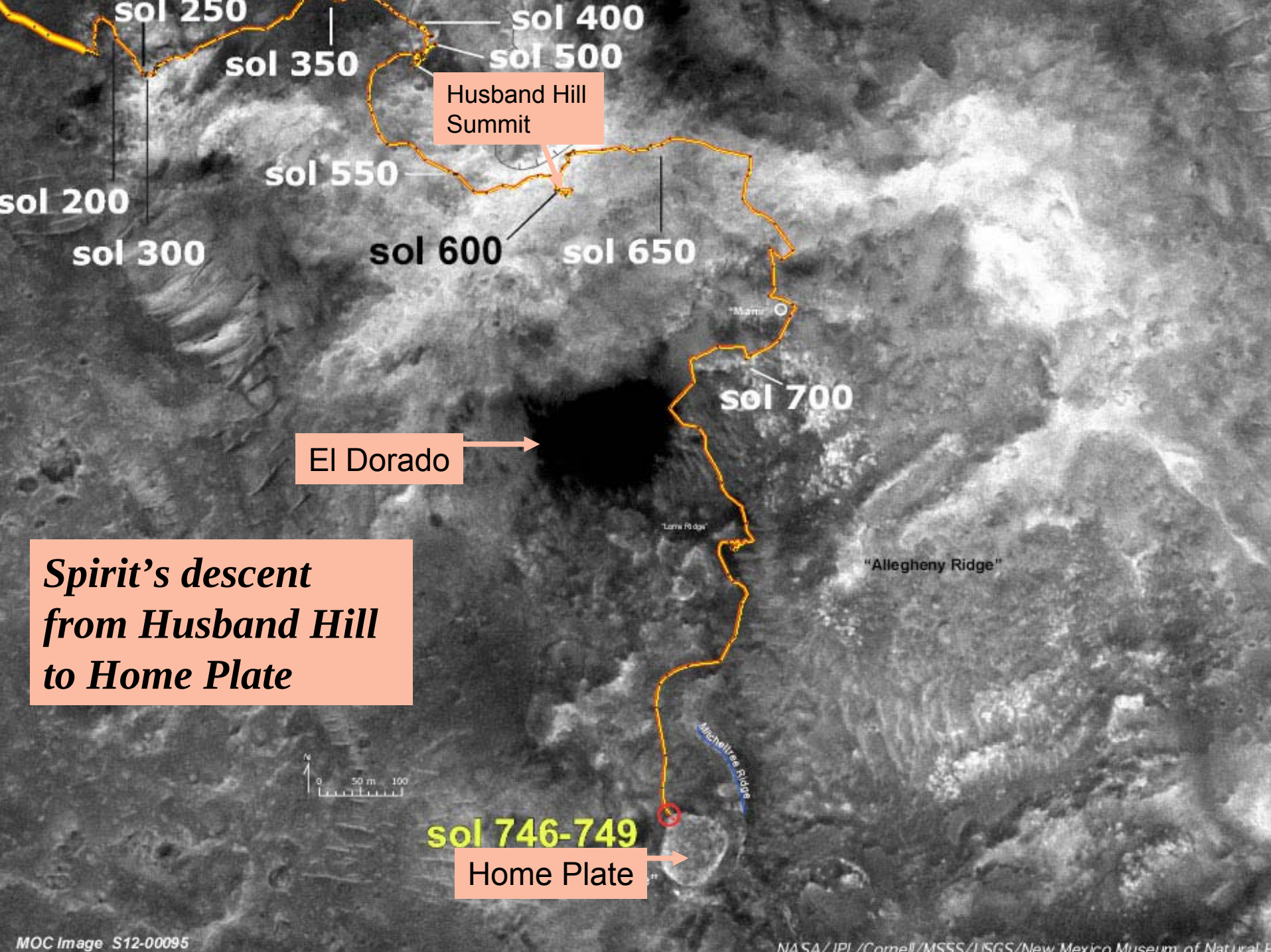


- THEMIS 300-m resolution global infrared mosaic has been compiled and released.
- 100-m resolution map in production.
- 100-m example above from 3D flyover of Valles Marineris (image width = 300 km)

Mars Exploration Rovers Status

- Spirit
  - Driven 6.5 km (1.5 km in last 5 months)
  - All Instruments healthy, except
    - RAT grinding bit worn out, but can still brush
  - All other systems healthy

- Opportunity
  - Driven 6.5 km (0.6 km in last 5 months)
  - All Instruments healthy
    - Occasional problems with Mini-TES
  - All other systems healthy, except
    - Right Front Steering Actuator Jammed
      - Can steer effectively with other 3 actuators
    - IDD Joint 1 (Azimuth) Actuator Degraded
      - Motor coil winding broken (believed due to deep thermal cycles)


sol 250
sol 350
sol 400
sol 500
Husband Hill Summit
sol 200
sol 300
sol 550
sol 600
sol 650
sol 700
El Dorado
"Allegheny Ridge"
Spirit's descent from Husband Hill to Home Plate
sol 746-749
Home Plate
MOC Image S12-00095

Spirit at "Home Plate"

We are testing multiple hypotheses for the origin of the layered rocks at "Home Plate", using data from all of the rover instruments.

These rocks could be:
- Explosive volcanic deposits?
- Sedimentary wind-transported deposits?
- Sedimentary water-transported deposits?
- Impact deposits?

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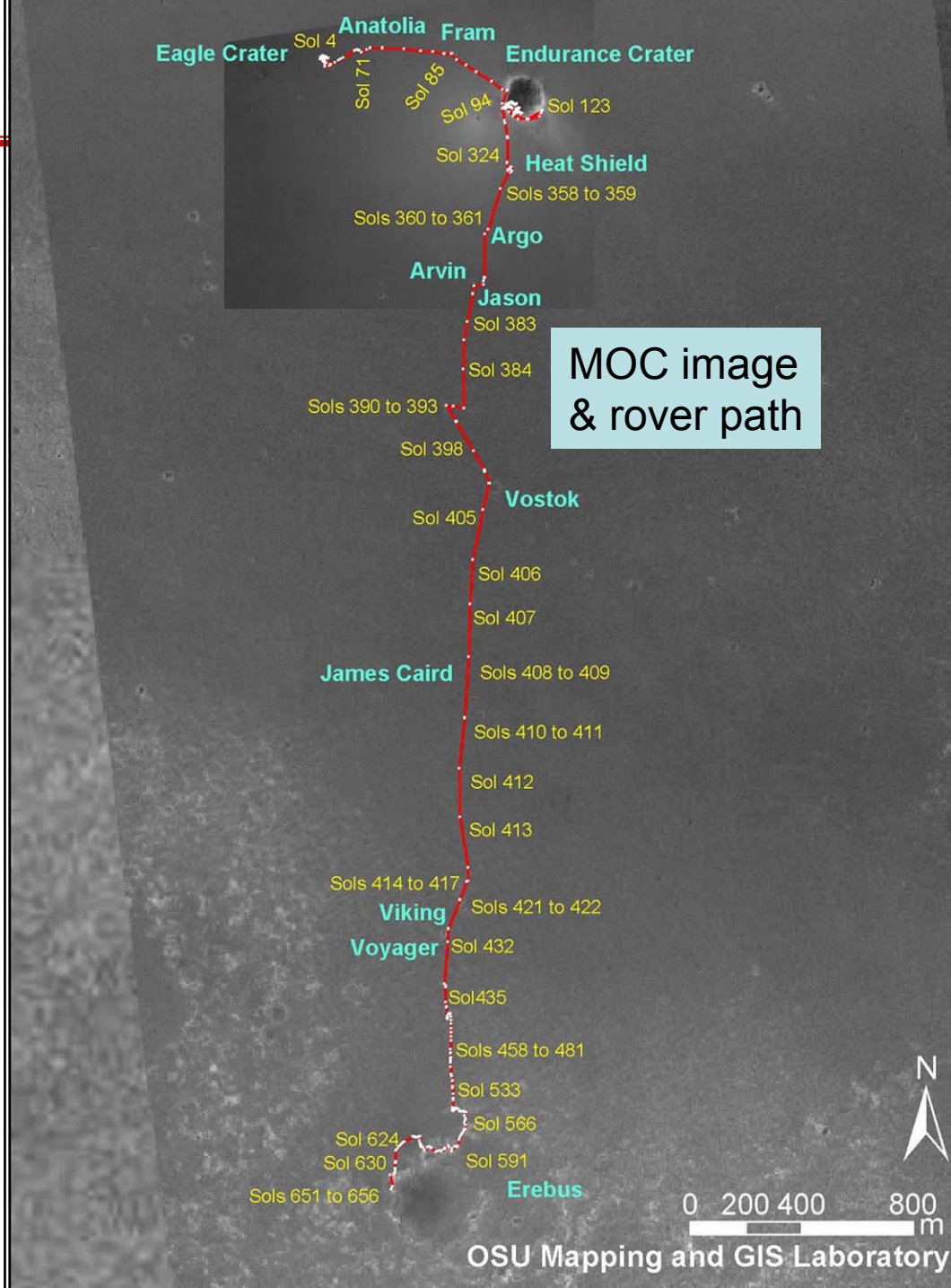
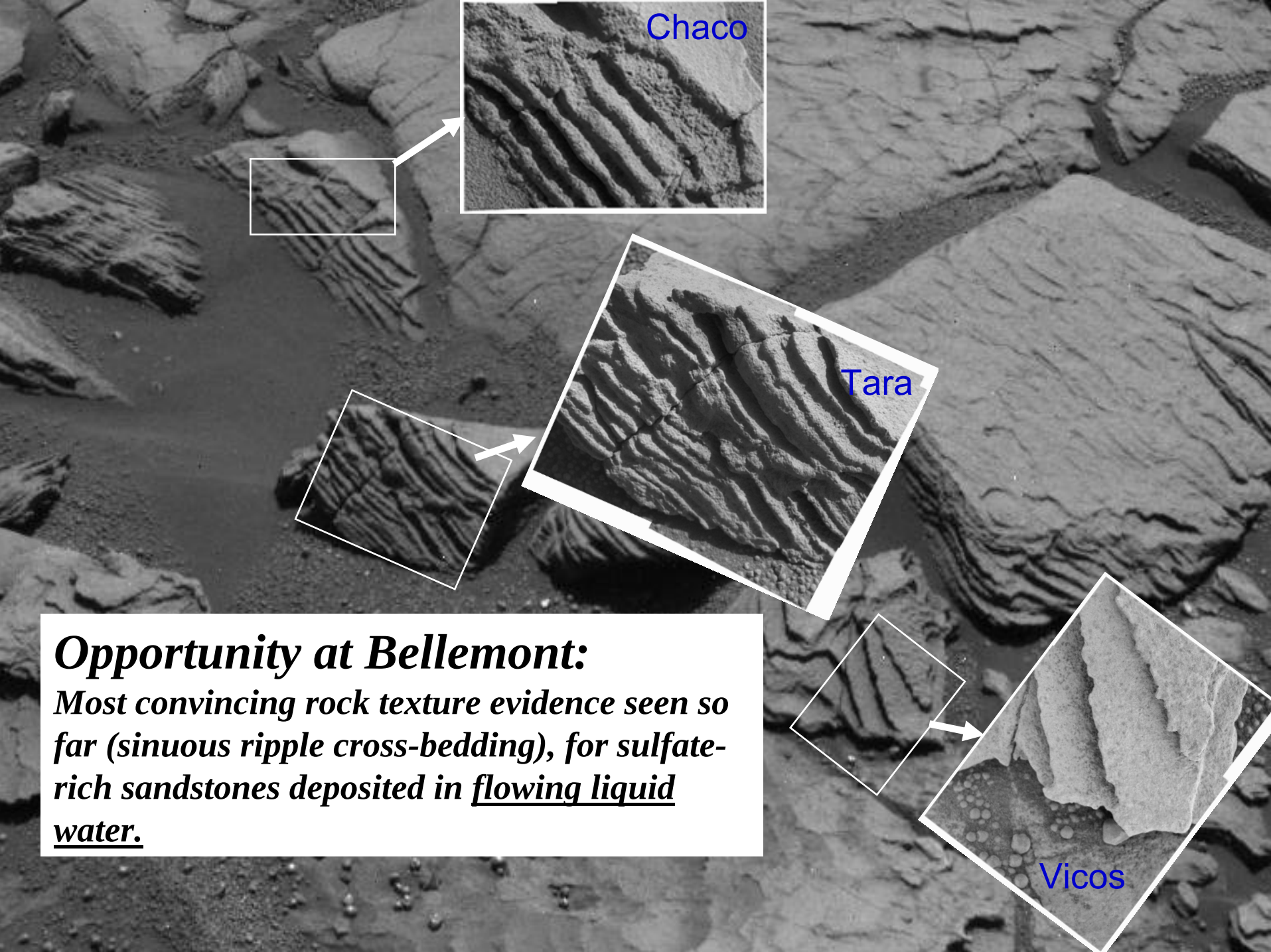
The nature of the rocks and mode of deposition at Eagle and Endurance craters (evaporite sandstones transported by wind and water) extends over ~3 km to the south

The regional pattern leads us to search for lake-bed sedimentary deposits that have not been transported by wind or water.

We will drive across the plains to Victoria (another ~ 2.5 - 3 km south) as quickly as possible while on the lookout for lake sediments. The real payoff will likely be the ~30 to 40 m stratigraphic section of rock that appears to be exposed in the rim of Victoria crater.





