



# *An Overview and Status on the Mars Reconnaissance Orbiter (MRO) Mission*

Dan Johnston

4 November 2011

*Jet Propulsion Laboratory  
California Institute of Technology*



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Pasadena, CA

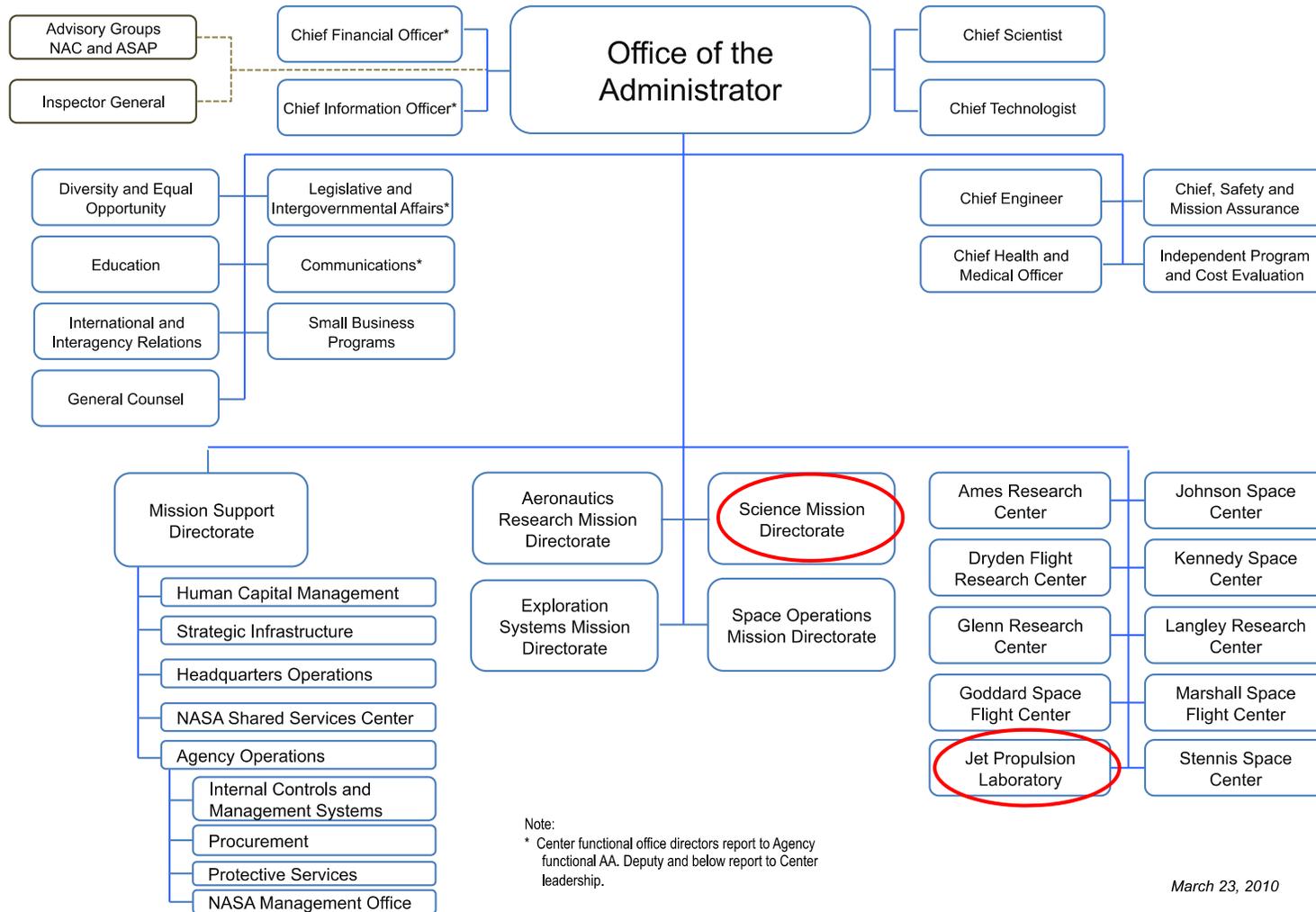
# Presentation Outline



- Mars Exploration Program
- MRO Mission
  - *Roles and Mission Status*
    - *High Resolution Science Platform*
    - *Communications Relay for Landed Missions*
    - *Landing Site Scout*
  - *Key Participants, Mission Synopsis, and Key Characteristics*
- MRO Spacecraft
  - *Spacecraft Bus & Payloads*
- MRO Science
  - *Project Organization*
  - *Mission Operations*
- Extended Mission Objectives



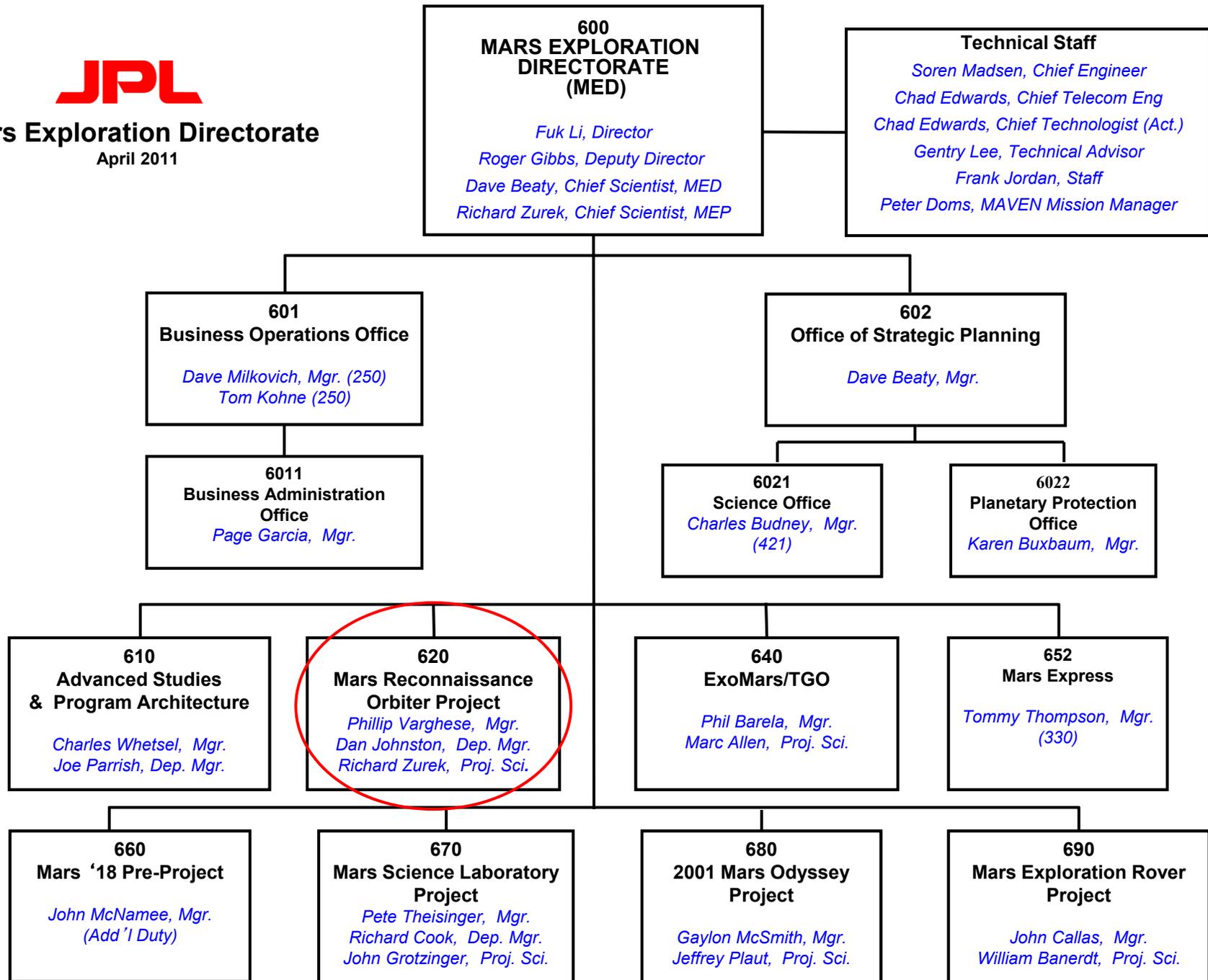
# National Aeronautics and Space Administration





# Mars Exploration Directorate

April 2011



# *This Decade Mars Exploration*

Launch Year

1996

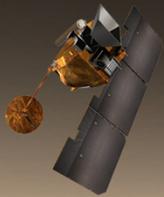


**Mars Global Surveyor**  
*(mission completed)*

**Mars Pathfinder**

*(mission completed)*

2001



**Mars Odyssey**

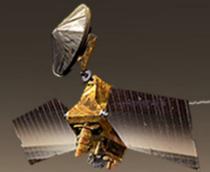
2003

**Mars Express Collaboration**



**MEP Rovers**  
*Spirit*  
*Opportunity*

2005



**Mars Reconnaissance Orbiter**

2007

**Phoenix**  
*(mission completed)*



2011

**Mars Science Laboratory**

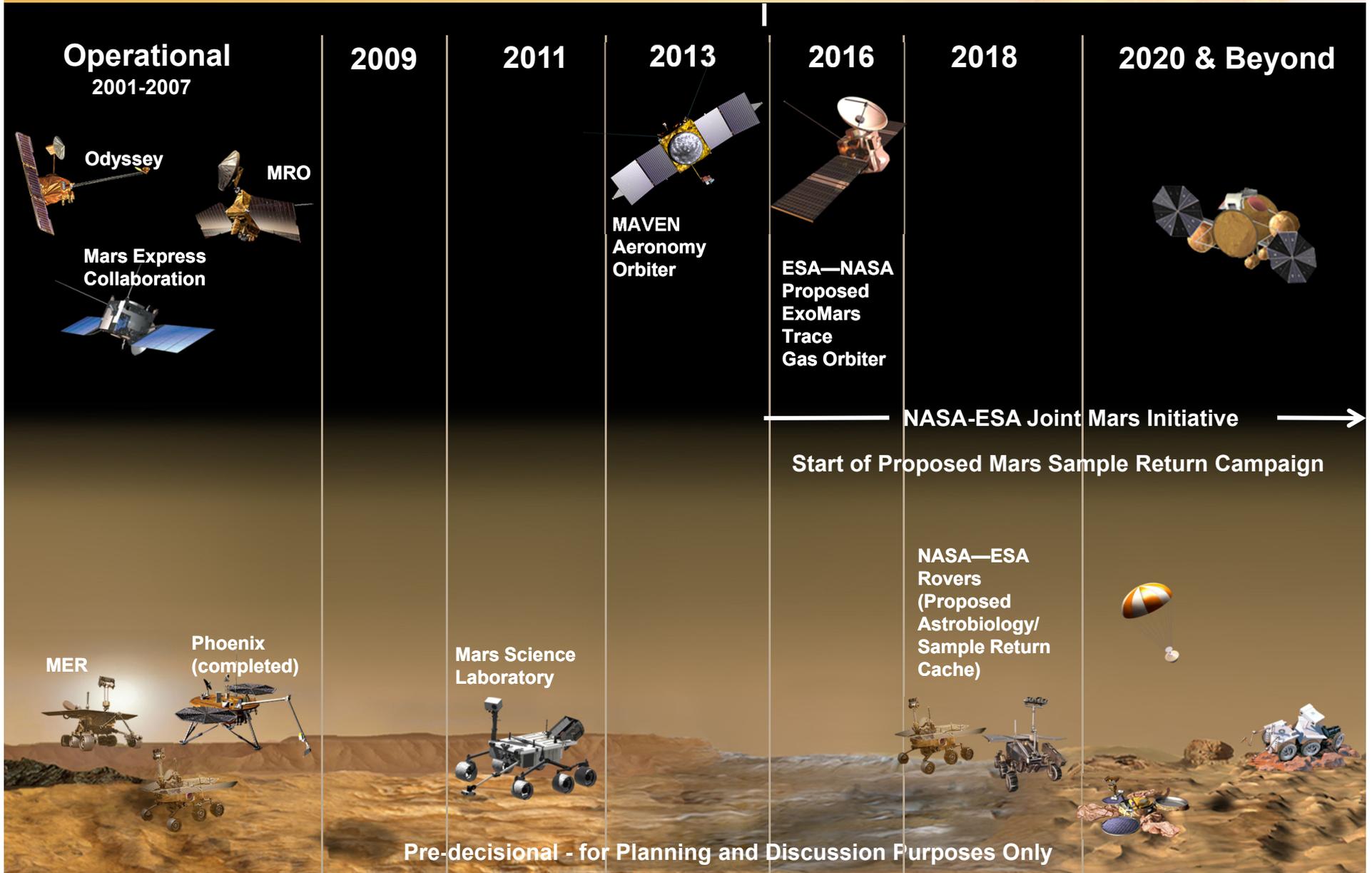




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# Mars Exploration Program Missions: **JPL**

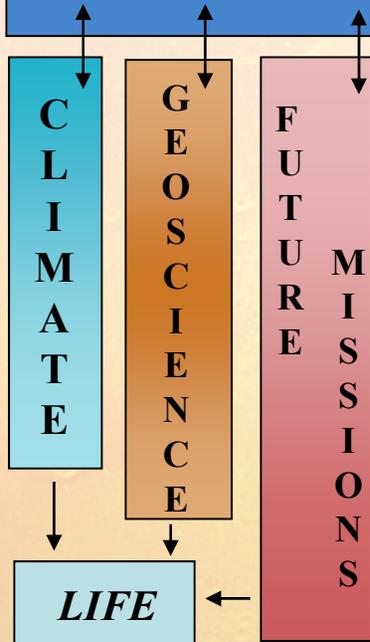
## Present Capabilities & Future Plans





# MRO Has Many Roles

## “Follow the Water” Theme



- **Weather and Climate Satellite**

- Monitor the present climate, seasonally and year-to-year
- Alerts Mars Exploration Rovers to evolving dust storm events
- Monitored atmosphere for Phoenix as it approached Mars entry

- **Geological Explorer**

- Identified water-related landforms and aqueous surface deposits
- Probed the subsurface looking for layering and water (ice)

- **Site Finder**

- Observed hundreds of sites at very high-resolution to find the best places for future landed exploration
- MRO data led Phoenix to a new site, also characterized & certified by MRO

- **Communications Satellite**

- Provided relay for Phoenix (2008) augmenting relay by Mars Odyssey
- Will provide critical event coverage (entry, descent and landing) and relay for Mars Science Laboratory (2012-2013)

- **Technology Pathfinder**

- Demonstrated optical navigation and use of new telecom frequencies (Ka-band) for future missions



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## *Key Mission Participants*

- Project Management/Leadership, Navigation, Sequencing, & Ground Data System – **Jet Propulsion Laboratory**
- Spacecraft Bus & Systems Integrator – **Lockheed Martin**
  - *Spacecraft Operations Team => Flight Engineering Team*
- Science Payloads – Science Data Acquisition & Return
  - *HiRISE (PI Lead) – High Resolution Imager - 30 cm per pixel (UofA)*
  - *CRISM (PI Lead) – High Resolution Vis/NIR Imaging Spectrometer (APL)*
  - *CTX (Facility Investigation) – Context Imaging – 6 m per pixel (MSSS)*
  - *MARCI (PI Lead) - Mars Color Imager – Daily Global Maps (MSSS)*
  - *MCS (PI Lead) – Atmospheric Sounder (JPL)*
  - *SHARAD (Facility Investigation) – ASI Provided Subsurface Radar (ASI)*
  - *Gravity Science (Facility Investigation) – 2-way data tracking data (MIT)*
- Engineering Payloads
  - *Electra – UHF Telecommunications Relay (JPL)*
  - *ONC – Optical Navigation Camer (JPL)*



## Mission Synopsis

- MRO is a NASA assigned mission
  - *Formulation Phase: November 2000–September 2002*
  - *Implementation Phase: September 2002–September 2005*
  - *Phase E Mission: Operations - Started in FY06*
    - *Primary Science Phase (PSP): November 2006 to November 2008*
    - *Extended Science Phase (ESP) & Relay: December 2008 to September 2010*
    - *Extended Mission (EMI-approved): October 2010 to September 2012*
- *Launch – August 12, 2005*
- *Mars Orbit Insertion – March 10, 2006*
- *Aerobraking – March 30 through August 30, 2006*
- *Science Orbit Establishment – September 2006*
  - *MRO has been in a full science mode since November 2006*
  - *MRO supported the Phoenix Mission in relay mode*
    - *MRO provides weekly relay support to the MER Mission*



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*Launch: August 12, 2005*

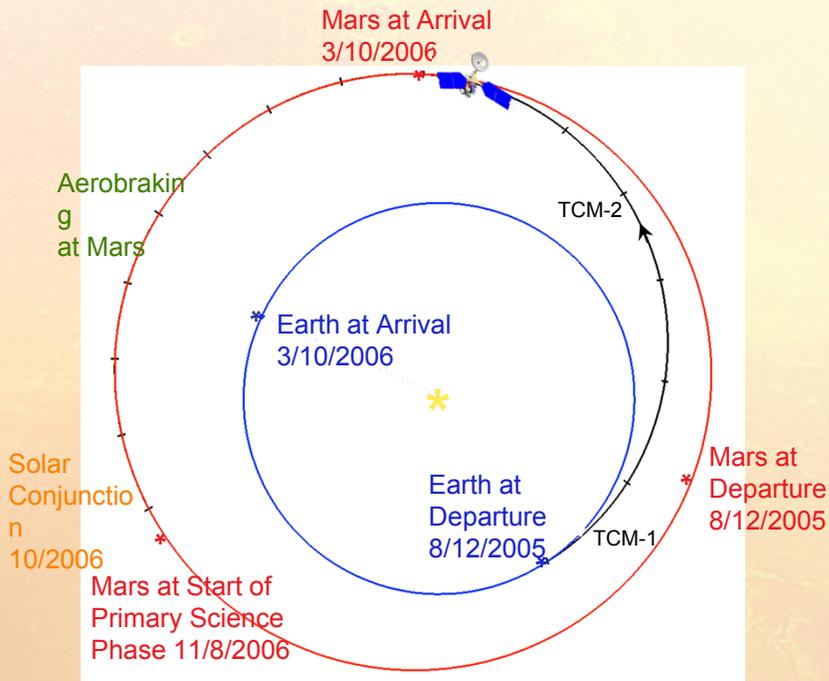




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# Interplanetary Transit:

## August 2005 - March 2006

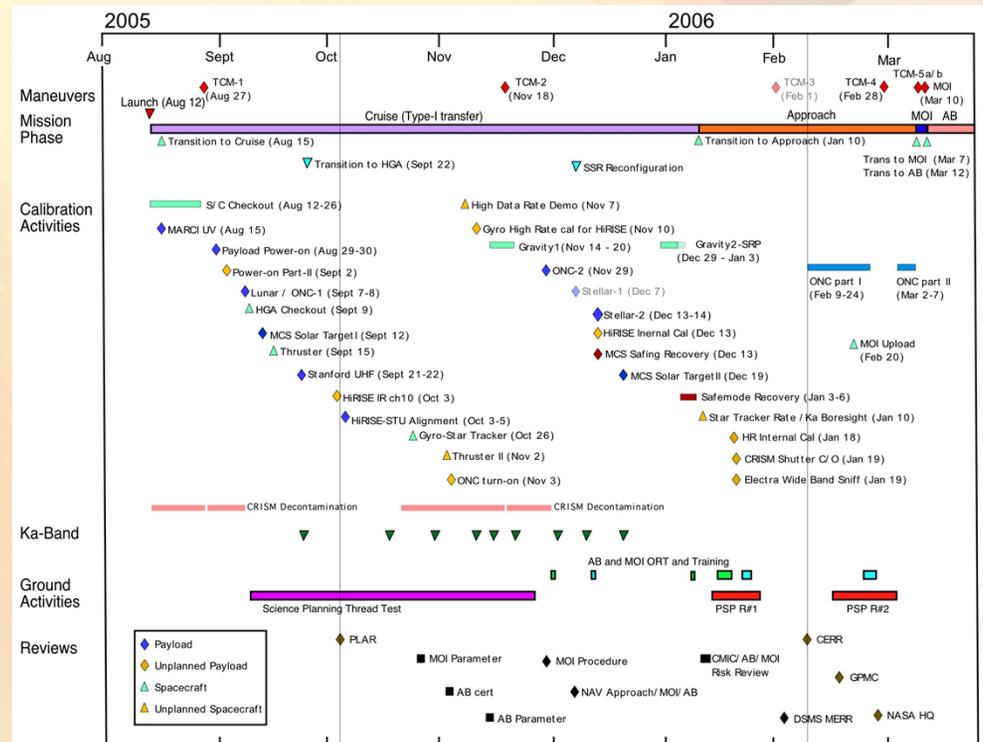


## Interplanetary Trajectory

- 7 month interplanetary flight time
- 5 planned trajectory correction mnvrs (TCMs)
  - Only 2 TCMs required!
  - Total interplanetary DV: 8.6 m/s

## Spacecraft Activity Timeline

- Engineering (spacecraft bus) calibrations
- Science instrument check-out/calibrations





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# *Mars Orbit Insertion: March 10, 2006*

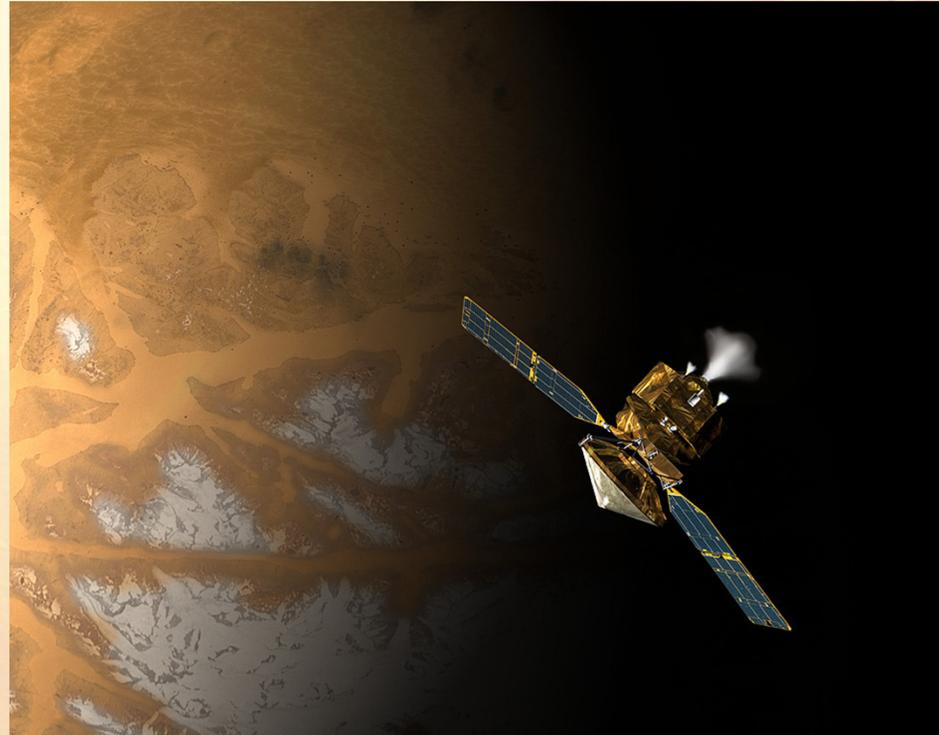
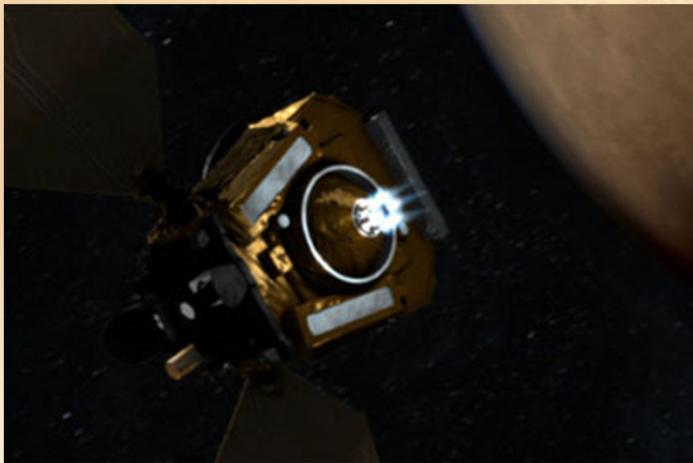
## Mars Orbit Insertion

Interplanetary Delivery --

- Southern Approach Trajectory
- Approach Altitude: **518 km**

Resulting Capture Orbit --

- Orbit Period: **35.5 hrs**
- Periapsis Altitude: **426 km**
- Asc Node Orientation: **8:30 pm**



## Mars Orbit Insertion Maneuver

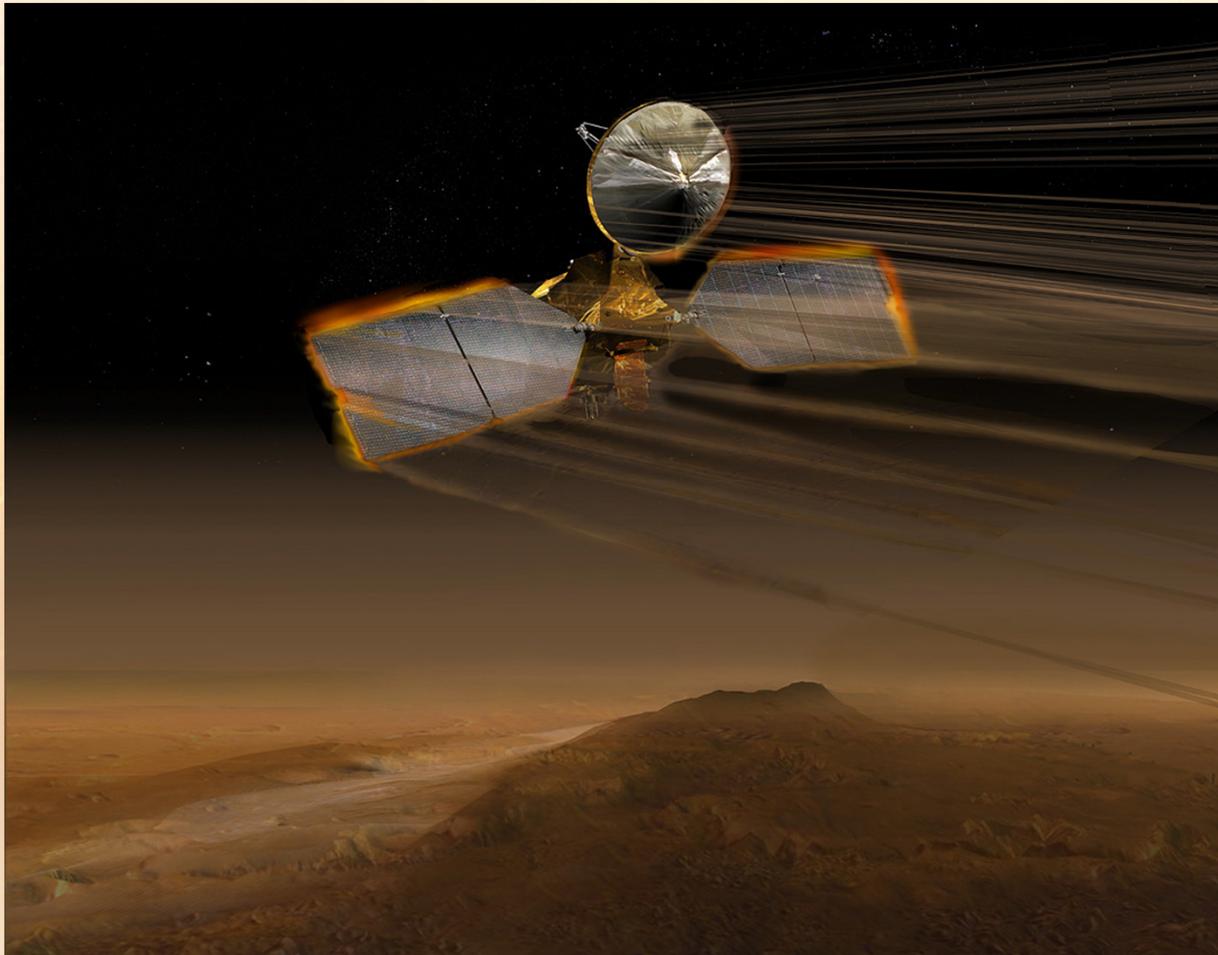
- Pitchover maneuver
- Magnitude: **1000 m/s**
- Burn Duration: **27 min**



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# Aerobraking:

## March - August 2006



### Aerobraking

Number of days: 145 days

Orbit period change: 33.6 hrs

Apoapsis alt change: 44,496 km

Ave periapsis alt: 100 km

Number of drag passes: 426

Number of control mnvrs: 27

Asc Node Orientation: 3:10 pm

DV & Propellant Savings --

DV Savings: 1184 m/s

Propellant Savings: ~600 kg

Robust Thermal Margins

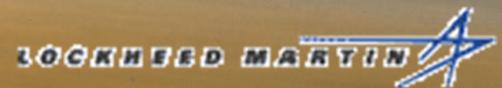
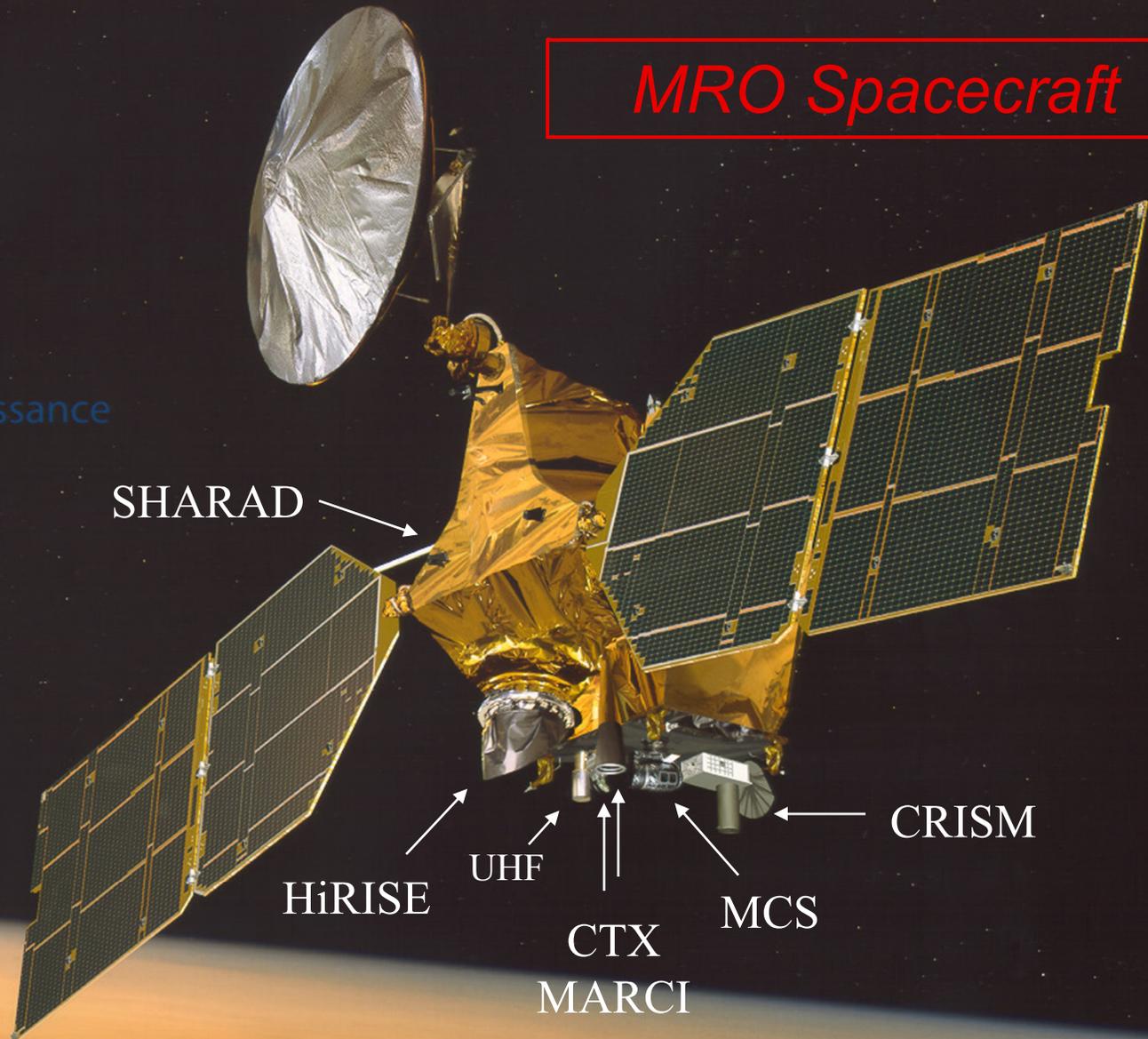
Orbit crossings with other spacecraft



**JPL**

*MRO Spacecraft*

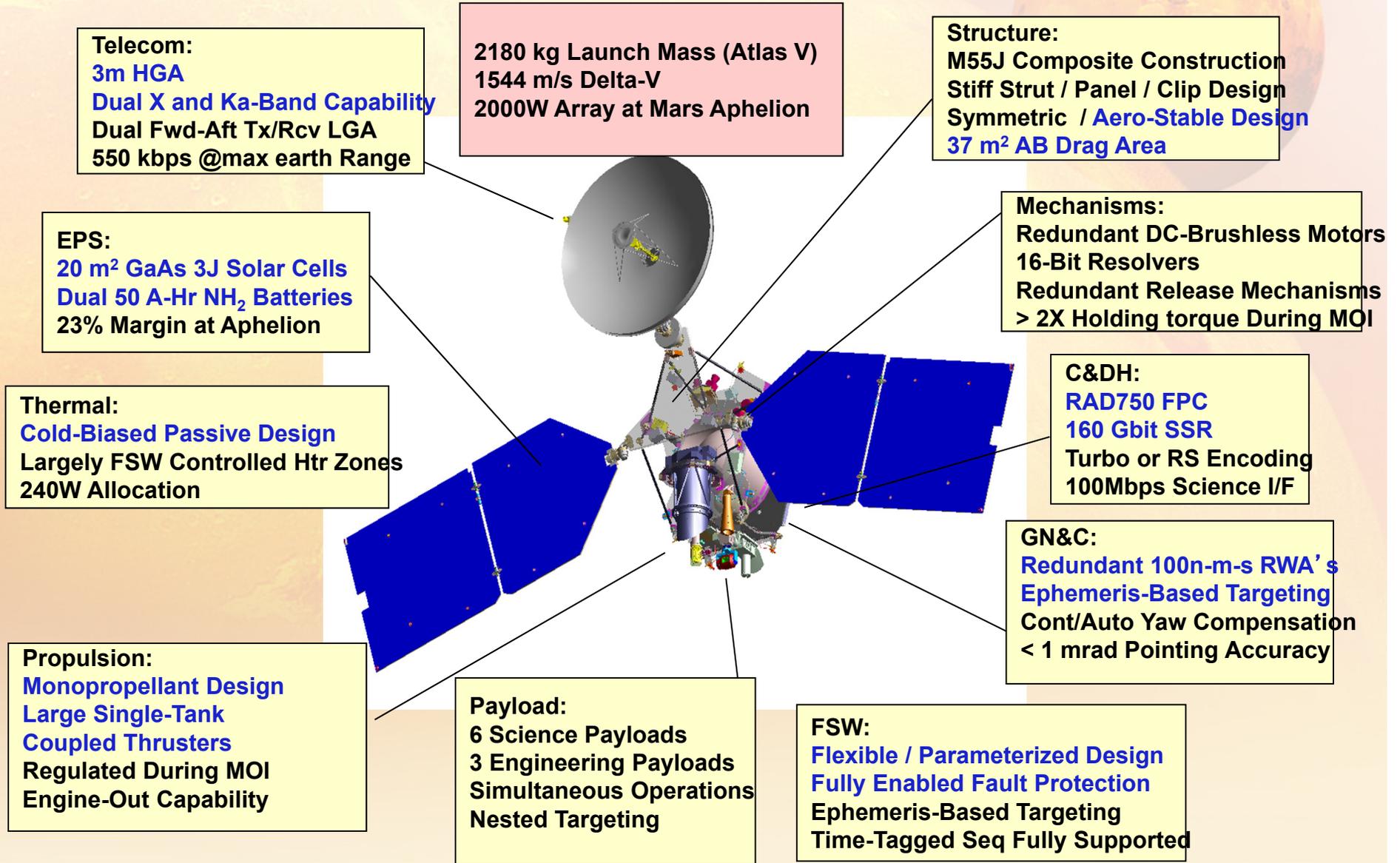
Mars  
Reconnaissance  
Orbiter





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# Spacecraft Overview





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# Science and Engineering Payloads

Contingency  
Only

## Ka-Band Telecom

## Optical Nav Camera

*Technology Demo*

## ELECTRA Antenna

*UHF Relay*

## MARCI

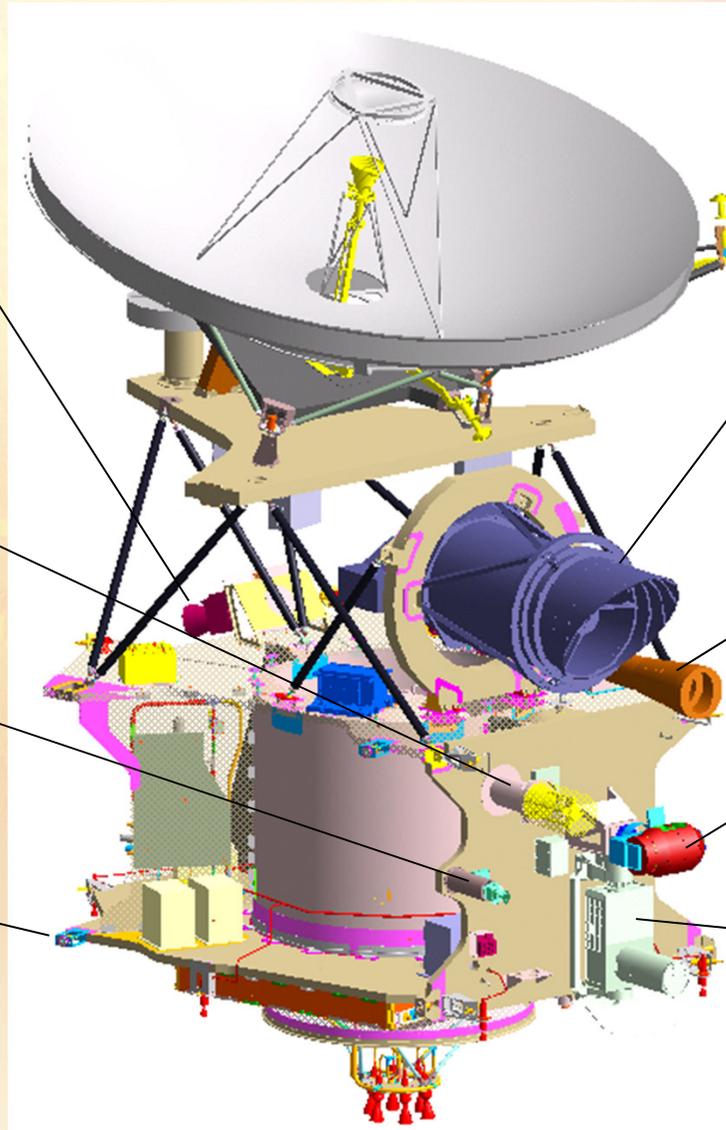
*Color imager - Daily global views of the atmosphere*

## SHARAD

*Sub-surface Sounding Radar*

## Gravity Science

*via tracking data*



## HiRISE Telescope

*Very High Resolution Imager  
(Targeted Observations)*

## CTX

*Context Imager*

## MCS

*Atmospheric Sounder*

## CRISM

*High Resolution Spectrometer -  
Key mineralogical indicators of  
water and hydrothermal systems*



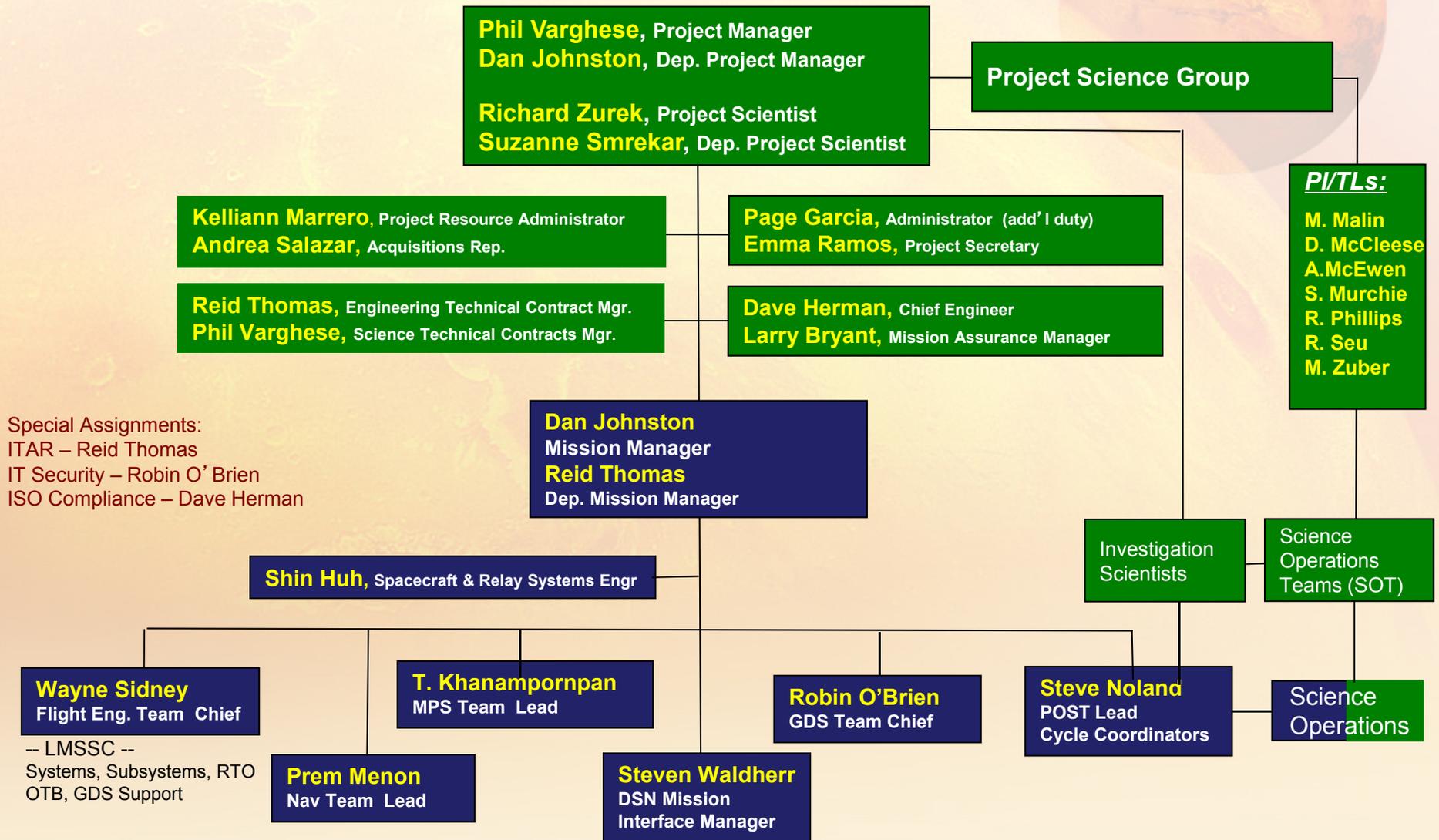
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## Science & Relay Ops - Key Characteristics