Opportunity at Bellemont:

Most convincing rock texture evidence seen so far (sinuous ripple cross-bedding), for sulfate-rich sandstones deposited in <u>flowing liquid water.</u>

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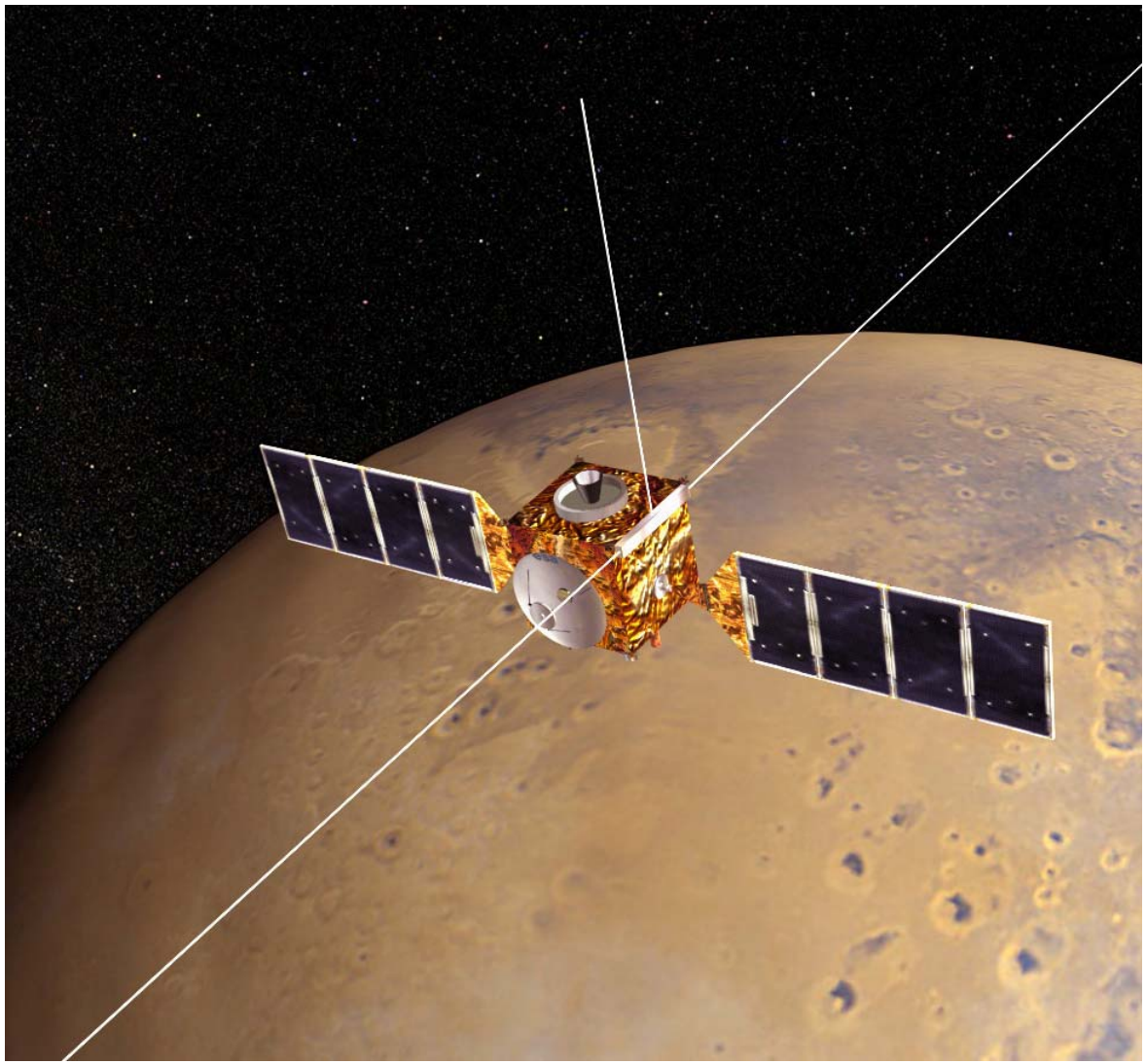
MARSIS - Subsurface Radar Sounder on Mars Express



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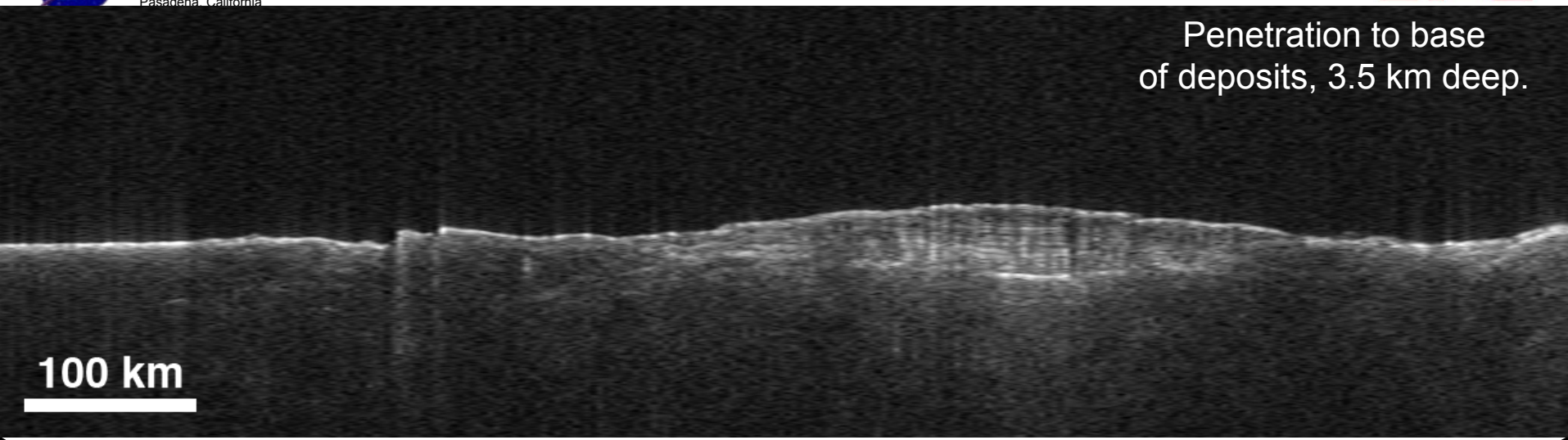
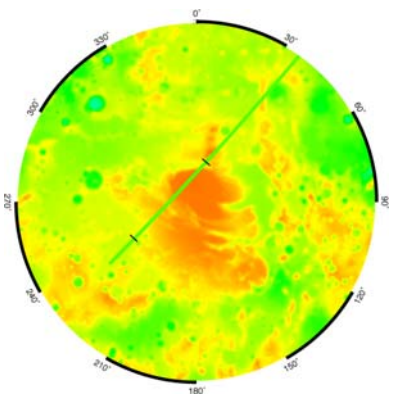
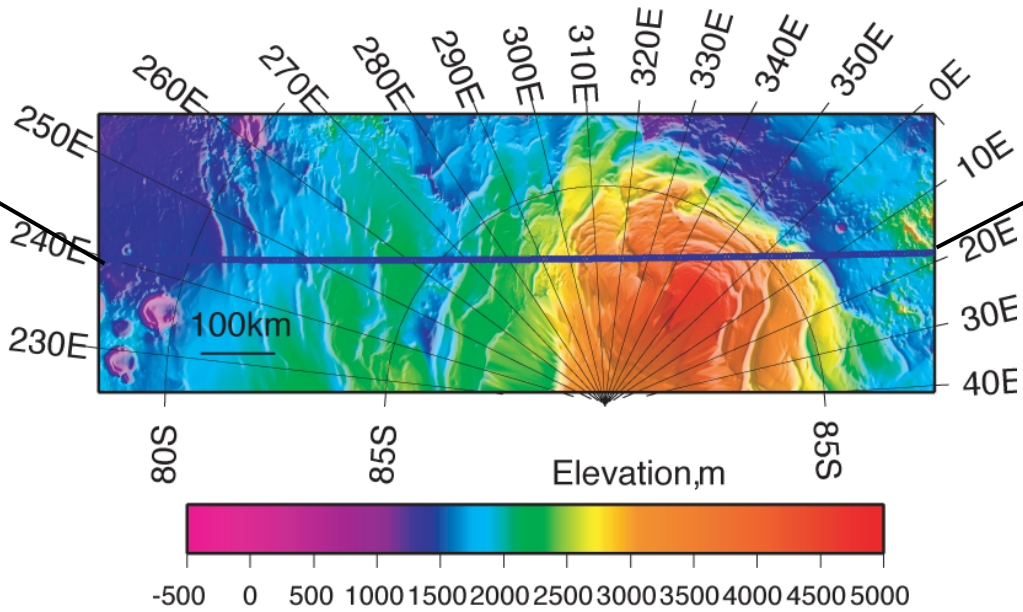
MARSIS - South Polar Layered Terrain

JPL

Penetration to base of deposits, 3.5 km deep.








Mars Reconnaissance Orbiter

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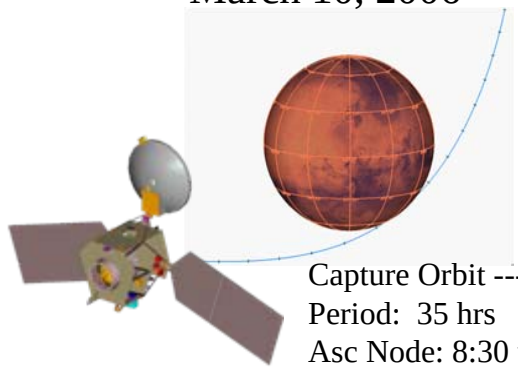
MRO Mission Overview

Launched
August 12, 2005

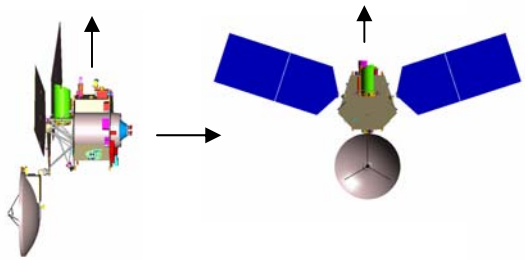
Interplanetary Cruise
Aug 2005 - Mar 2006

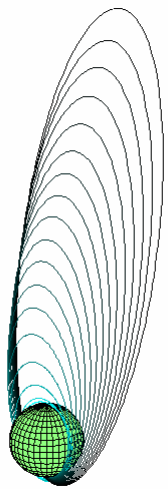
Approach and Orbit Insertion
March 10, 2006



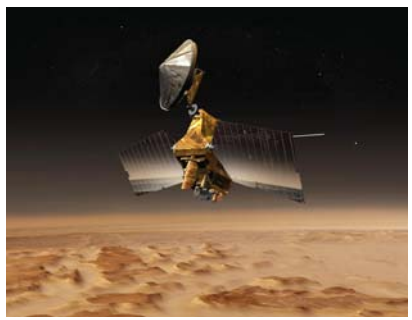
Capture Orbit ---
Period: 35 hrs
Asc Node: 8:30 pm LMST

Aerobraking
Mar-Sep 2006

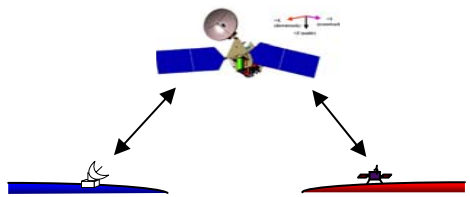




Primary Science/Relay
Nov 2006 - Dec 2010



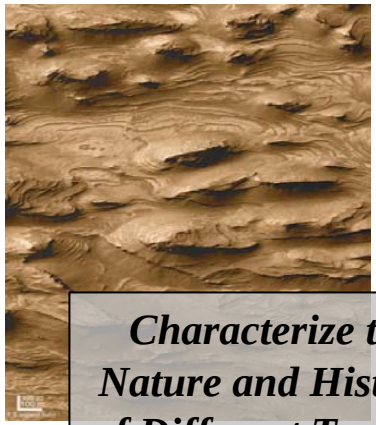
Science Data
Acquisition/Return



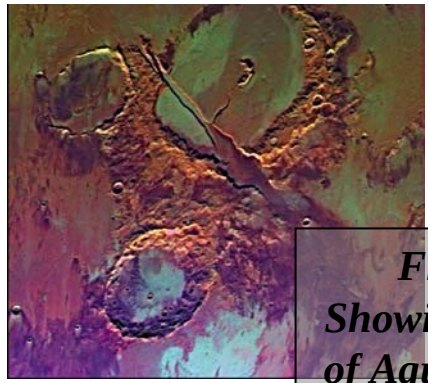
Primary Science/Relay Orbit ---
Period: 112 min
Hp: 255 km Ha: 320 km, Frozen
Ascending Node: 3:00 pm LMST (Sun-Sync)

MRO Science Goals

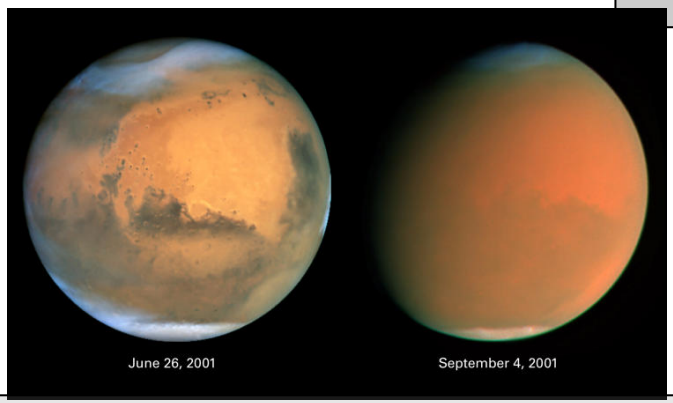
Understand the Processes of Climate Change, Past and Present



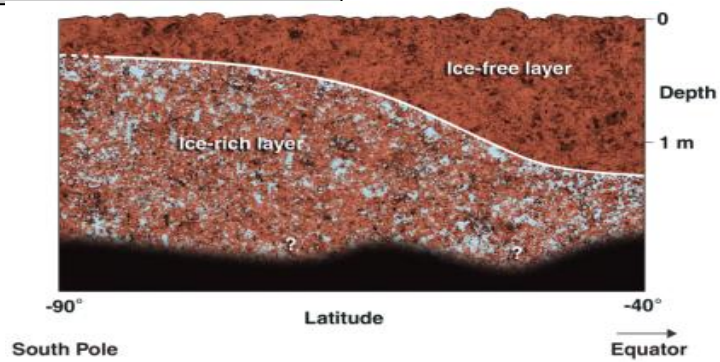
Characterize the Nature and History of Different Terrain Types



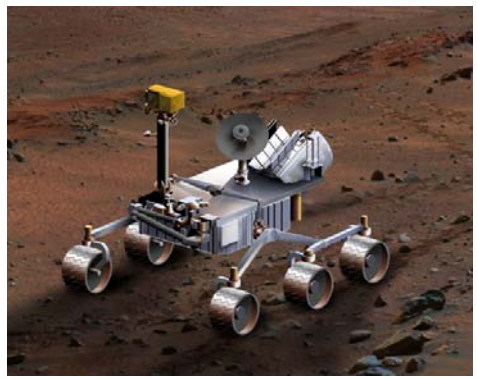
Find Sites Showing Evidence of Aqueous and/or Hydrothermal Activity