- Low Altitude, Sun Synchronous Science Orbit
  - *Sun-synchronous => Nodal orientation (asc node) at 3:00 PM LMST*
  - *Frozen orbit - periapsis near south pole (stationary)*
    - *Periapsis Altitude:  $H_p = 255$  km, Apoapsis Altitude:  $H_a = 320$  km*
  - *Repeating groundtrack design – Active groundtrack control (OTM every other month)*
    - *Complete global targeting coverage in 17 days*
    - *Exact repeat: Sub-5 km spacing after 4602 orbits over 358 days*
  - *Perturbative Effects: gravitational and atmospheric forces -- spacecraft small forces*
- Science Data Acquisition and UHF Relay
  - *Mission objectives include both science observations and relay/support objectives*
    - *MRO operations distinguished by mixed mode of operations to accomplish global mapping, regional surveys, targeted surface observations, and relay support*
  - *High-resolution targeting requires very accurate/frequent navigation predicts*
- Science and Relay Data Return – Prodigious User of the Deep Space Network
  - *16 hours per day of DSN tracking: One 34m pass per day & One 70m pass per day*
    - *12 hours per day of 2-way tracking (gravity science)*

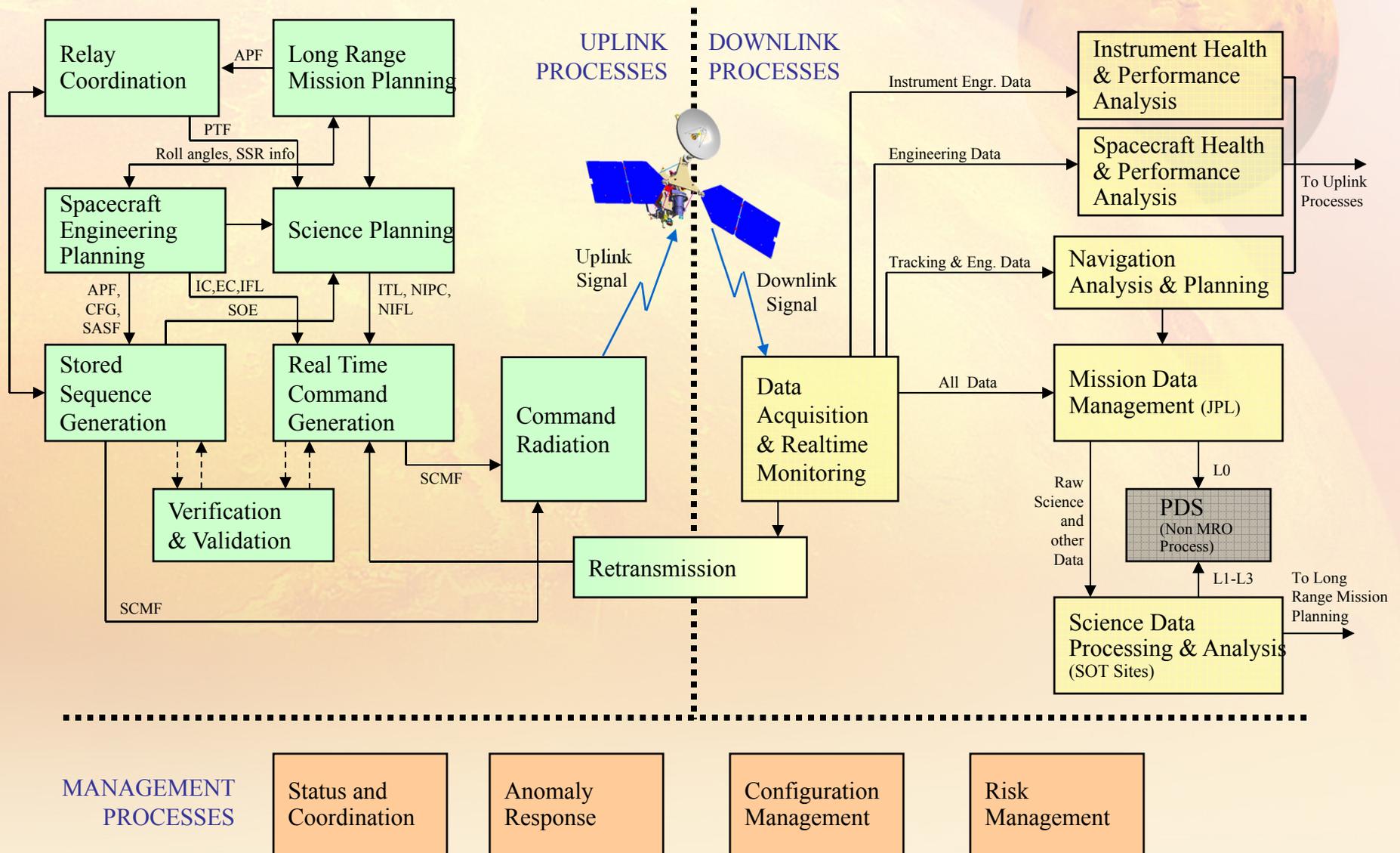


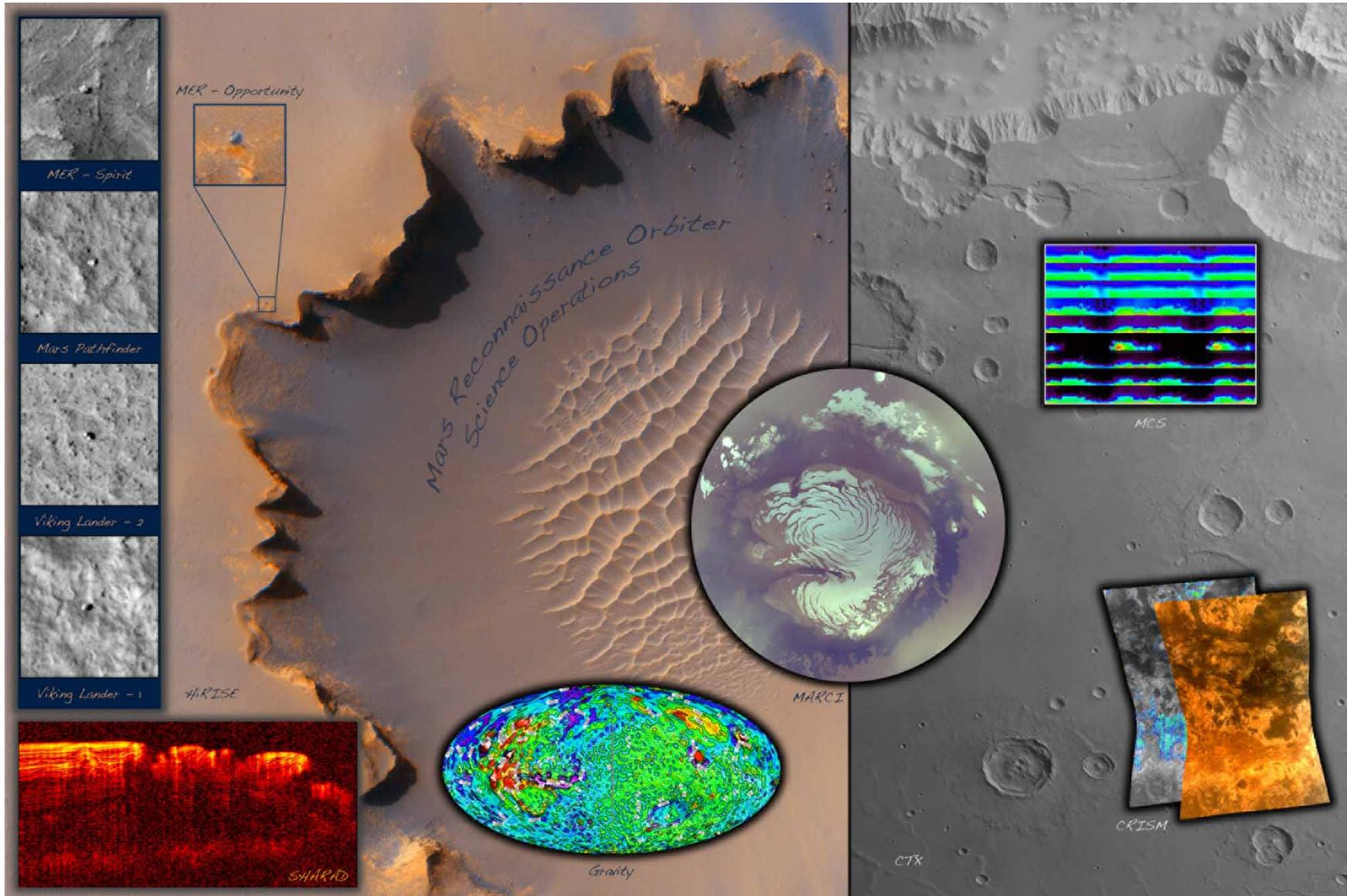
# Project Organization (Mission Operations)





# Mission Operations Processes

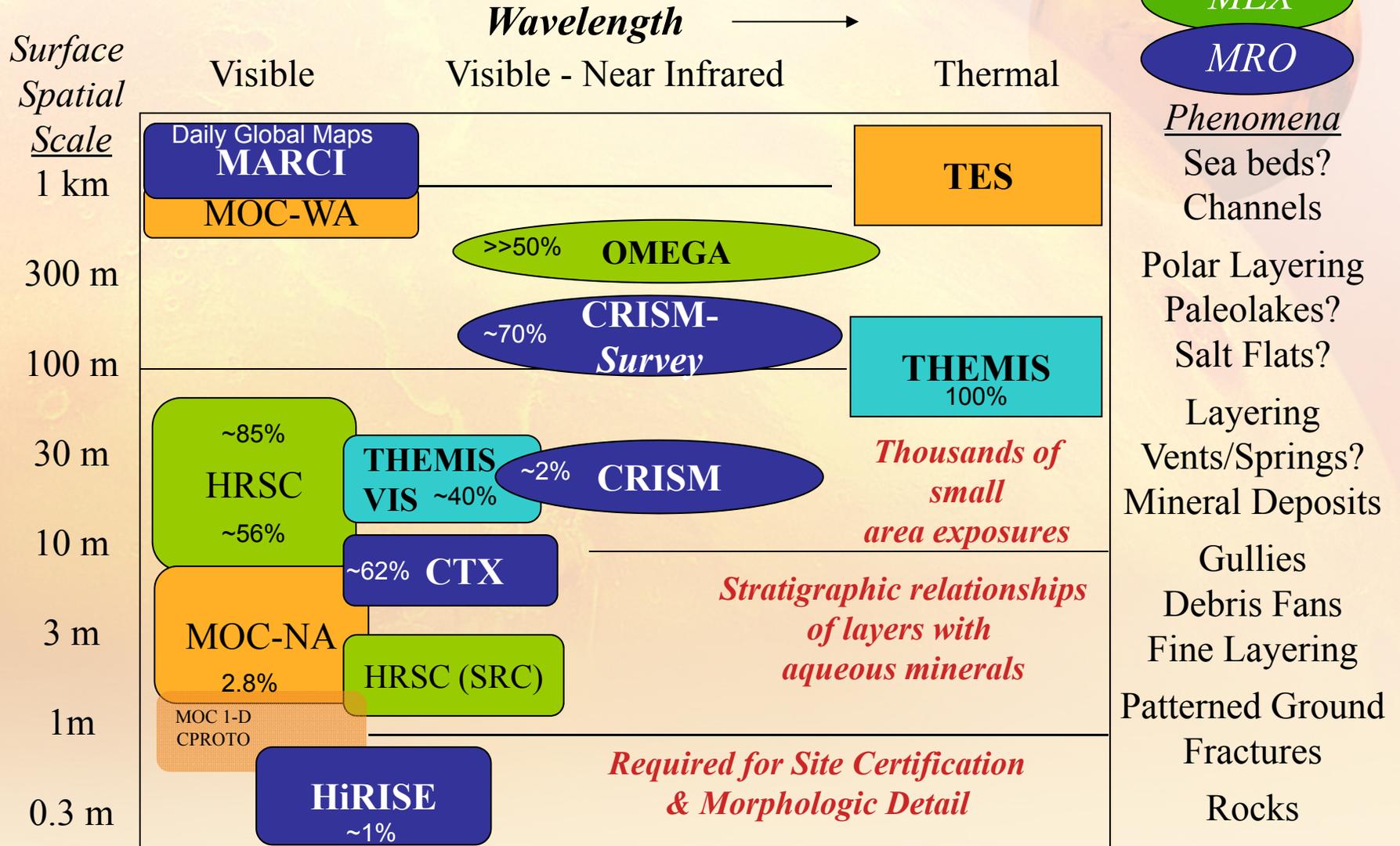






# Gains in Resolution

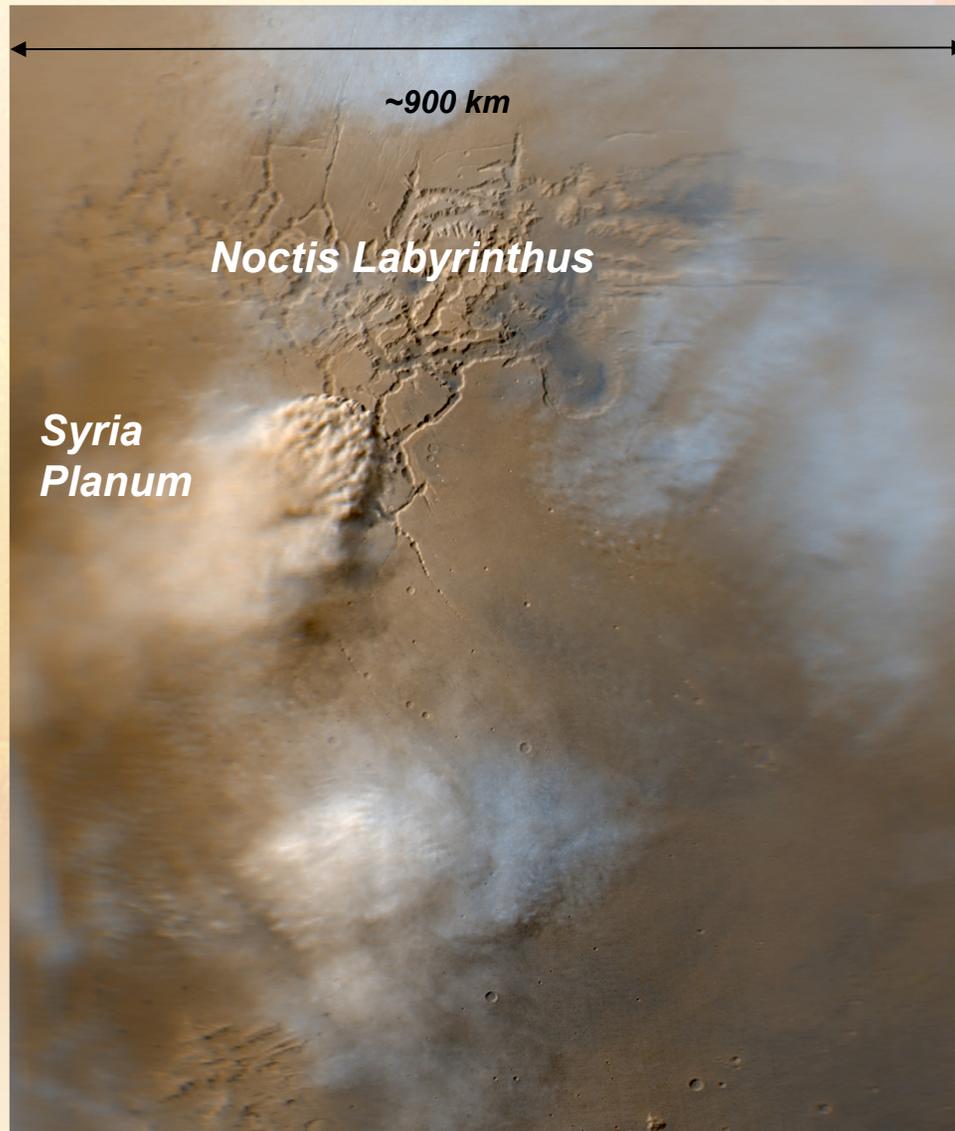
- MGS
- ODY
- MEX
- MRO





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## *MARCI: Dust Storm*



~900 km

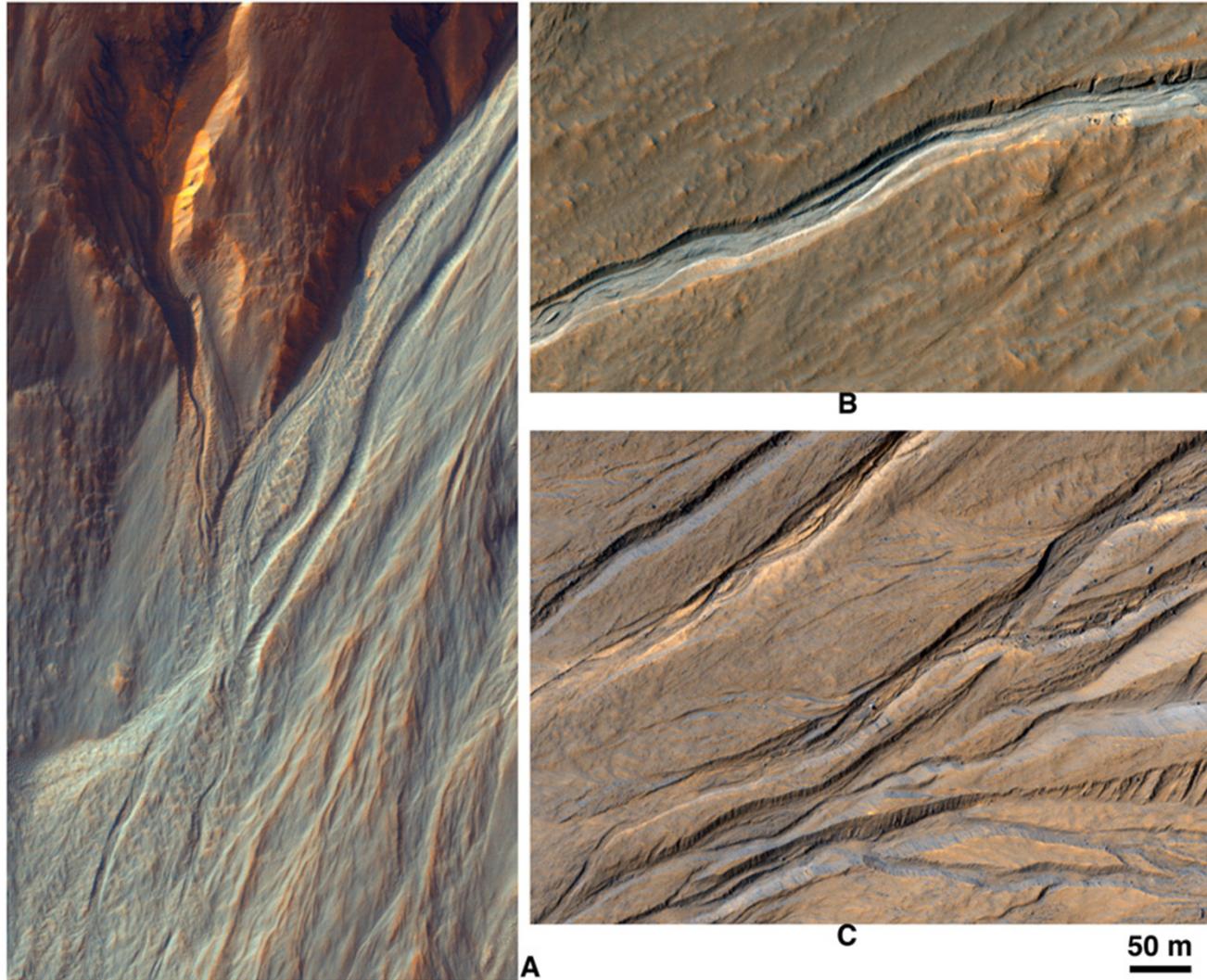
*Noctis Labyrinthus*

*Syria  
Planum*



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# Gully Channels: Geologically Recent Flows



MRO HiRISE / U. Arizona / JPL / NASA



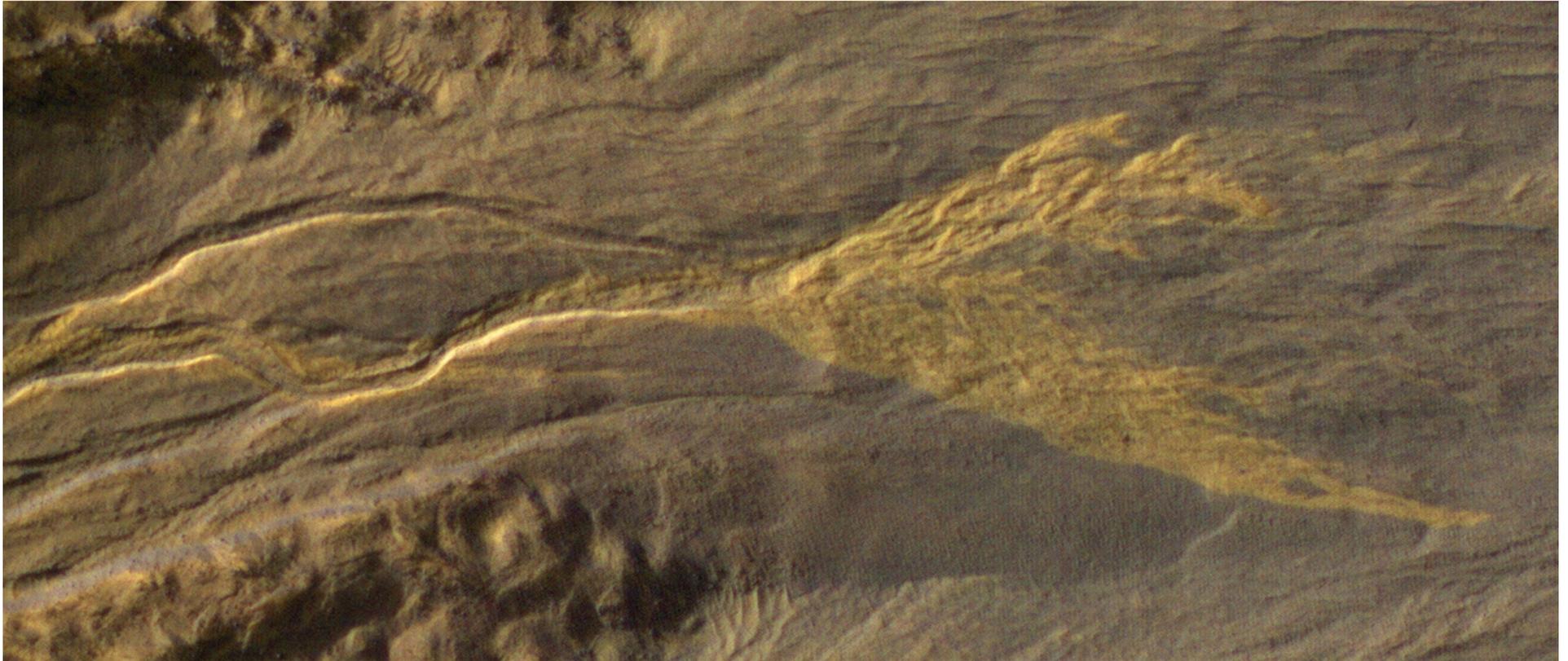
MRO HiRISE / U. Arizona / JPL / NASA

PSP\_002200\_1380

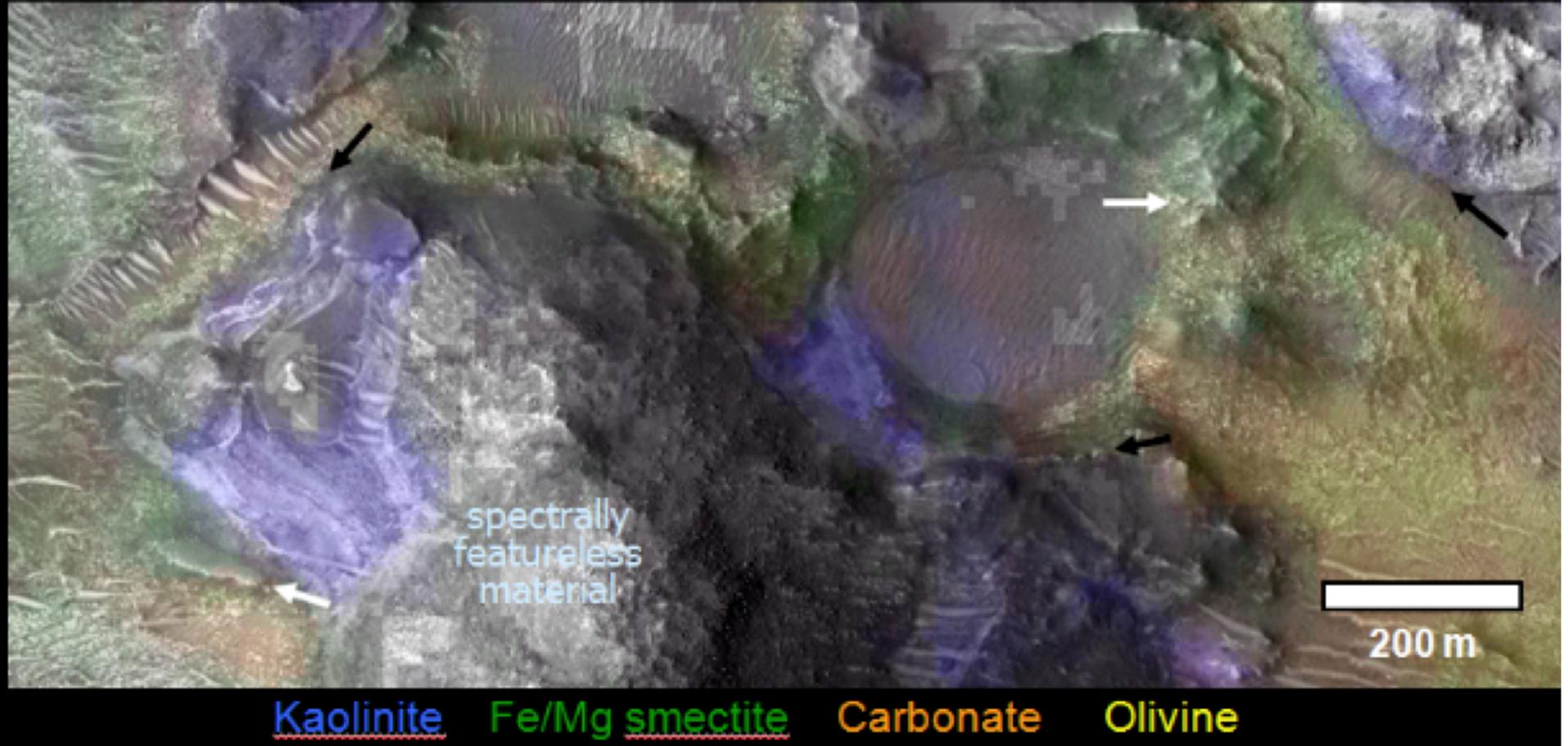
0.25 km



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CRISM FRT00003FB9 parameters (R: BD2500, D2300, BD2200) overlain on HiRISE



### *Diverse Mineralogy of Mars*

Largest exposure of carbonate-bearing rock observed so far on Mars is found in the Nili Fossae region in the northeastern sector of the prominent dark area known as Syrtis Major. This scene illustrates the complex geologic history of Mars in that different aqueous minerals and unaltered materials are located in close proximity. This diversity of environments increases the probability that life originated on Mars and, if so, will have left some evidence preserved on its surface.