Characterize the Present Climate;Understand Seasonal & Year-to-Year Variability

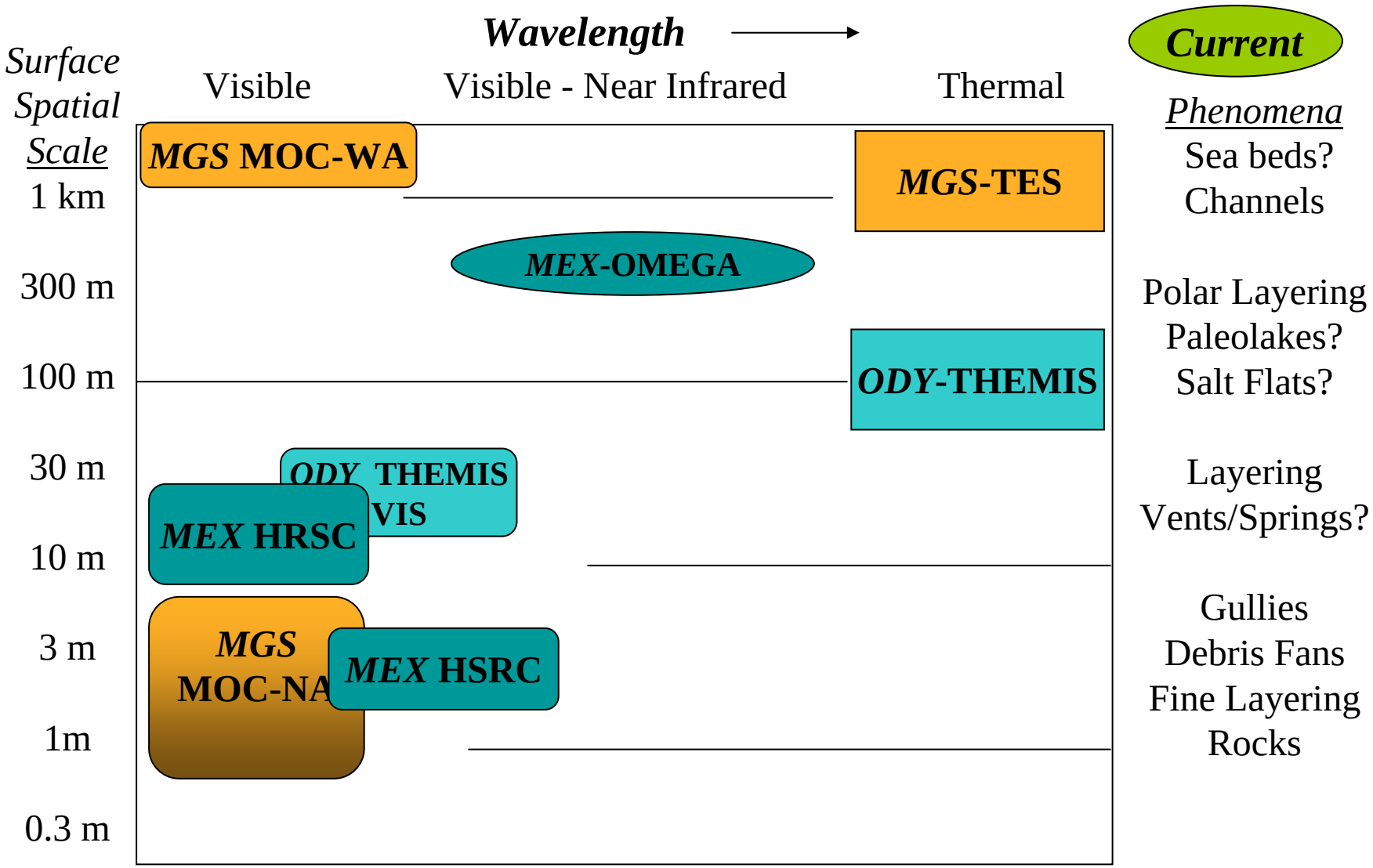


Identify Subsurface Structure and Potential Reservoirs of Water Ice

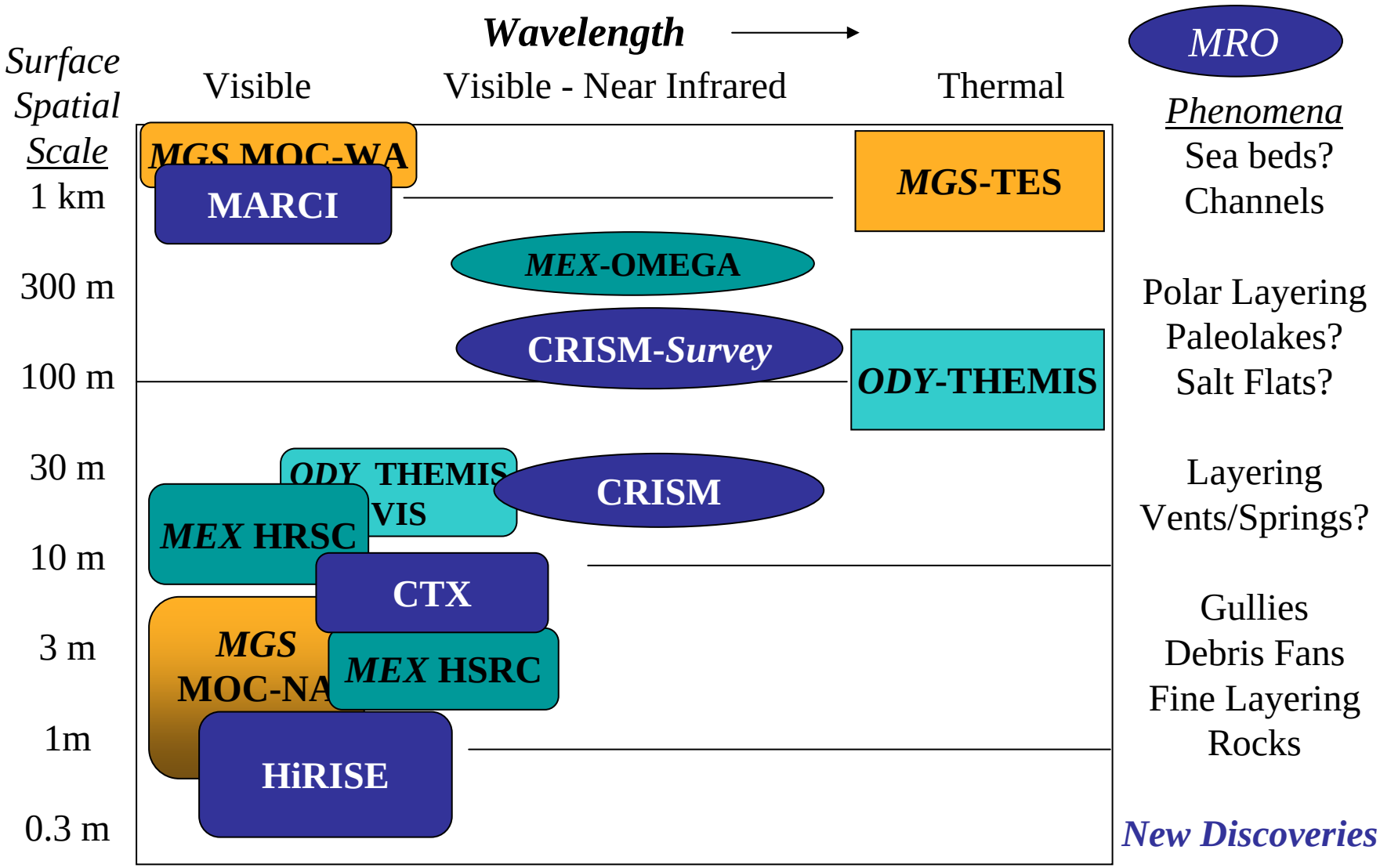


Identify Landing Site for future missions

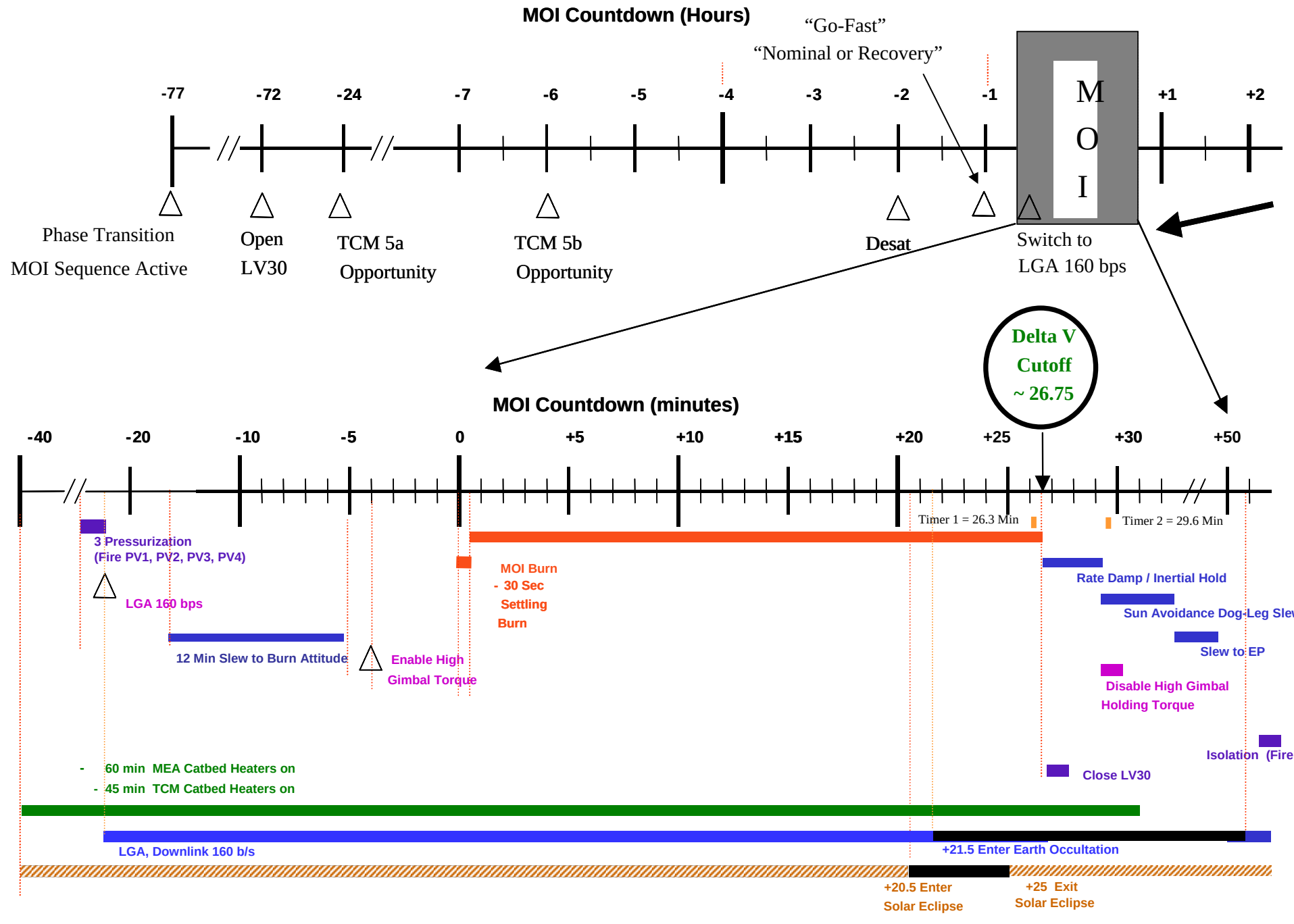
Relation to Other Mars Missions for Imaging



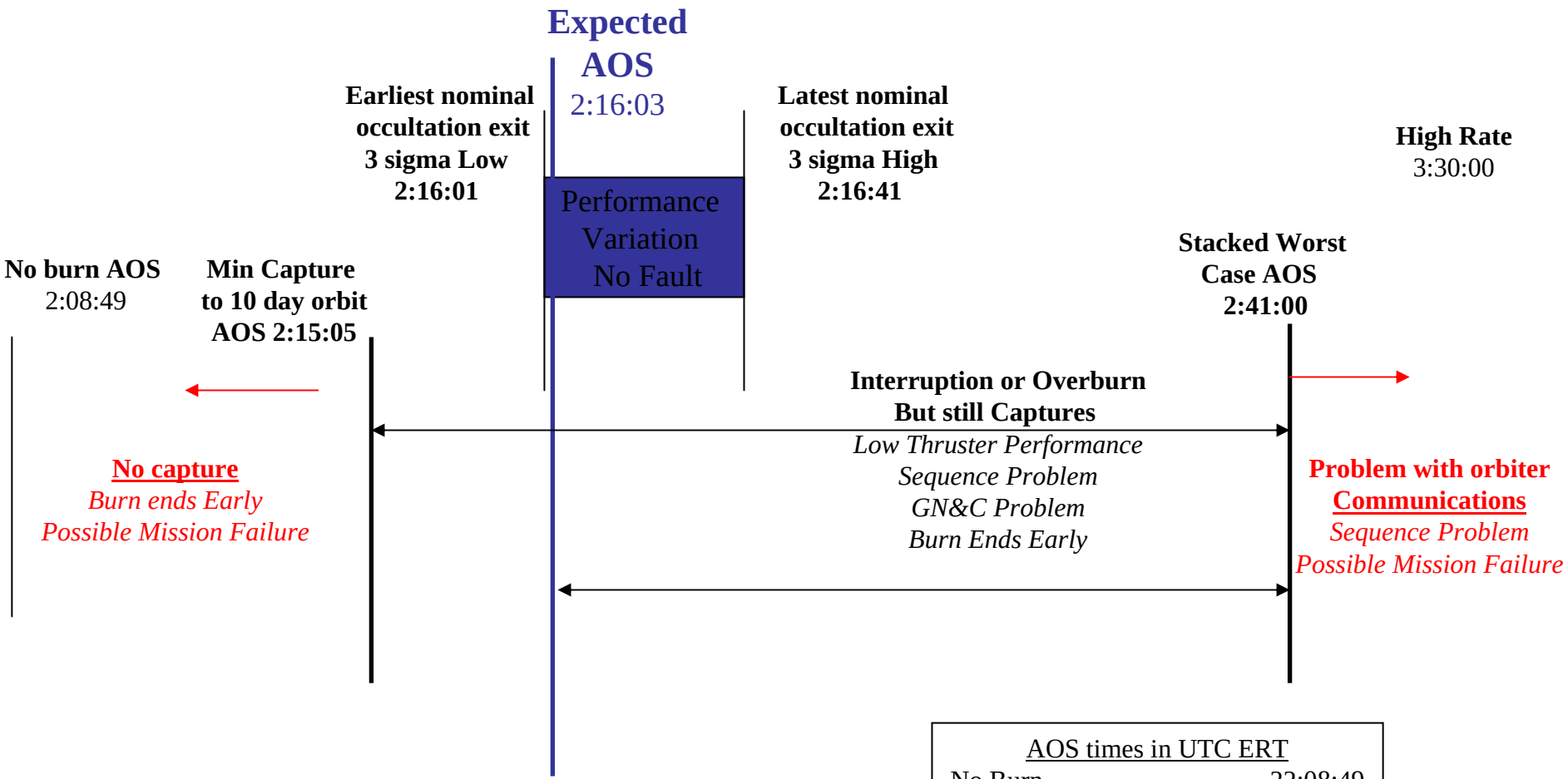
Relation to Other Mars Missions for Imaging



MOI Phase Events and Timeline

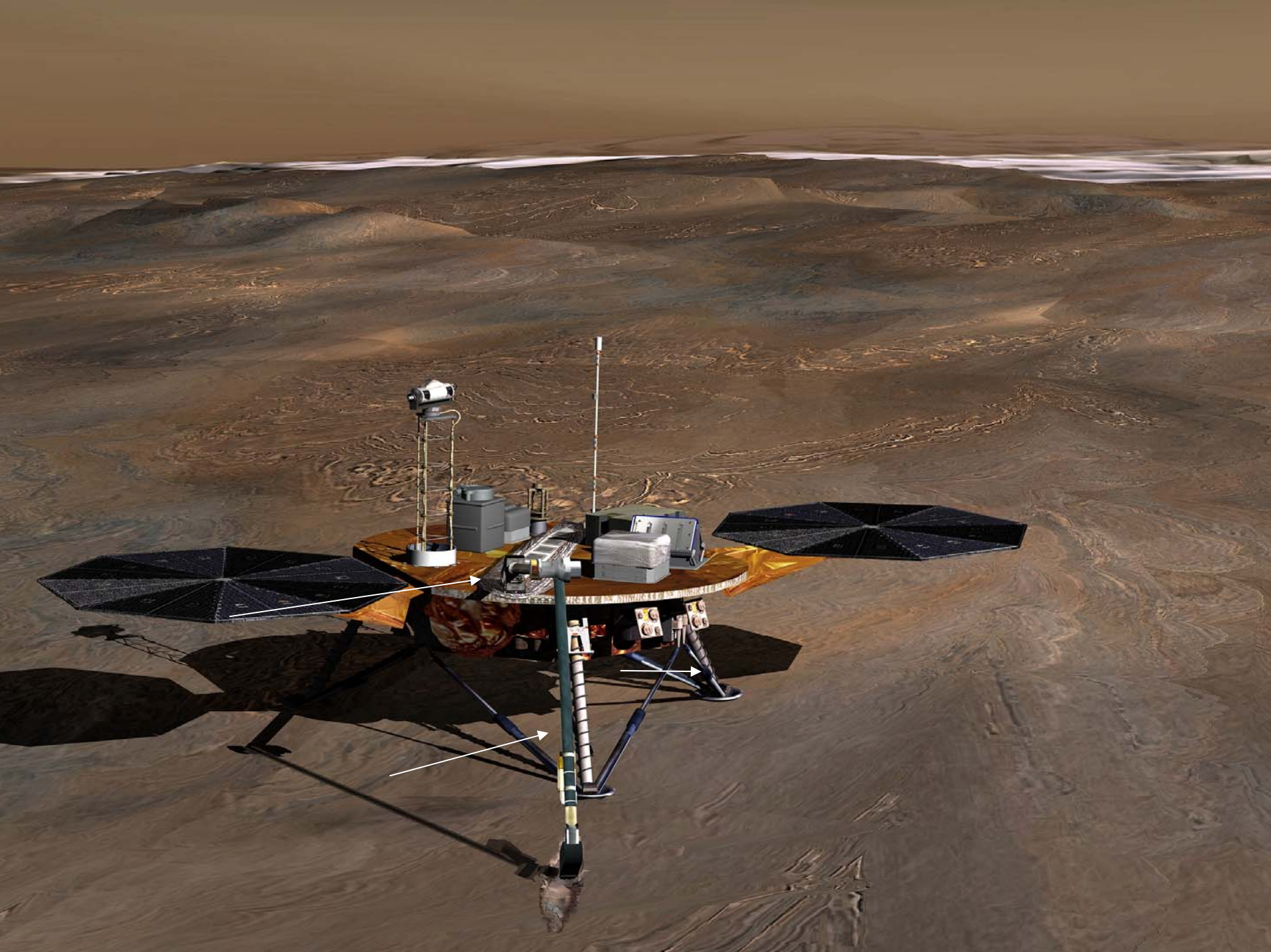


Timeline of Possible Reacquisition Times



AOS times in UTC ERT	
No Burn	22:08:49
10 day orbit	22:15:05
Eng out T3	22:15:59
3-sigma Low T1	22:16:01
Expected AOS	***22:16:03***
3 sigma HighT2	22:16:41

**All times given in PST ERT. AOS times represent the geometric link visibility. Radio Science Recorders (RSRs) will see signal within a few seconds. 1-way lockup and telemetry updating will take ~3 min to begin*



Phoenix Investigation Overview

- Study the Martian hydrological cycle
  - Land where Odyssey has found water ice in the subsurface
  - How is water stored and released from the polar region?
  - Determine the diffusion of water vapor through the regolith
- Determine the recent history of the subsurface ice
  - Has liquid water altered the mineralogy of the soil?
  - What is the aqueous chemistry of the soil? In other words, if the ice melts, what is the chemical environment?
- Study the polar region processes
  - How does the climate change with season?
  - Study the boundary layer processes
  - What are the processes that shape the geology?
- Determine the habitability of the ice-soil boundary
  - Are organic molecules able to survive intact in this environment?
  - Do environmental factors support the presence of life?
  - Are there environmental hazards?

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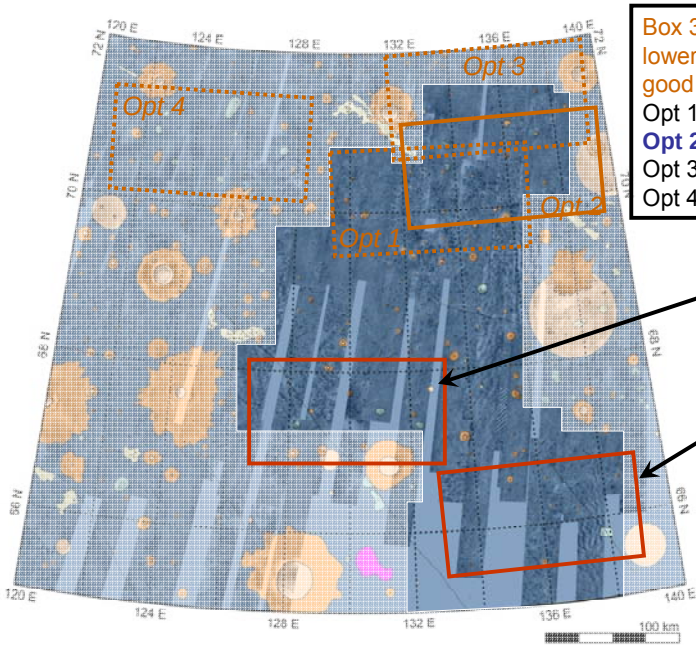
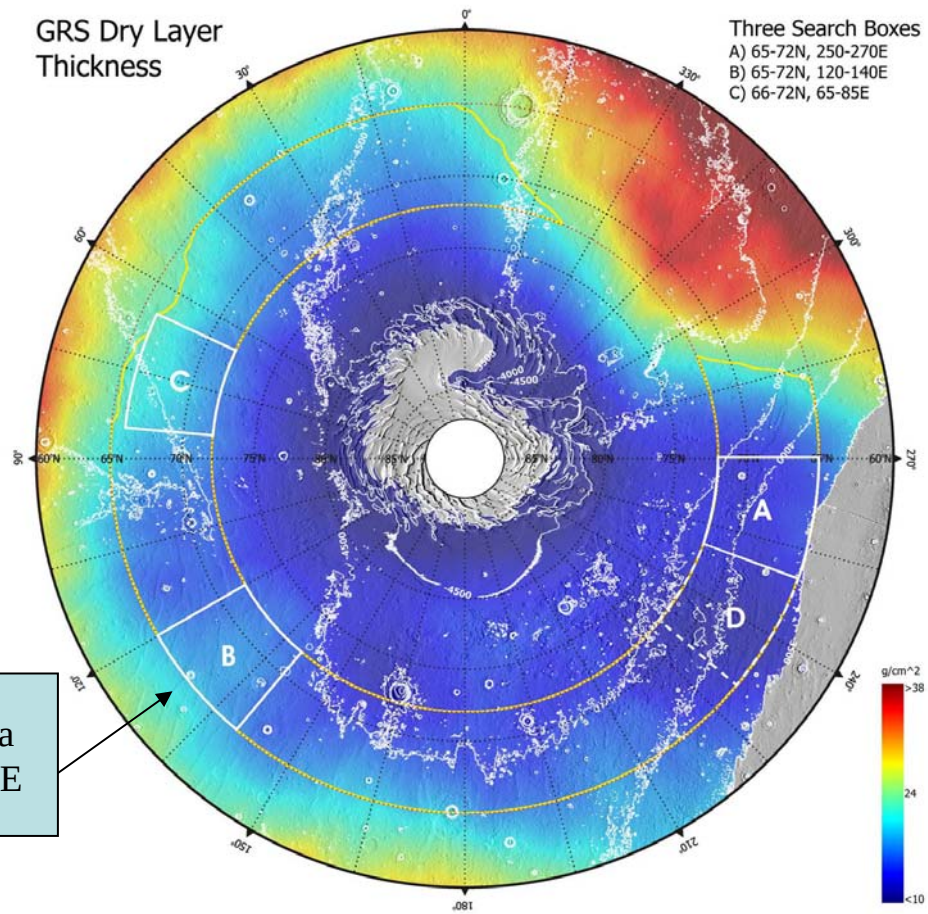
Landing Site Area for Phoenix



Box 3: High latitude, lower soil thickness, good comm:
Opt 1: 70.2N 133E
Opt 2: 70.5N, 136E
Opt 3: 71.4N, 135.6E
Opt 4: 70.8N,124.5E

Box 1: centered at 67.5N,130E

Box 2: low latitude, higher soil thickness centered at 66N, 136E



Landing Site area
65-72N, 120-140E

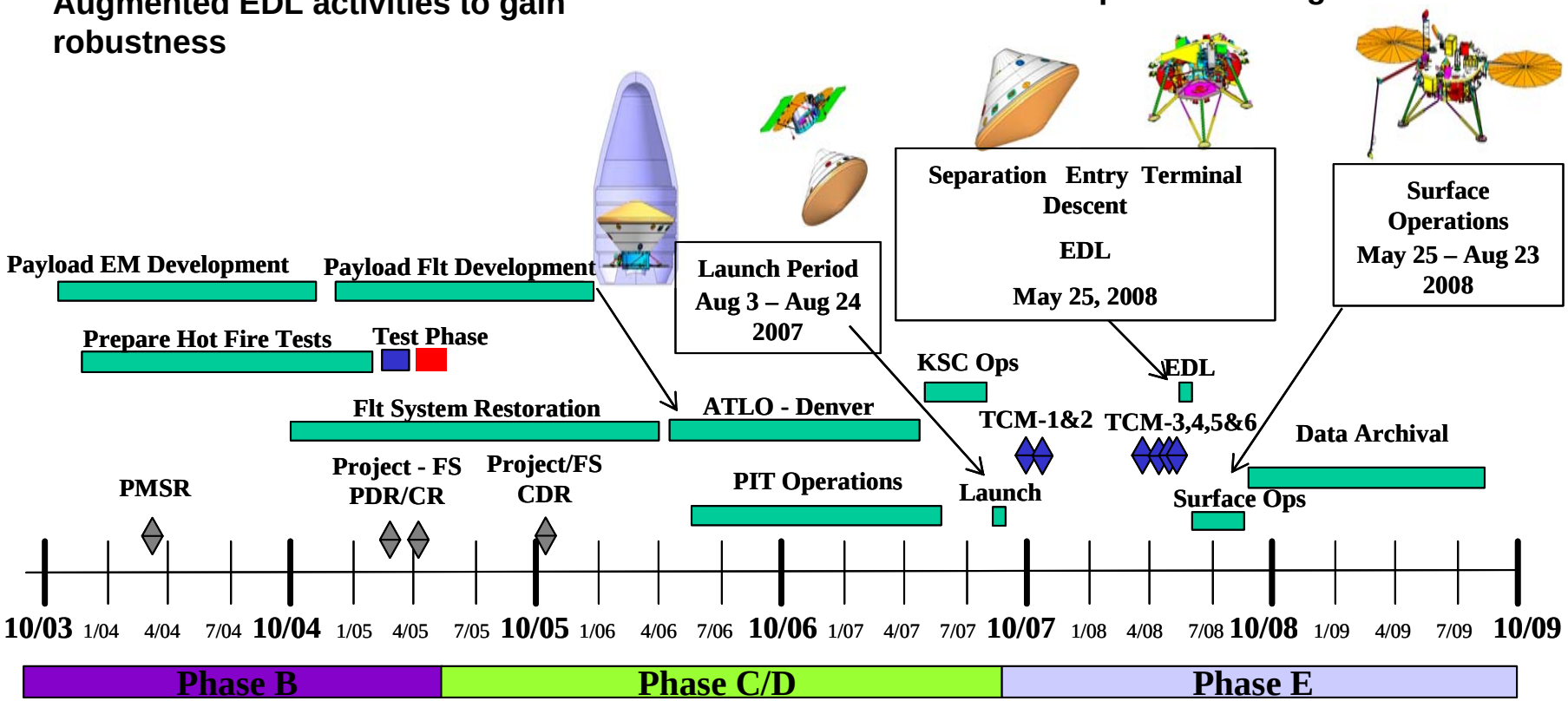
Rationale:

- No large craters in center area
- Benign slopes, with low rock abundance
- Lowest elevations
- Reasonable amount of soil over ice

Mission Discussions

- Thorough review/compliance to 'Return to flight' criteria
  - Comprehensive inheritance reviews; flight system reliability re-analysis, comprehensive waiver review, etc.
  - Terminal descent system hot fire test to validate design/models
- Augmented EDL activities to gain robustness

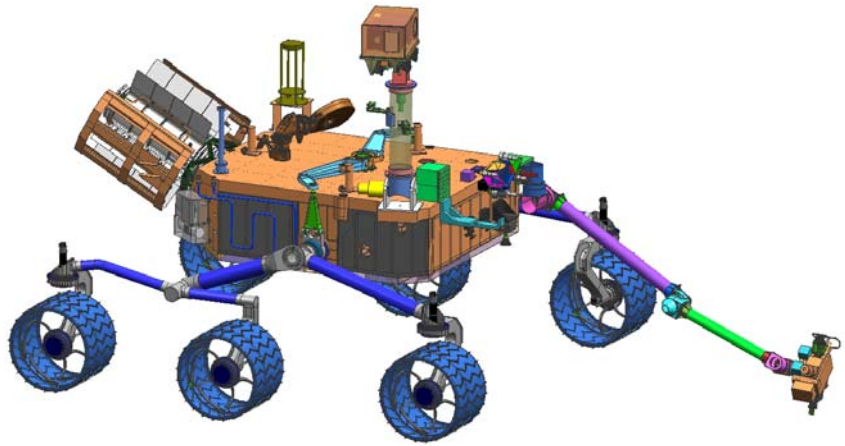
- Phase C/D
  - ATLO Start: April 2006
  - Ship: May 2007
  - Launch: August 2007
- Phase E
  - EDL: May 2008
  - End Of Operations: August 2008



Mars Science Laboratory

Salient Features

Mobile Science Laboratory
One Mars Year surface operational lifetime (669 sols/687 days)
Discovery Responsive over wide range of latitudes and altitudes
Controlled Propulsive Landing
Precision Landing via Guided Entry

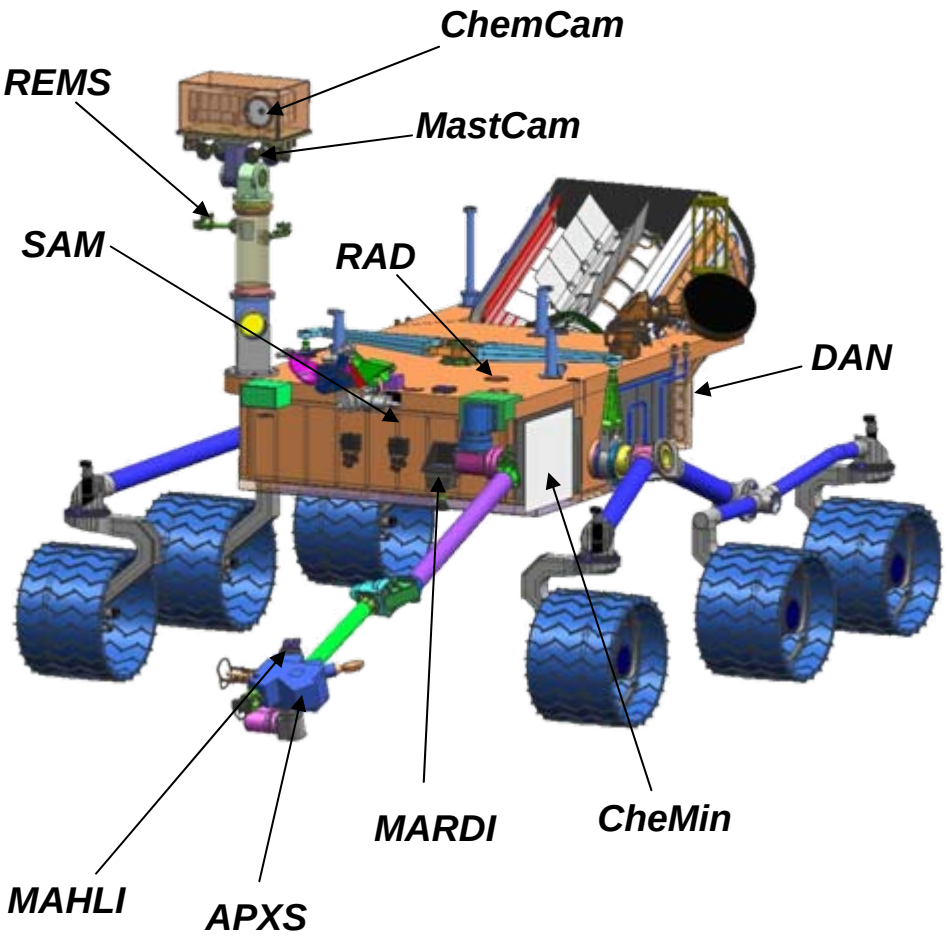


Design Concept

Science

Mission science will focus on Mars habitability
Highly capable analytical laboratory science investigations
Next Generation remote sensing/contact investigations
Suite of Environmental Monitoring Instruments

MSL Payload



Design Concept

Remote Sensing (Mast)

ChemCam** (PI: Wiens, LANL/CNES) – Mineralogy

MastCam (PI: Malin, MSSS) - Color Stereo Imager

Contact Instruments (Arm)

MAHLI (PI: Edgett, MSSS) - Microscopic Imager

APXS* (PI: Gellert, UofGuelph) - Elemental Composition

Analytical Laboratory (Front Chassis)

SAM** (PI: Mahaffy, GSFC/CNES) - Sample Comp/ Organics

CheMin (PI: Blake, ARC) - Definitive Mineralogy

Environmental Characterization (Body-mount)

MARDI (PI: Malin, MSSS) - Descent Imager/Geomorphology

REMS* (PI: Vasquez, CAB) - Meteorological monitoring

RAD*** (PI: Hassler, SWRI) - Surface Radiation Flux Monitor

DAN* (PI Mitrofanov, IKI) - Subsurface hydrogen detection

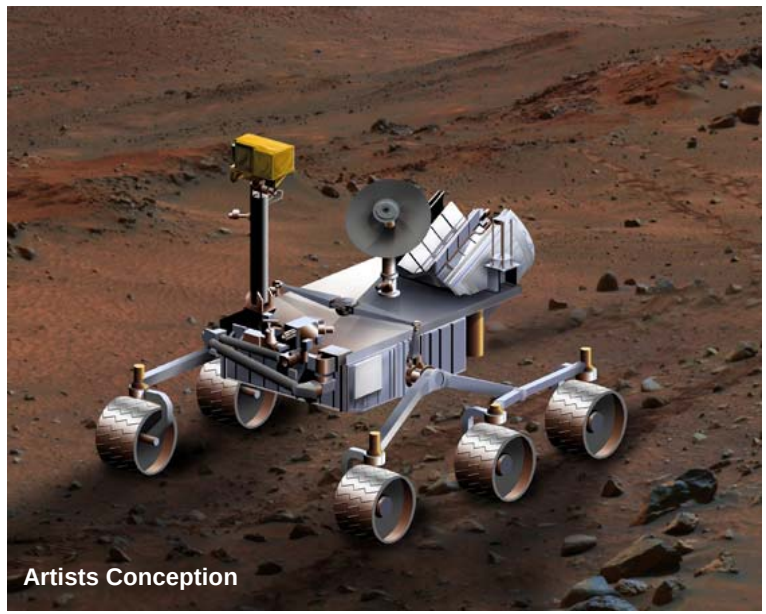
* - Foreign Instrument
** - Foreign Contribution
*** - ESMD Contribution

Measurement Capabilities

Payload Element	***Comparison to Other Mars Missions***
MastCam (Stereo Imager)	3x better resolution than MER, high rate video
CHEMIN (Mineralogy)	First definitive mineralogy, MER MB restricted to iron-bearing minerals, Mini-TES not definitive
MAHLI (Microscopic Imager)	3x better resolution than MER, first color & controlled illumination
APXS (Rock/Soil Chemistry)	5x increased sensitivity over MER, allows daytime ops
RAD (Radiation Monitor)	First radiation measurements from Mars surface
DAN (Hydrogen Detection)	Surface complement to Odyssey orbital measurements, 1m resolution vs. hundreds of km resolution from orbit
REMS (Meteorology)	Comparable to Viking & Pathfinder measurements with full diurnal and annual coverage, first humidity & surface UV
MARDI (Descent Imager)	Higher frame rate than Phoenix, includes color
ChemCam (Elemental Comp)	First UV/visible spectrometer, remote elemental analysis
SAM (Chemistry/Organics)	More sensitive organic/element detection over larger mass range than Viking GCMS, can determine isotopic ratios & trace atmospheric species, first derivitization capability
Sample Acquisition/Processing	First crushed rock, first rock subsurface sampling, shared sample, Viking-like soil sampling, MER-like abrasion

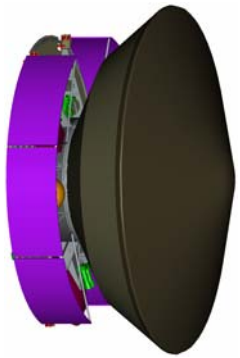
MSL Engineering Capabilities

	MER	MSL
Landed Mass	174 kg	<775 kg
Designed Driving Distance	0.6 km	20 km
Mission Duration	90 sols	669 sols
Power/Sol	400 - 950 w/hr	~2500 w/hr
Instruments	7/~5.5 kg	10/75 kg
Instr. Capability	contact	analytical lab
Data Return	50-150 Mb/sol	100-400 Mb/sol
EDL	Ballistic Entry	Guided Entry



Design Concept

Mission Overview

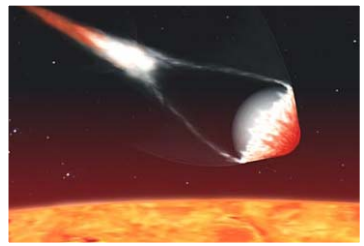


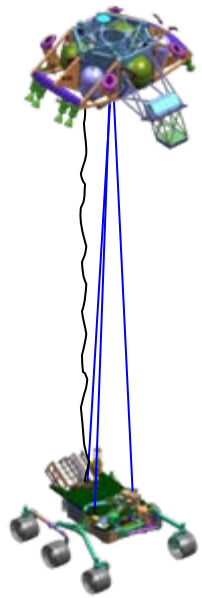
CRUISE/APPROACH

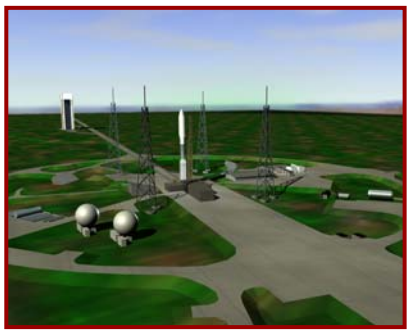
- 10-12 month flight time
- Jettisoned Cruise Stage

ENTRY/ DESCENT/ LANDING

- Direct Guided Entry
- Precision Landing ≤10 km radius
- Altitudes ≤ 2 km
- Skycrane Rover Deployment







LAUNCH

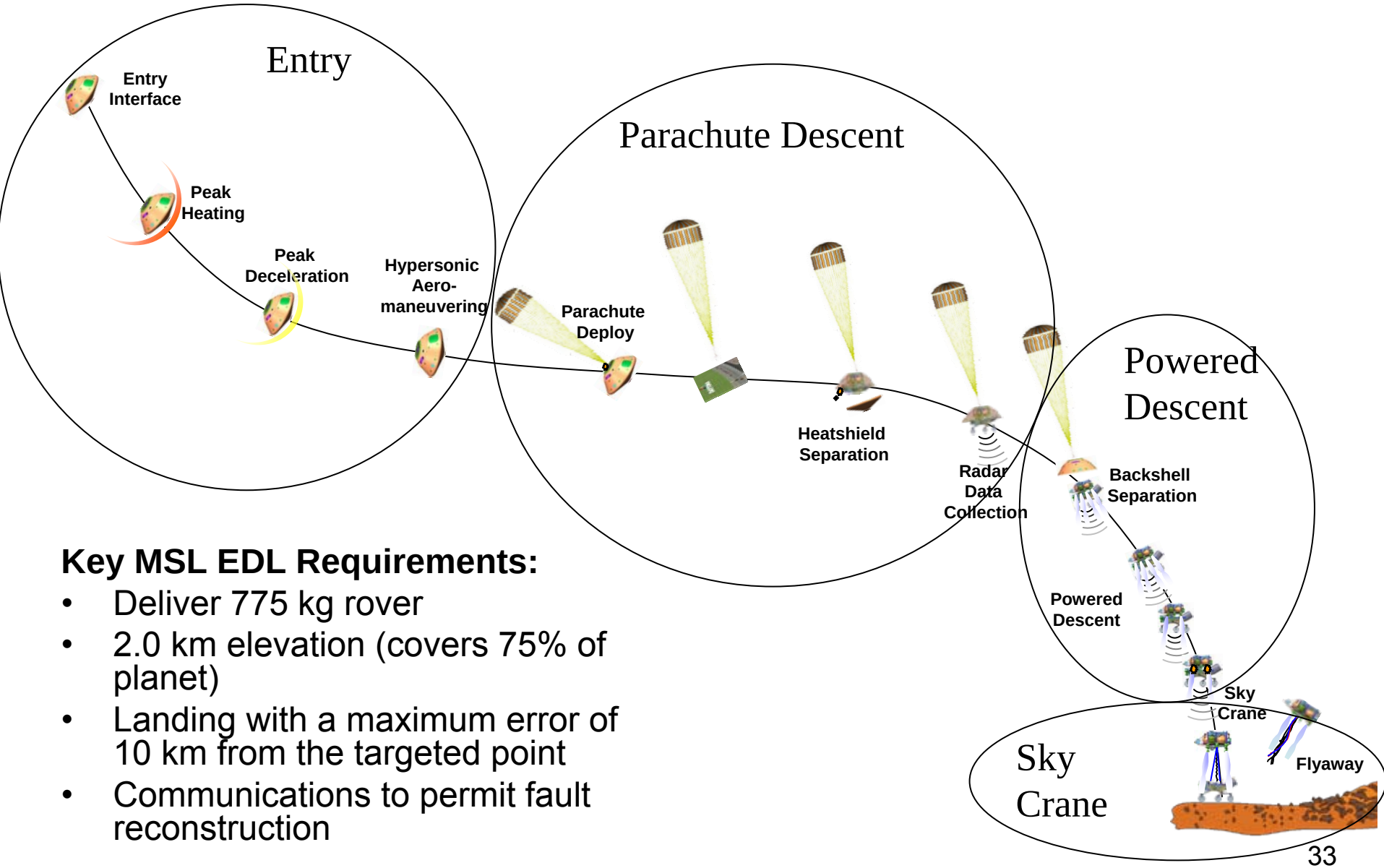
- September 2009
- Atlas V/Delta IV
- 5-m fairing