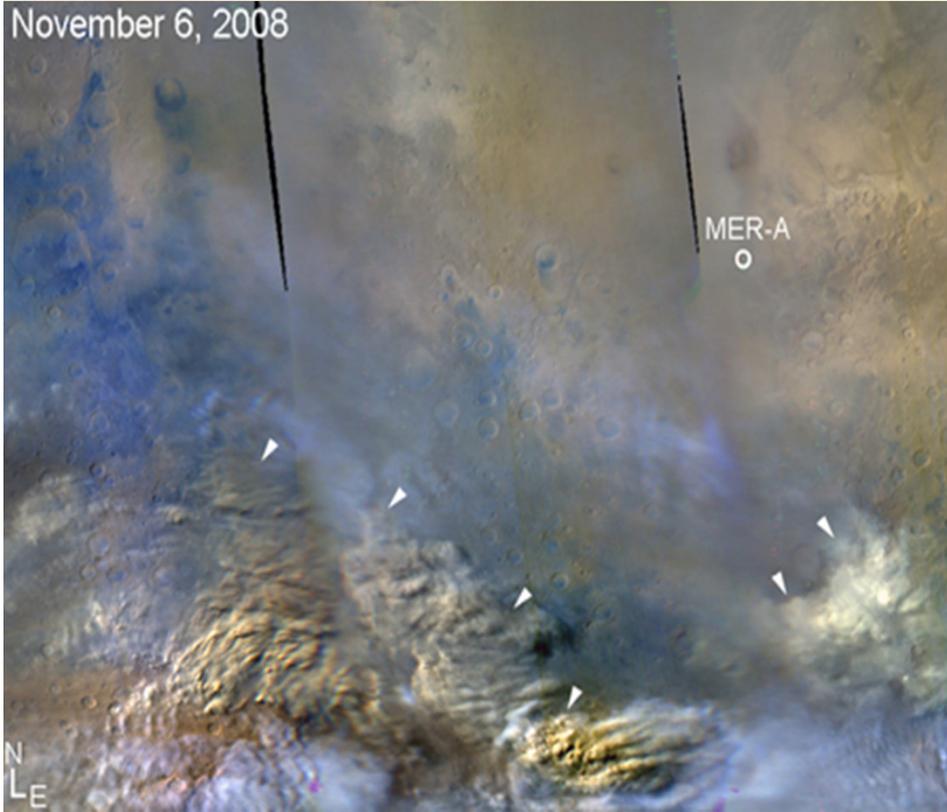
Credits: MRO CRISM / JHUAPL / JPL / NASA MRO HiRISE / U. Arizona / JPL / NASA



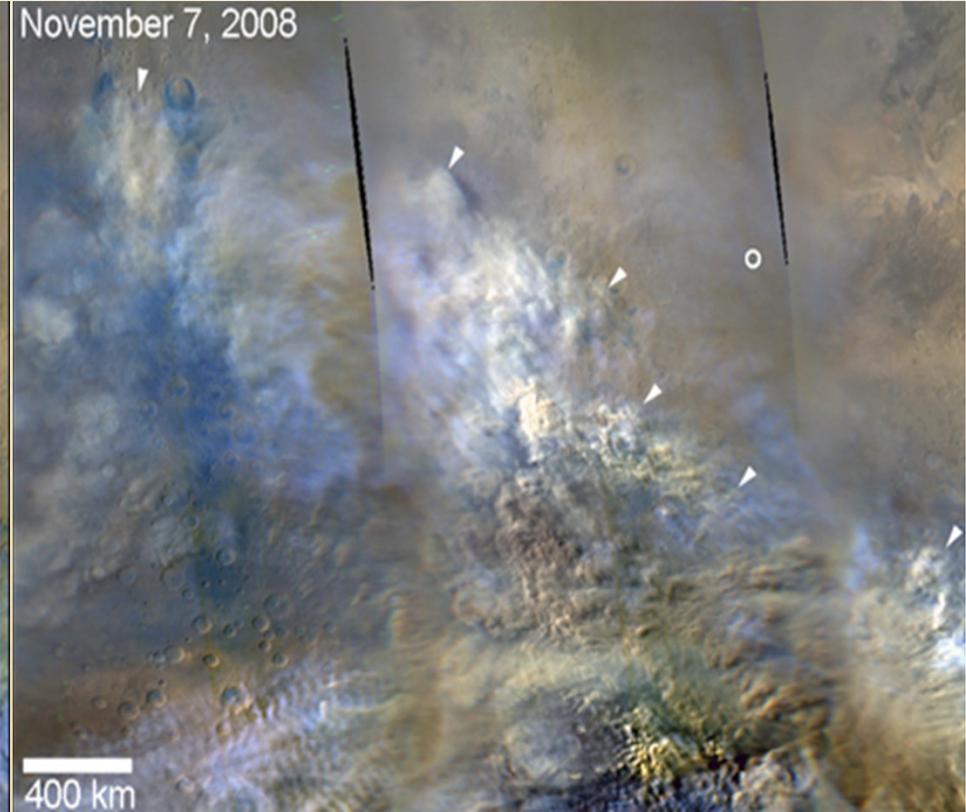
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# Mars Weather Watch

November 6, 2008



November 7, 2008

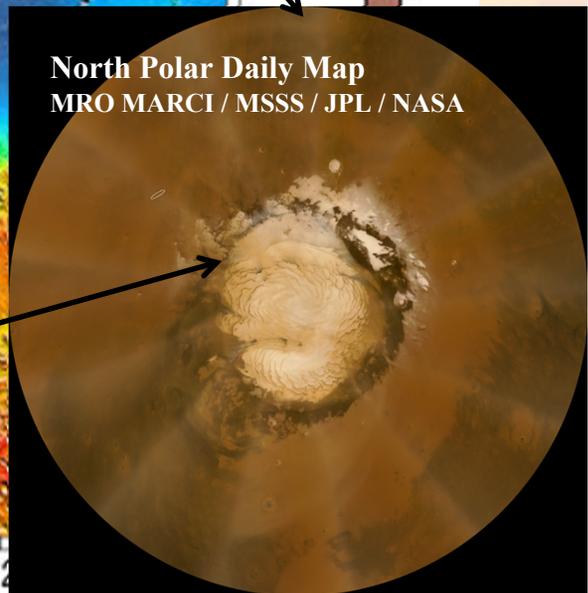
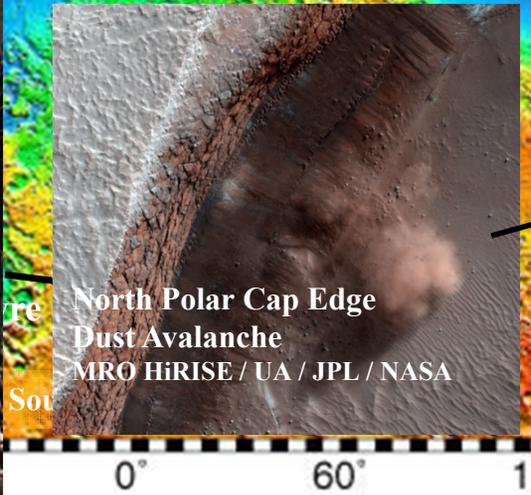
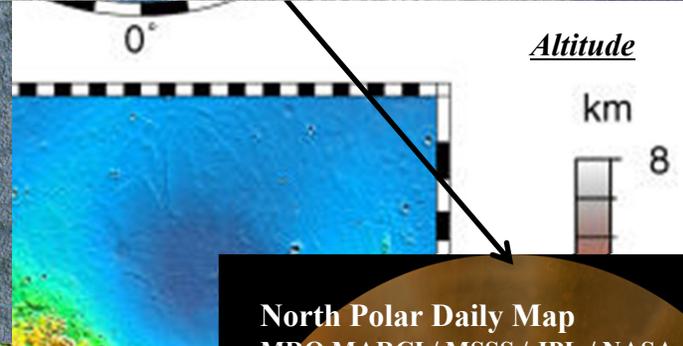
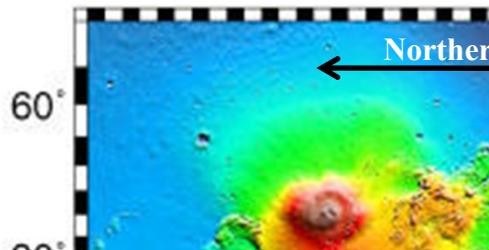
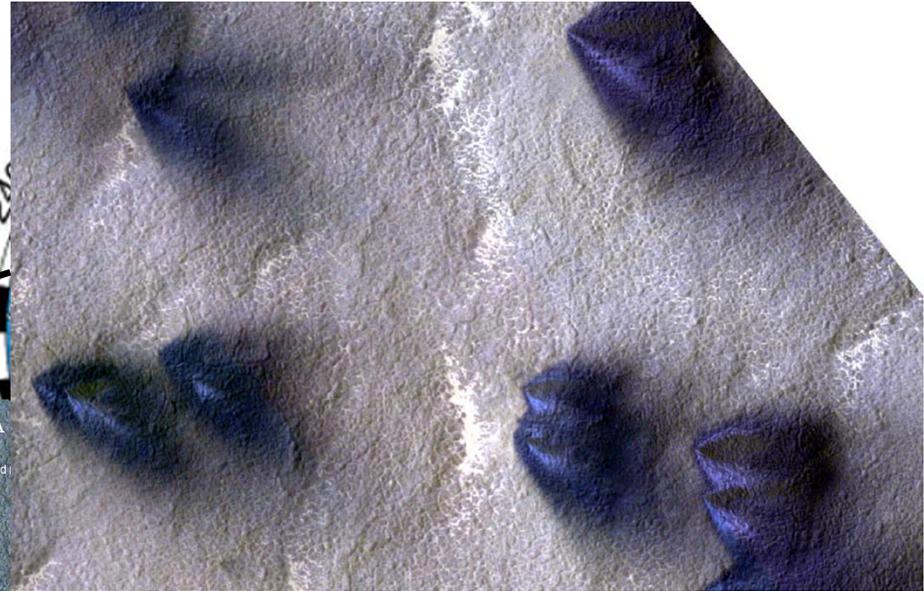
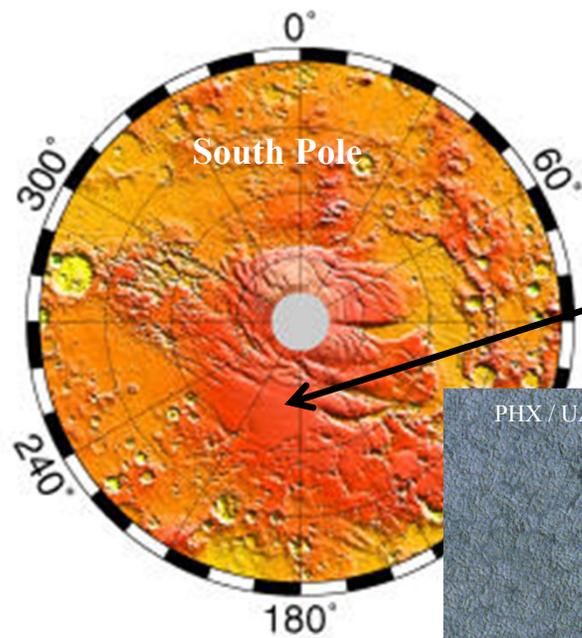


*From MRO MARCI Daily Global Map*

*MRO MARCI / MSSS / JPL / NASA*



**Topography**  
**Credit:**  
 MGS MOLA  
 MIT  
 GSFC  
 JPL  
 NASA





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# *Communications Relay*

*May 25, 2008*

*-EDL Open Loop Communications  
-UHF Surface Relay Support*

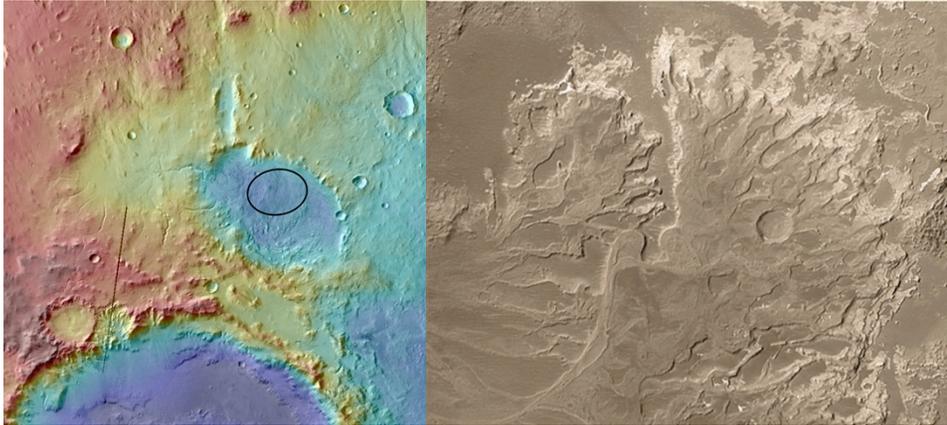


*HiRISE / U. Arizona / JPL / NASA*

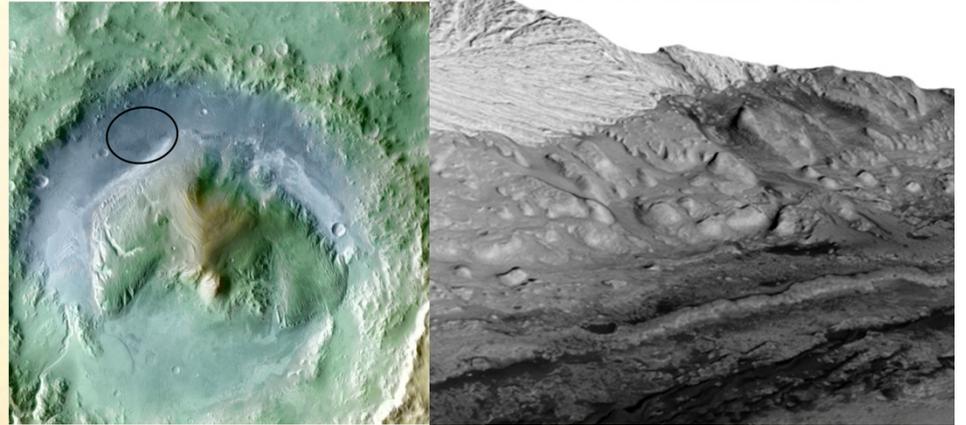


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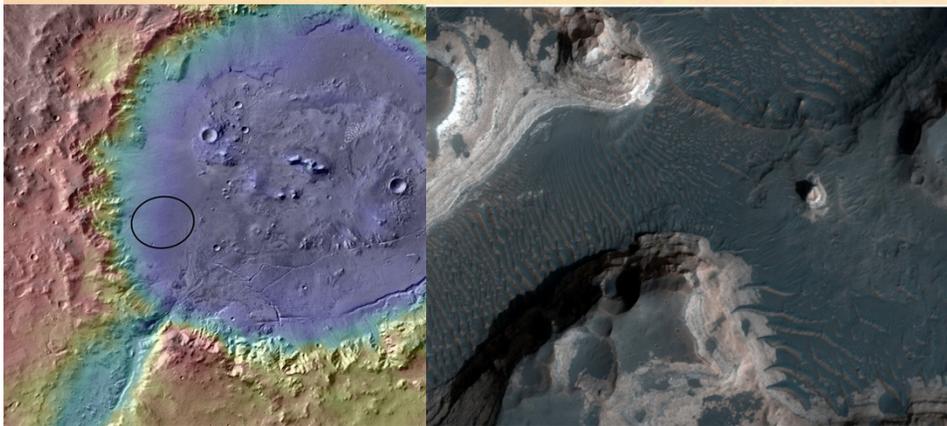
# Final Candidate MSL Landing Sites



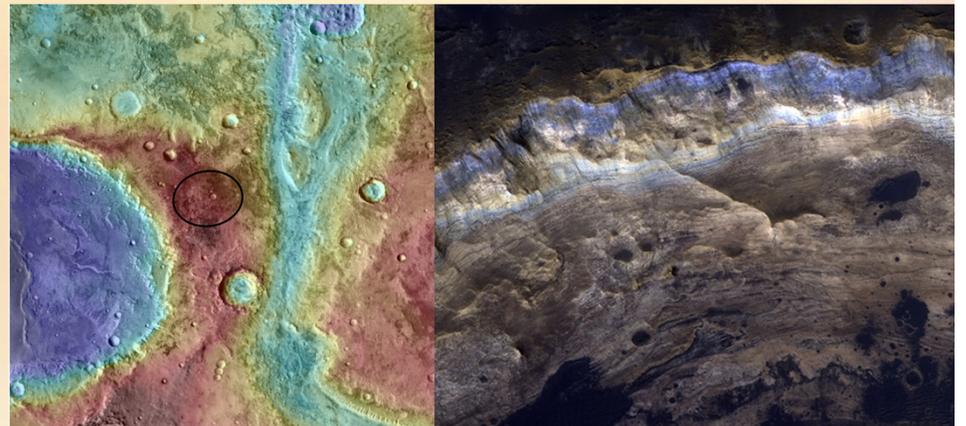
Eberswalde Crater



Gale Crater



Holden Crater

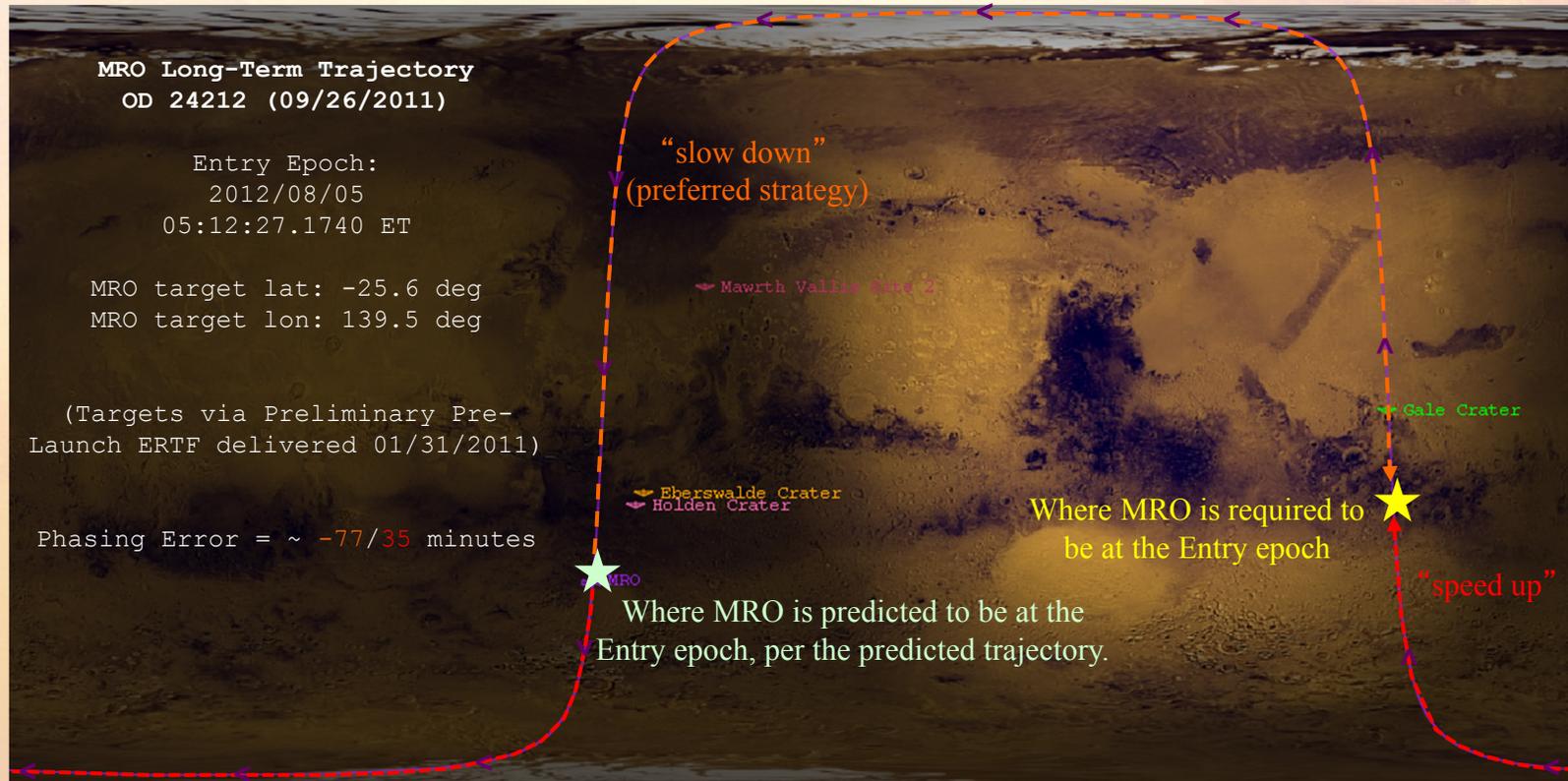


Mawrth Vallis



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# MRO Orbit Synchronization for MSL EDL Coverage



MRO is phased to the requested latitude at the specified Entry epoch by either:

1. “Speeding Up” (red path), to arrive at the requested latitude earlier than the nominal PSO will provide.
2. “Slowing Down” (orange path), to arrive at the requested latitude later than the nominal PSO will provide. This is the preferred strategy.



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# *Mission Summary*

- **Mission Summary (October 2011)**
  - *Over 144 Terabits of Science Data*
  - *Acquired over 100,000 images, and image equivalents*
    - *69% of the planet imaged at 6 m/pixel (CTX)*
    - *1.36% imaged at 30 cm/pixel (HiRISE)*
    - *74% of planet covered in 72 spectral channels at low opacity*
  - *Successful UHF Relay Support of the Phoenix Lander*
  - *A diverse planet with a complex geologic history has emerged*
    - *In particular, the diversity of early water-rich environments shows preservation potential for signatures of ancient life, if it developed*
- **Extended Mission-1**
  - *Continuing to acquire and analyze high resolution science data*
  - *Preparing to support the arrival of the Mars Science Laboratory in August 2012*



# MRO Science Observation Metrics

Investigation	Progress thru end of PSP	By end of ESP	Current EM1
<b>HiRISE</b>	~ 0.6 % of Mars; ~ 964 stereo pairs; ~ 9,550 images	~ 1%; ~ 1955 stereo; ~ 16,745 images	~ 1.36%; ~ 2,464 stereo; ~ 20,859 images
<b>CRISM</b>	56% multispectral survey w/ clear atmosphere 8,959 targeted observations completed and downlinked (0.7% of Mars) 1 Mars Year monitored	72% msp survey 17% hsp survey 14,958 targeted ob- servations (1.3% of Mars) 2 Mars yrs monitored	74% msp survey <sup>1</sup> 17% hsp survey <sup>1</sup> 19,118 targeted observations 2.7 Mars yrs moni- tored
<b>CTX</b>	18,020 images with ~ 38.5% unique coverage (~8% repeat coverage)	34,596 images with 62% regional coverage	41,530 images with 69% regional coverage
<b>SHARAD</b>	~45% of Mars sampled via 5,567 observing strips	~7946 observing strips	~9659 observing strips
<b>MARCI</b>	1 Full Mars year, global DE; 9,670 MARCI images;	97% of 2.1 Mars yrs monitored with 16,566 images	97% of 2.7 Mars yrs monitored with 21,391 images
<b>MCS</b>	1 Full Mars year, with GDE >30 x10 <sup>6</sup> MCS soundings	84% of 2.1 Mars yrs monitored with 54x10 <sup>6</sup> soundings	86.4% of 2.7 Mars yrs monitored with 69.9 x10 <sup>6</sup> soundings
<b>Gravity:</b>	~35% increase in gravity field resolution	Seasonal mass variation	Seasonal mass variation
<b>Accelerometer</b>	Data taken during Aero- braking phase; archived during PSP	Completed	Completed
<b>Science Data Return</b>	~73.4 Tb	~123.2 Tb	~143.9 Tb

<sup>1</sup>CRISM numbers, updated quarterly, are from 28<sup>th</sup> PSG



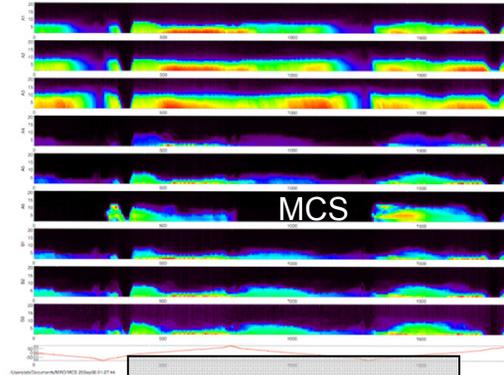
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# Mars: A Complex Planet

## Climate Change



HiRISE



## Atmosphere

## Surface Composition

True color

False color infrared image



CRISM

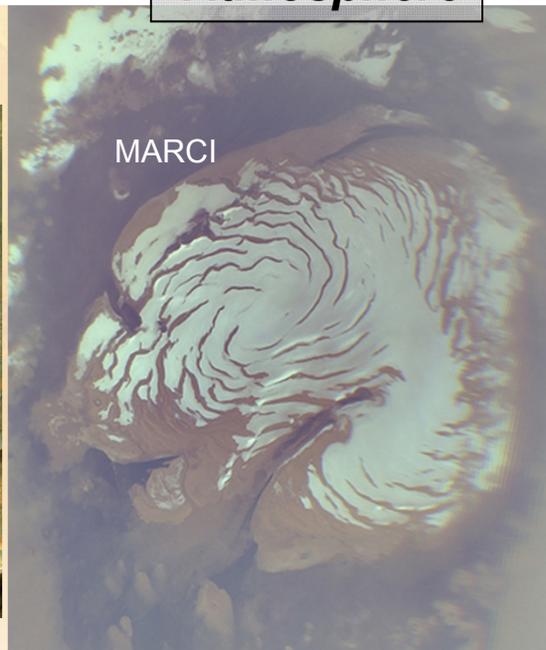
CTX

## Surface Layering

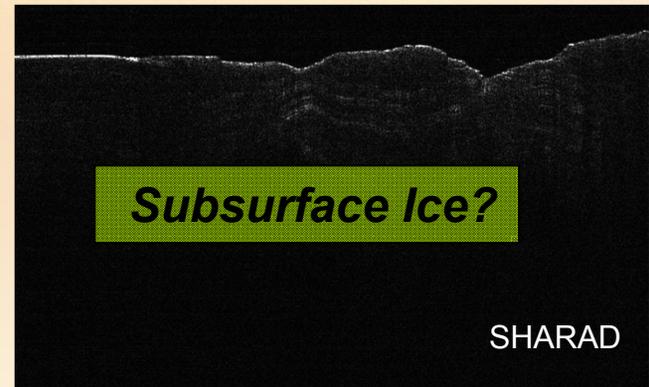


HiRISE

MARCI



## Subsurface Ice?



SHARAD



## *Extended Mission Objectives*

- Continuation of the baseline MRO mission: performing both Mars programmatic support tasks and science data acquisition & return for the MRO science teams
- Mars Program priorities for MRO
  - *Flight system health and safety - No increase in risk*
  - *MSL support (EDL, then early surface operations)*
  - *MRO science and MSL surface relay*
  - *Other Programmatic Support (including MER relay)*



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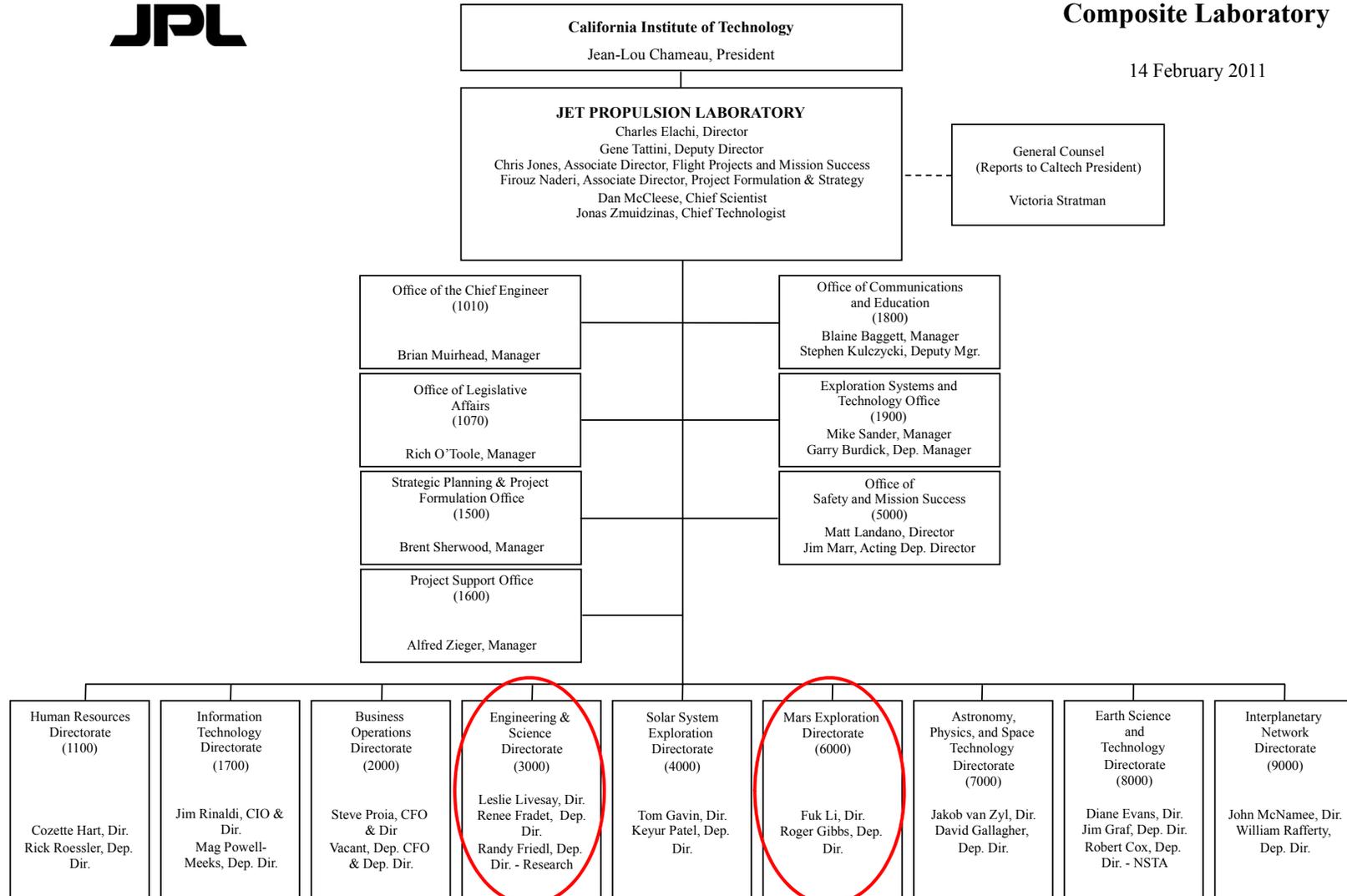
# Back-up Charts