SURFACE MISSION

- 775 kg rover
- 10 instruments (75 kg)
- One Mars year mission
- ± 60° latitude
- Discovery Responsive
- ≥ 20 km mobility
- RTG and Batteries Power Source
- UHF Comm. (X-band B/U)

Design Concept

EDL Events



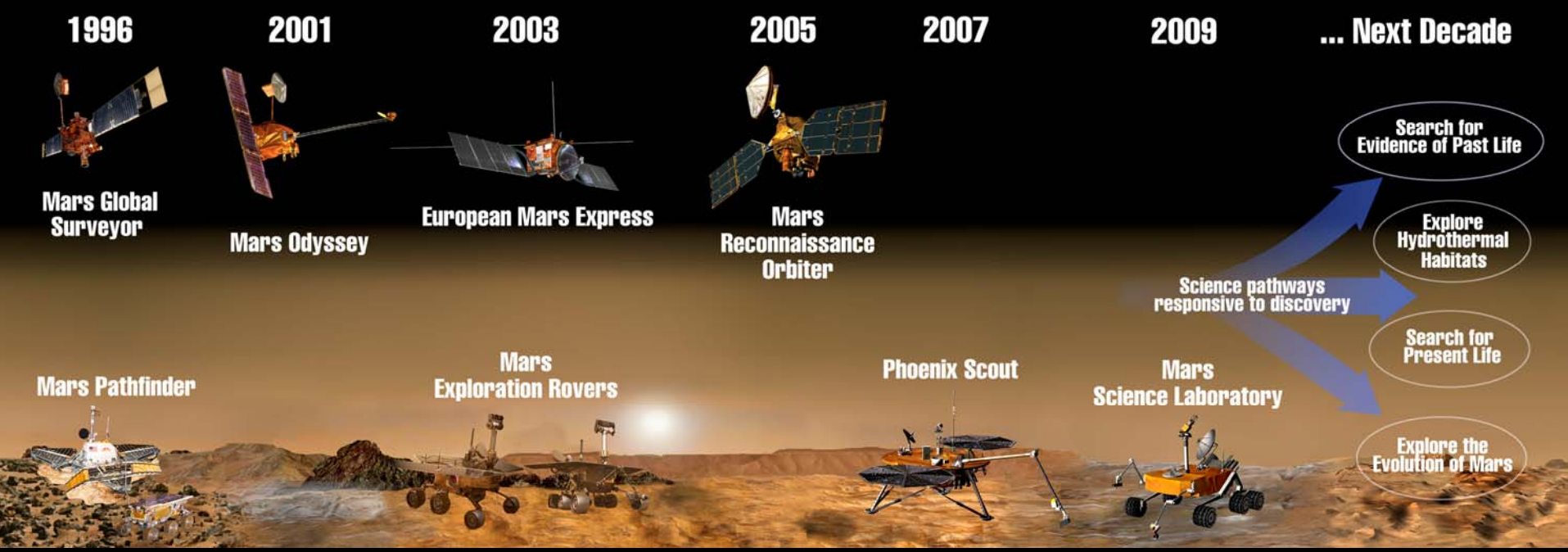
Key MSL EDL Requirements:

- Deliver 775 kg rover
- 2.0 km elevation (covers 75% of planet)
- Landing with a maximum error of 10 km from the targeted point
- Communications to permit fault reconstruction

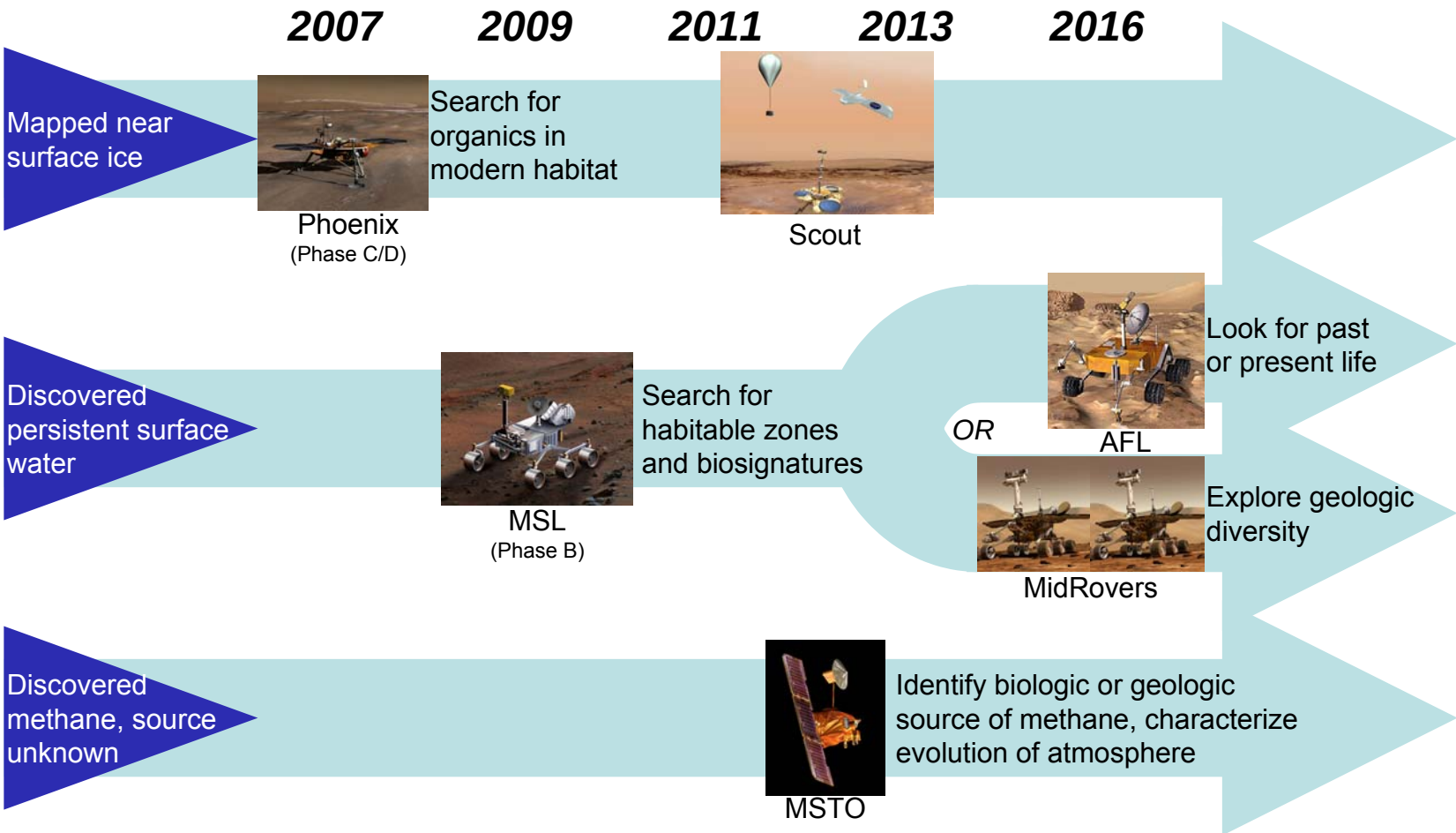
National Aeronautics and Space Administration

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

Mars Exploration Program



Mars Exploration Program
Next Decade Plan



Continuing discussions on ‘18/’20:

- Tentative candidates are Scout for ‘18 and Network for ‘20

BACKUP

National Aeronautics and Space Administration

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

Mars Exploration Program

JPL

Jan. ’06 | Apr. ‘06 | Jul. ’06 | Oct. ‘06

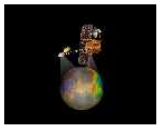
MGS

9th yr operation

Support MRO Aerobraking

Extended Mission Proposal

Continue science observations



Odyssey

Elemental Maps

Support MRO Aerobraking

Extended Mission Proposal

Continue science observations

MER

Spirit

Climb Husband Hill and descent

Exploration of Home Plate

Extended Mission Proposal

Opportunity

Exploration of Erebus

March towards Victoria

MEx

South Polar Region Mapping

Extended Mission Proposal

MRO

Mar. 10, ’06

MOI

Aerobreaking

Science Mission Phase

Phoenix

MOS/GDS CDR

ARR

ATLO

MSL

PNAR

SRR

Phase B

PDR

NAR

Phase C/D

Next Decade Planning

MEPAG Final Draft

COMPLEX IPAO Program Review

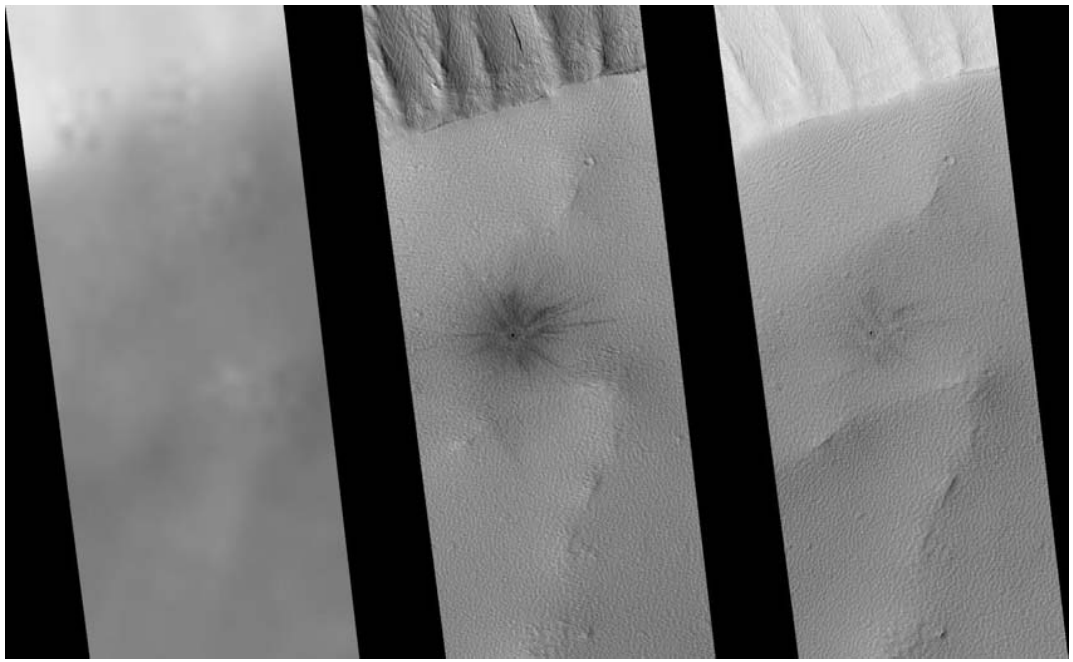
NAR

FY’08 Planning

National Aeronautics and
Space Administration

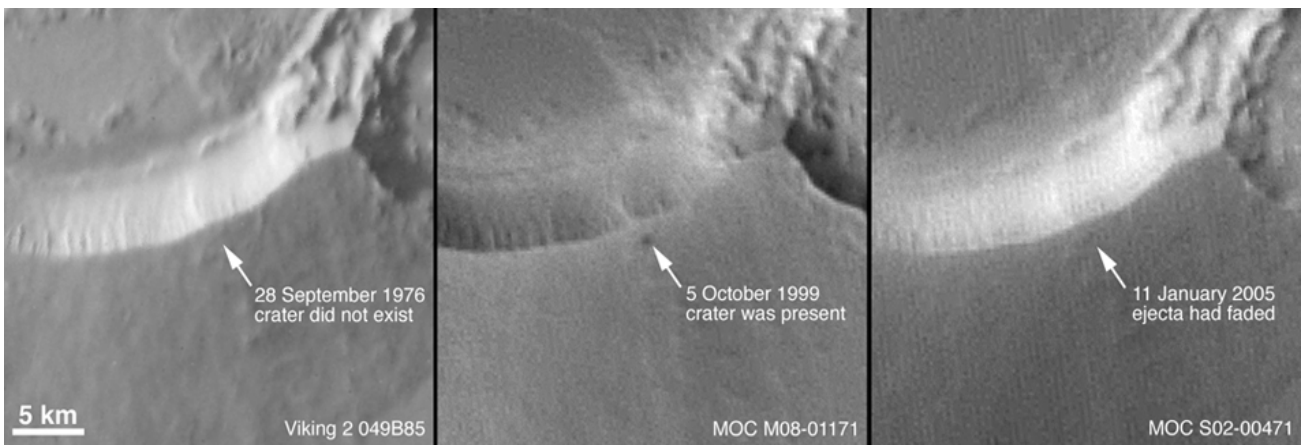
Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

Mars Global Surveyor
Recent Impact Crater



Aero-News.net MGS observed new impact craters formed since t he 1970s suggesting changes to age-estimating models.

SPACE.com, Researchers poring through MGS images by hand found a fresh crater that apparently formed in t he 1980s. The crater, a 65-foot (20-meter) pit carved into the southern rim of t he Martian volcano Ulysses Patera, did not appear in photographs taken by NASA's Viking orbiter in 1976. But MG S' camera found the crater, ringed by a dark ejecta blanket and radial lines, in 1999. By 2 005, the ejecta blanket was nearly faded, but t he crater remained.



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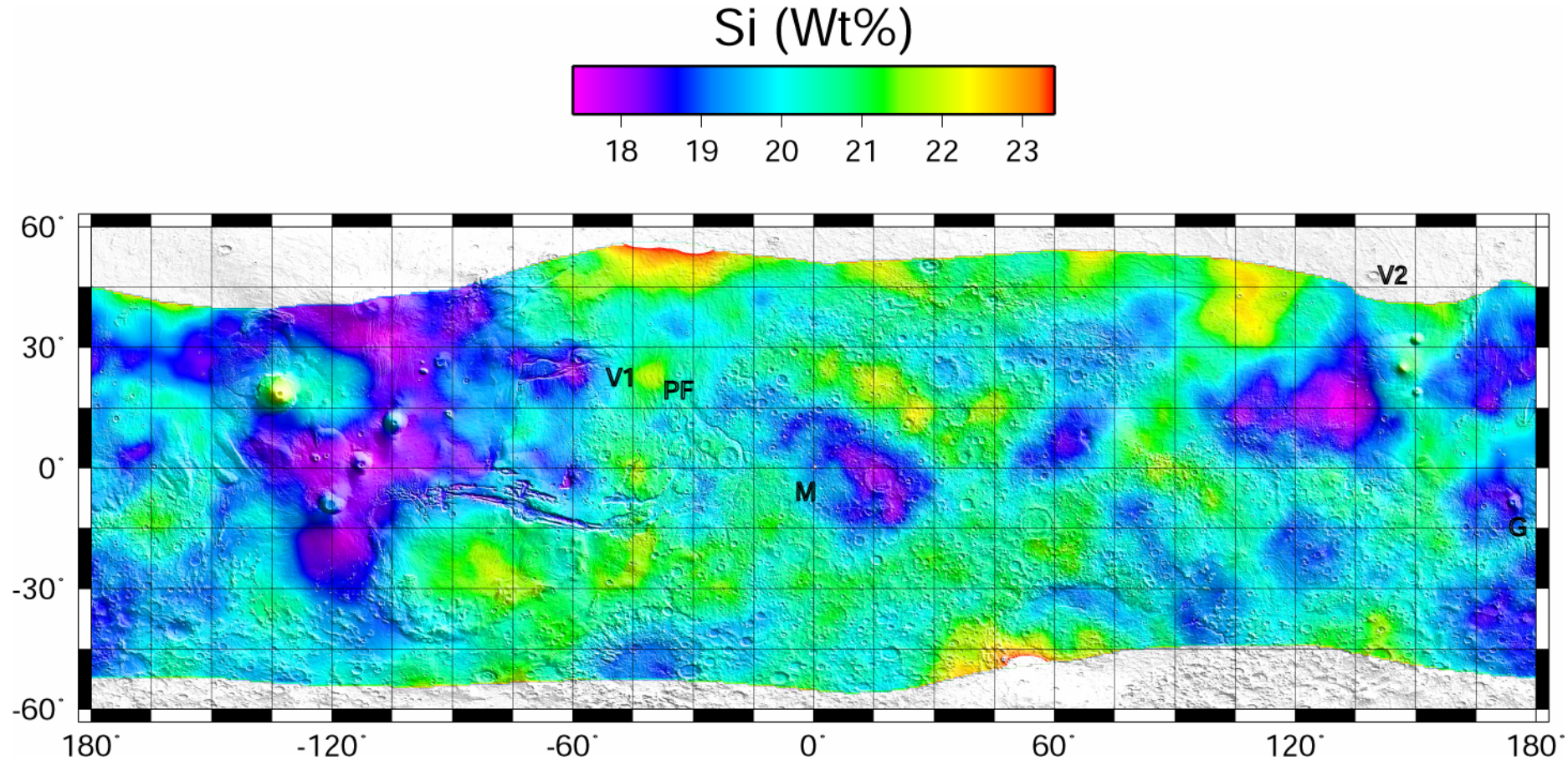
California Institute of Technology
Pasadena, California

Mars Odyssey GRS Element Maps - Silicon



- Variations in Si abundance are small, except for a significant depletion on the Tharsis volcanoes.
- Indicates dilution by secondary minerals (salts) or a compositional change in the youngest volcanics.

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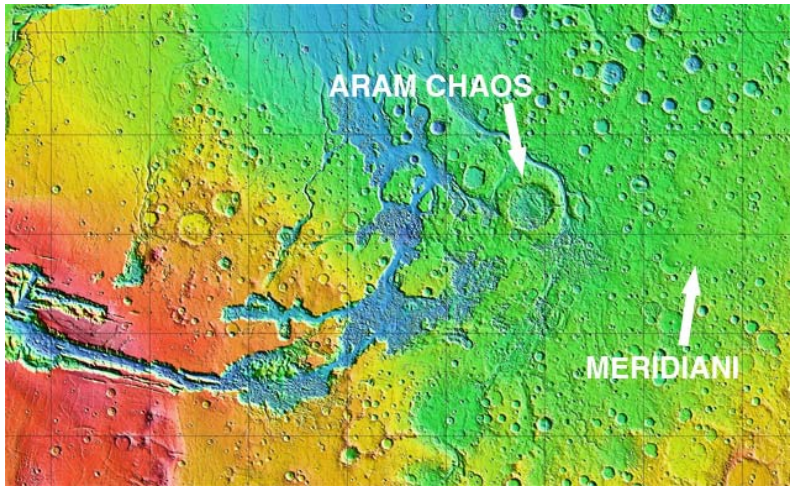
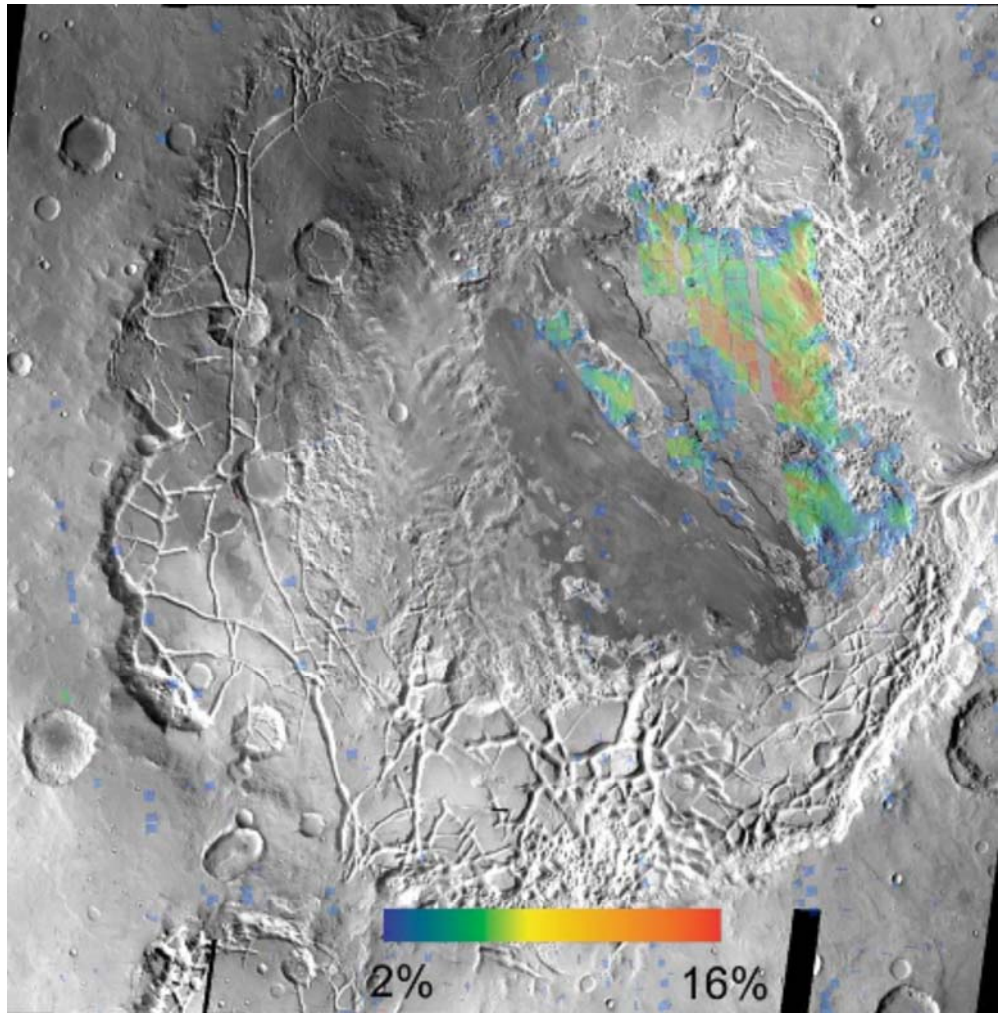
Mars Odyssey THEMIS Science Update



- Aram Chaos is the second largest occurrence of hematite on Mars, after Meridiani.

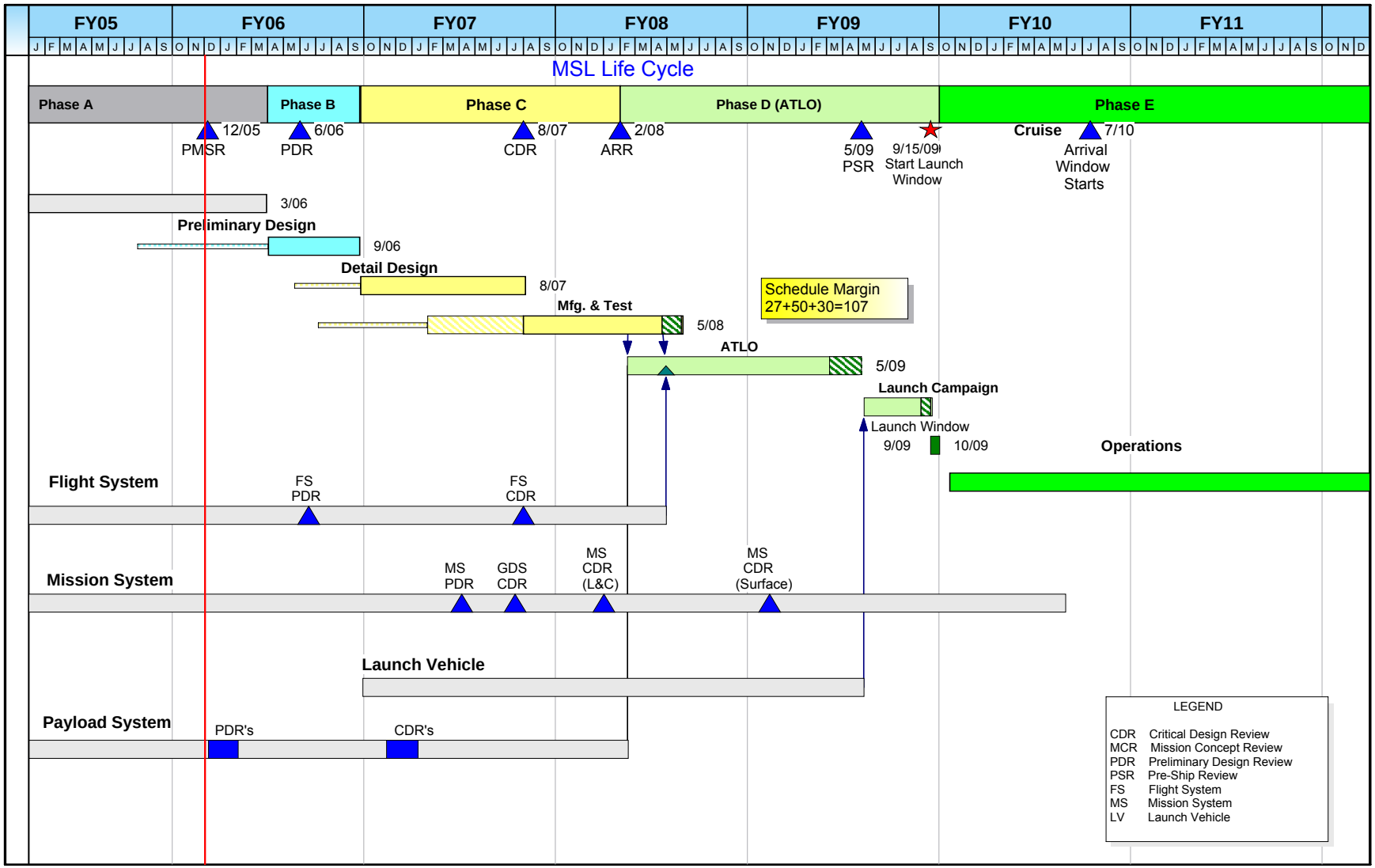
- THEMIS data suggest that Aram probably contained a standing body of water.



THEMIS infrared image of Aram Chaos, with hematite abundance from MGS TES (Circular feature diameter = ~300 km)

Glotch and Christensen, JGR 2005

Summary Schedule



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Space Administration

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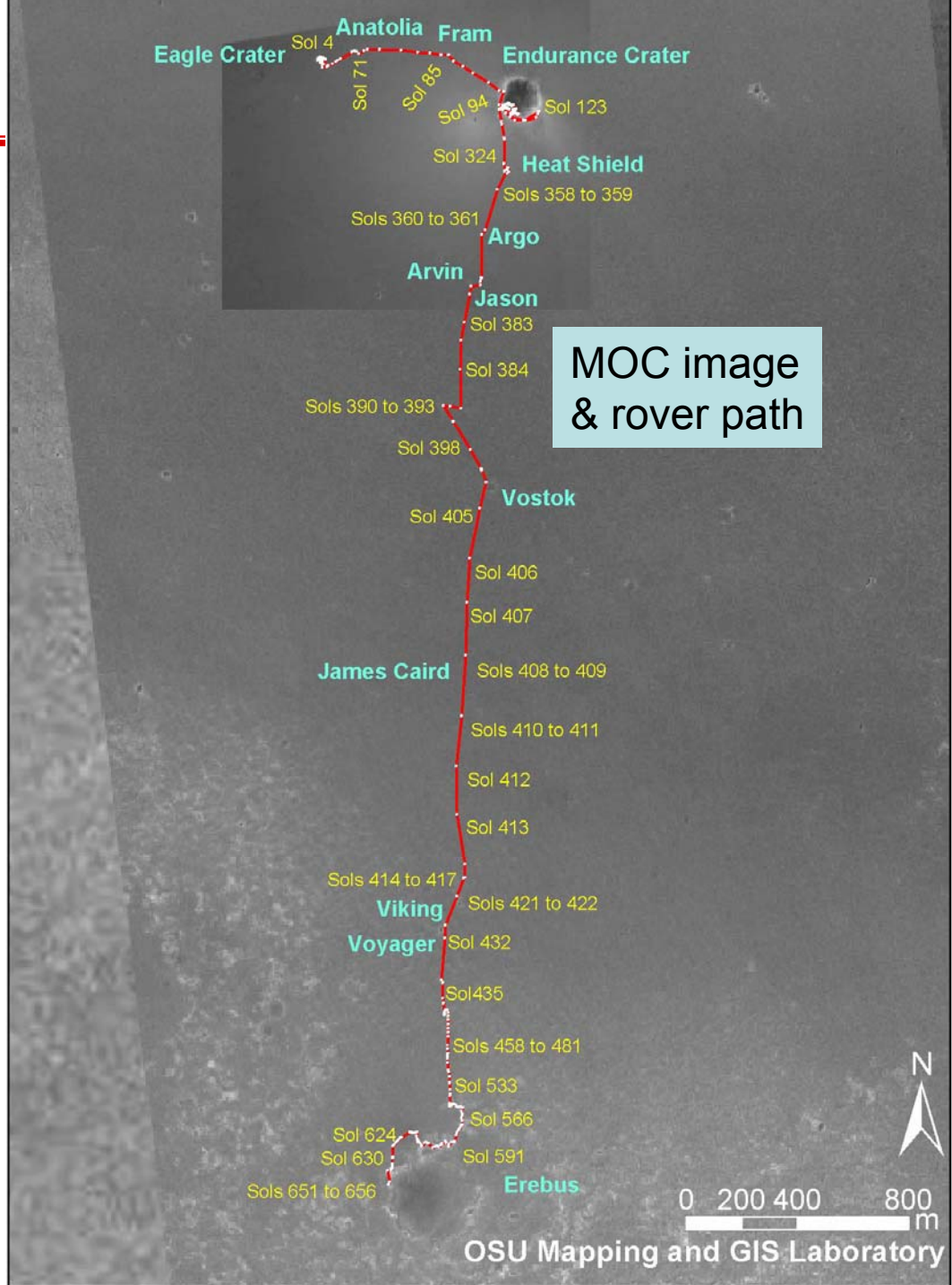
Pasadena, California

The nature of the rocks and mode of deposition at Eagle and Endurance craters (evaporite sandstones transported by wind and water) extends over ~3 km to the south

The regional pattern leads us to search for lake-bed sedimentary deposits that have not been transported by wind or water.

We will drive across the plains to Victoria (another ~ 2.5 - 3 km south) as quickly as possible while on the lookout for lake sediments. The real payoff will likely be the ~30 to 40 m stratigraphic section of rock that appears to be exposed in the rim of Victoria crater.



Phoenix Payload

Mars Descent Imager (MARDI)

MSSS

Surface Stereo Imager (SSI)

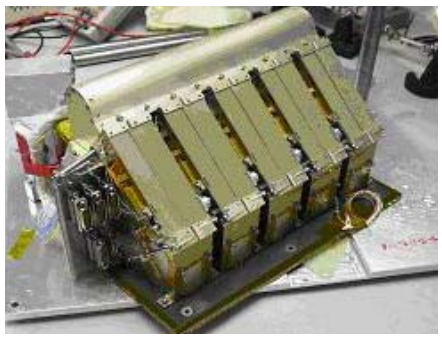
University of Arizona

Robotic Arm (RA)

JPL

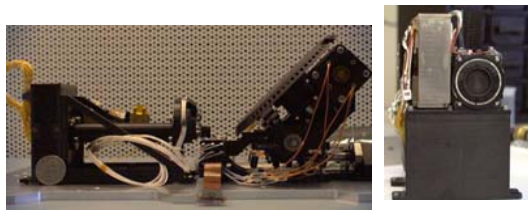
Robotic Arm Camera (RAC)

Max Plank Institute



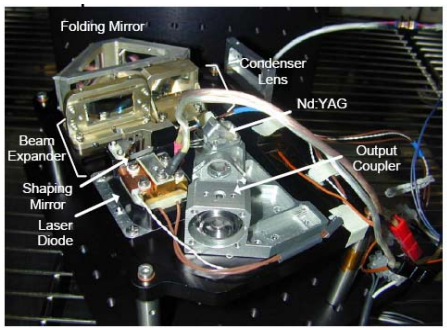
Thermal and Evolved Gas Analyzer (TEGA)

University of Arizona



Microscopy, Electrochemistry & Conductivity Analyzer (MECA)

JPL

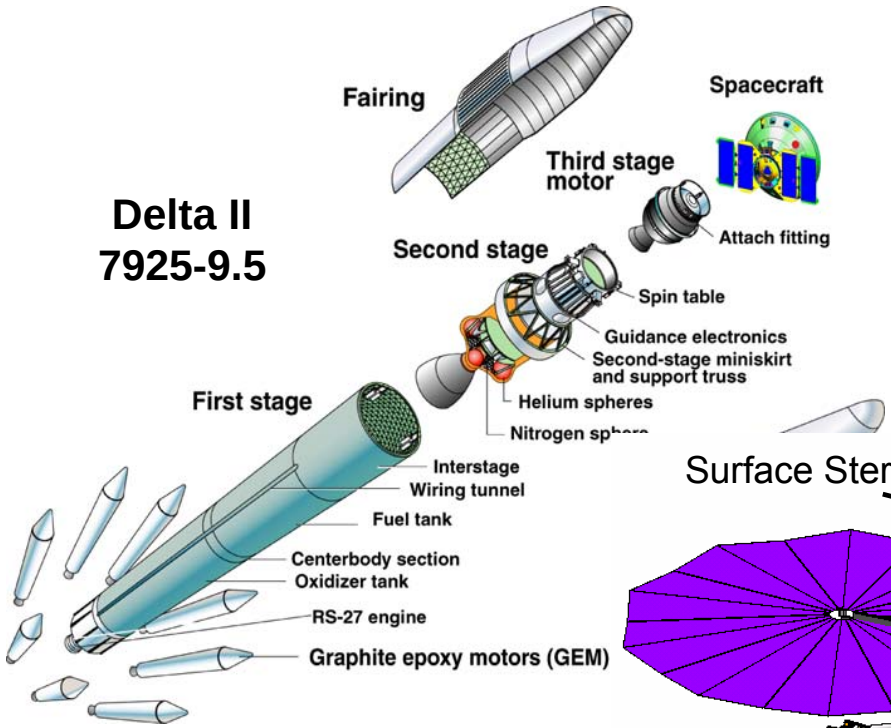


Meteorological Package with LIDAR

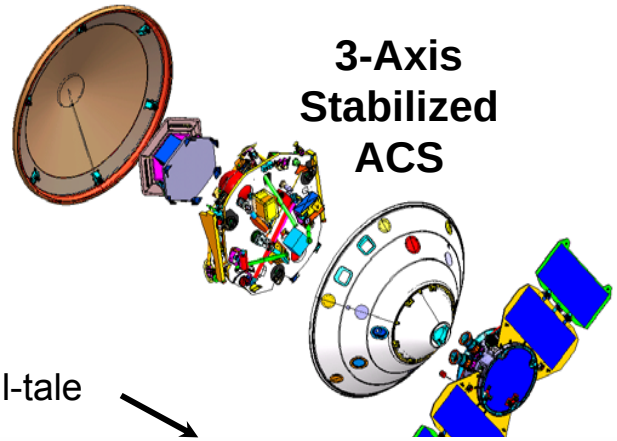
Canadian Space Agency

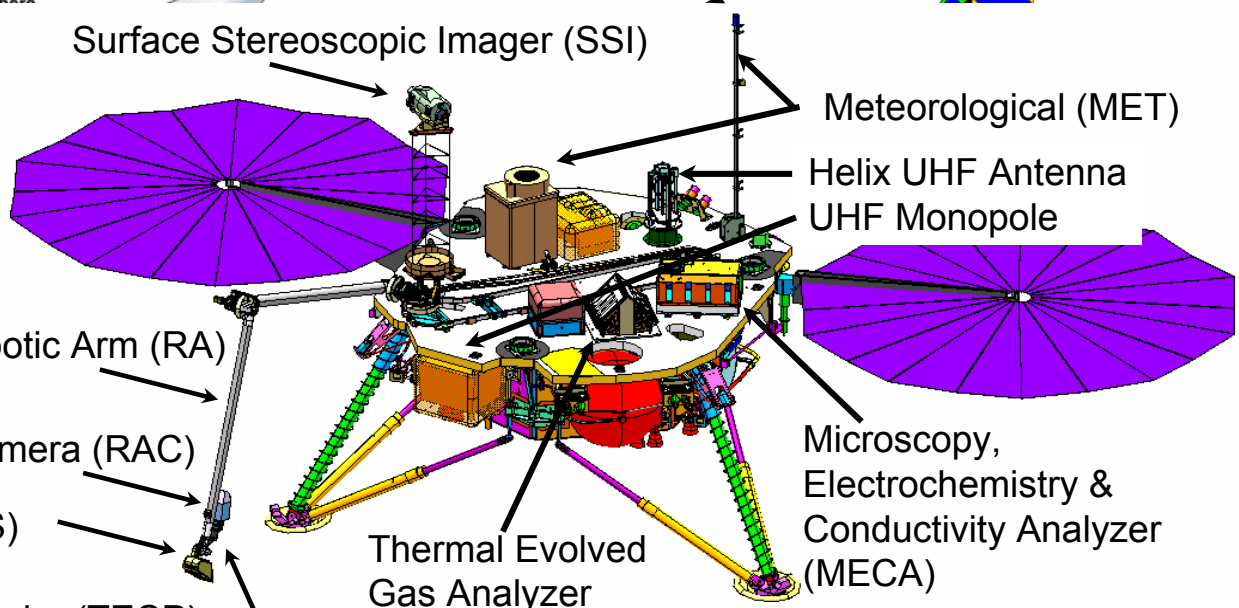
Phoenix Flight System

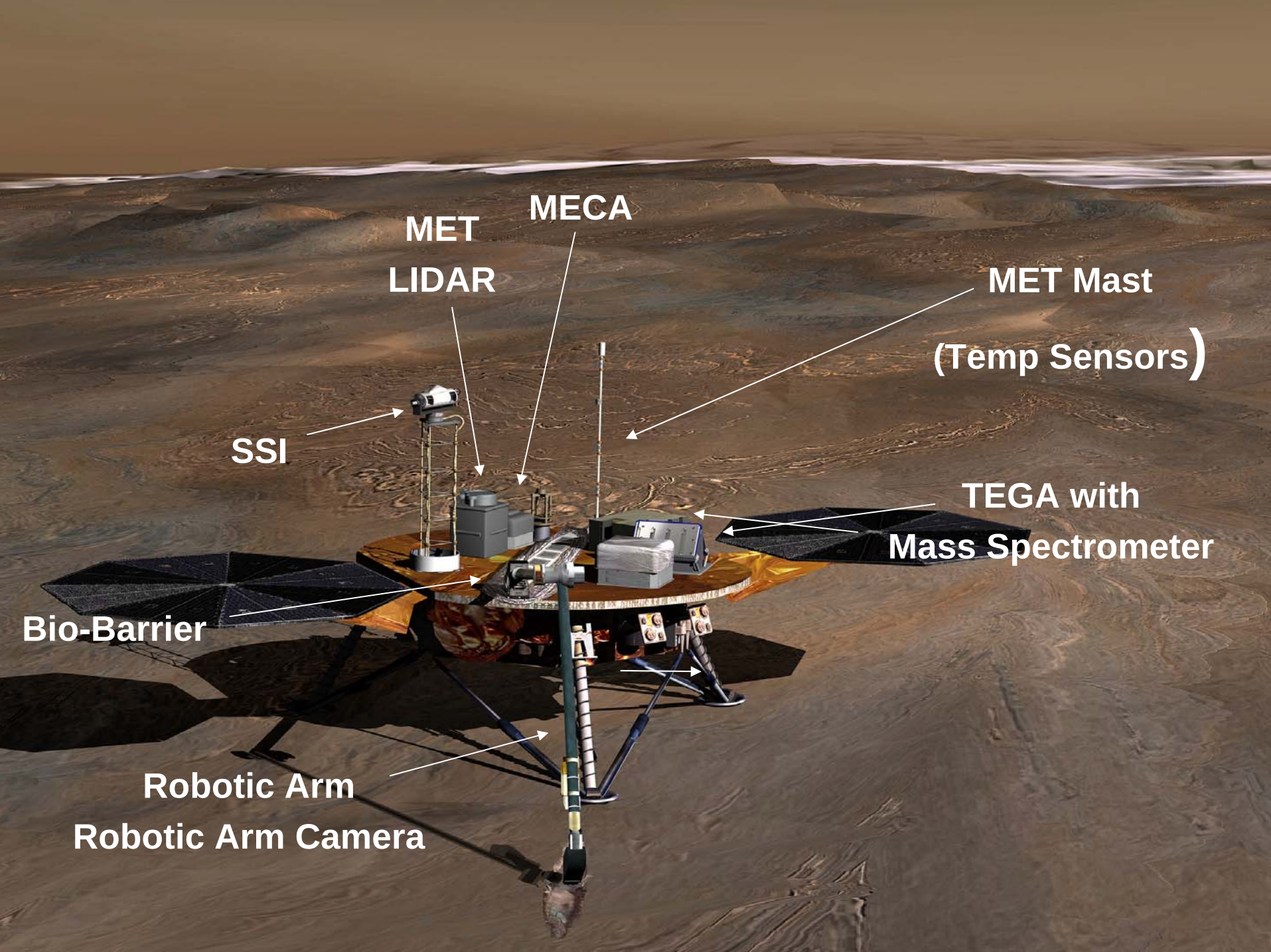
Delta II 7925-9.5



3-Axis Stabilized ACS






MET
LIDAR
MECA
MET Mast
(Temp Sensors)
SSI
TEGA with
Mass Spectrometer
Bio-Barrier
Robotic Arm
Robotic Arm Camera

Science Objectives

Biological Potential

- Determine the nature and inventory of organic carbon compounds
- Inventory the chemical building blocks of life (C, H, N, O, P, S)
- Identify features that may represent the effects of biological processes

Geology

- Investigate the chemical, isotopic, and mineralogical composition of the Martian surface and near-surface geologic materials.
- Interpret the processes that have formed and modified rocks and regolith.

Habitability

- Assess long-time scale atmospheric evolution processes.
- Determine present state, distribution, and cycling of water and CO_2.

Radiation

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