# Jet Propulsion Laboratory



## Composite Laboratory

14 February 2011



*JPL is a  
matrix organization  
(3X = line organization)*



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- JPL is NASA's lead center for solar system exploration (planetary science) and performs missions for NASA's Science Mission Directorate (SMD)
  - *Science driven missions*
- Institution's have their own cultural identities and their own best practices

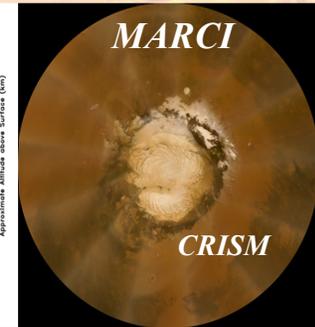
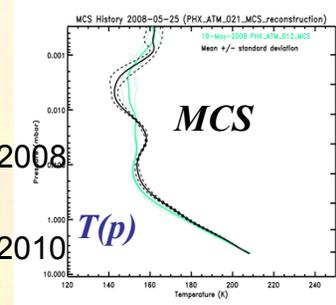


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# Mars Reconnaissance Orbiter Mission

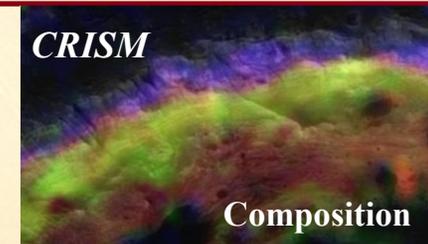
## MRO Mission Overview (2006-2012)

- **Category: II, Risk Class: B**
- Mission Phases
  - Primary Science Phase (PSP): November 2006 to November 2008
  - PHX critical event (EDL) coverage: May, 2008
  - Extended Science Phase (ESP): December 2008-September 2010
  - Extended Mission Phase: October 2010 to September 2012



## Program Support Objectives

- Characterize landing sites for MSL and future Mars landers & rovers
- Add to atmospheric environment data bases to support future Mars missions
- Cover future mission critical events (e.g., MSL EDL August, 2012)
- Provide telecommunications relay for surface assets



## Extended Mission Phase Science Objectives

### Extend survey coverage and targeted observations:

- Determine the nature and history of the Martian upper crust, emphasizing crustal stratigraphy and aqueous deposits;

### Extend monitoring and change detection:

- Investigate the polar caps and layered terrains and ground ice at all latitudes;
- Characterize ongoing surface changes, including aeolian processes, slope processes such as gullies, and impact cratering;
- Capture atmospheric interannual variability, while extending the climatological record of atmospheric weather, thermal structure, dust, ice and water vapor.



SHARAD



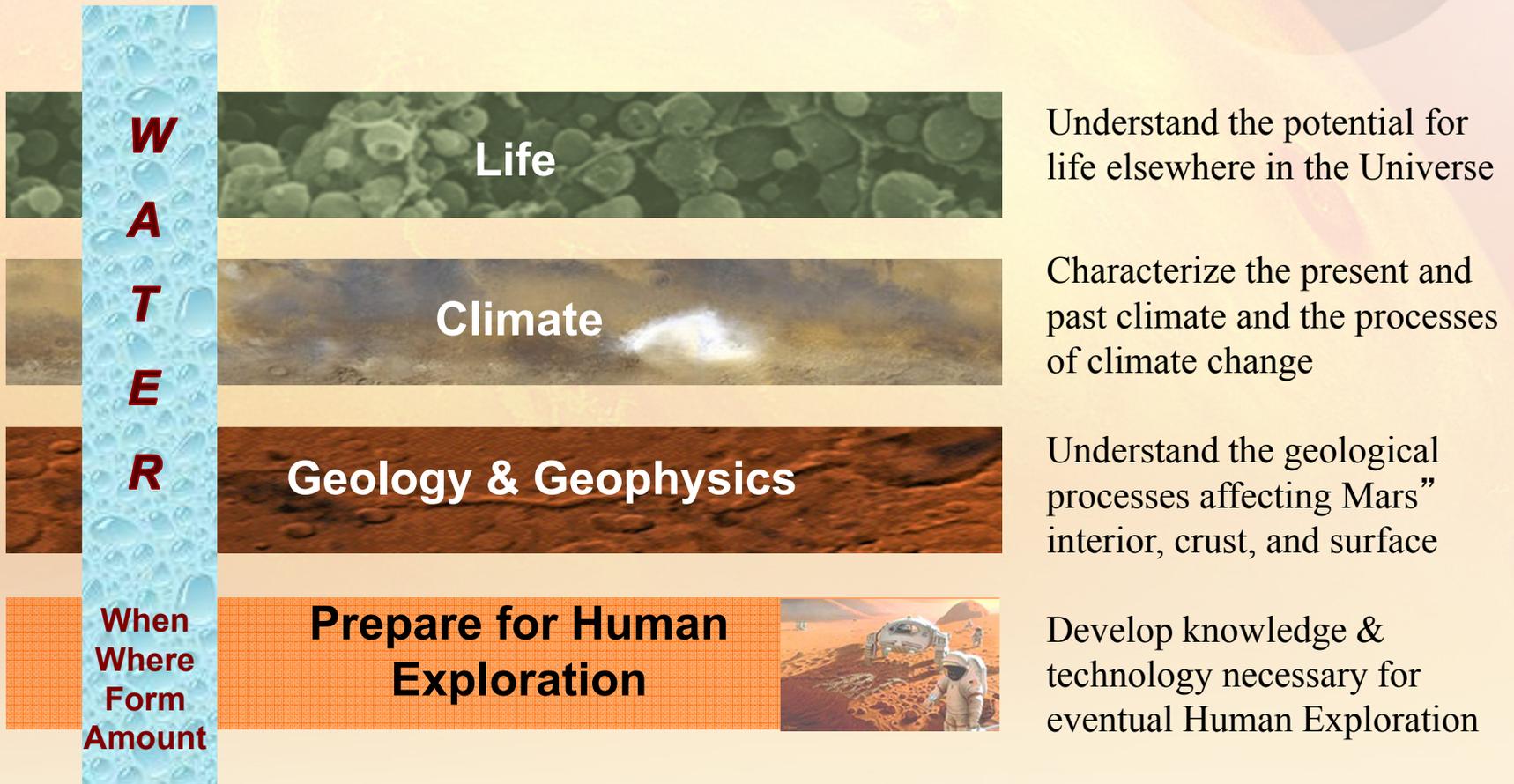
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# Mars Exploration Science Goals

2000-2010 *“Follow the Water”*: Found evidence of water activity, past and present

2011-2015 *“Explore Habitability”*: Explore a possibly habitable environment

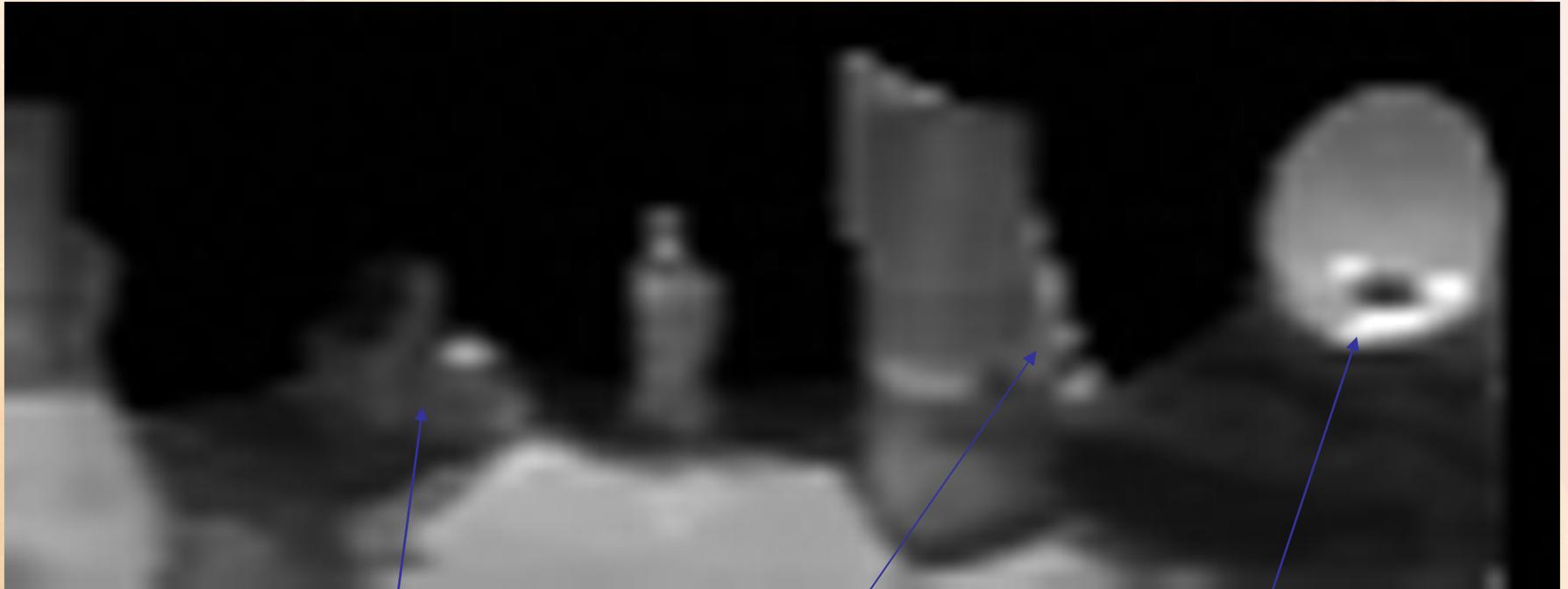
2015- *“Seeking Signs of Life”*: Search for bio-signatures & climate indicators





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# MCS Thermal Scan of MRO Instruments In Mars Orbit



CRISM  
HiRISE

Thruster

MARCI

Solar Panel

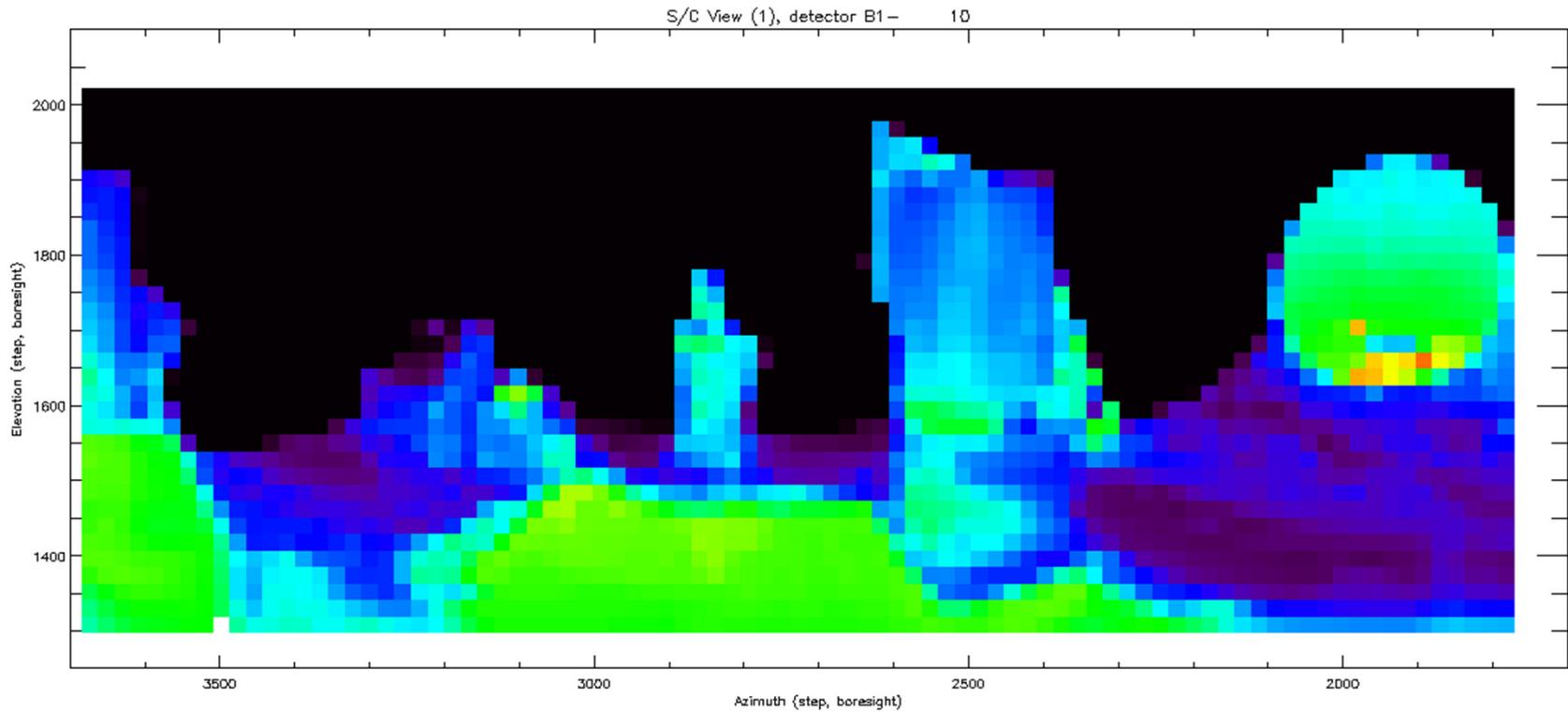
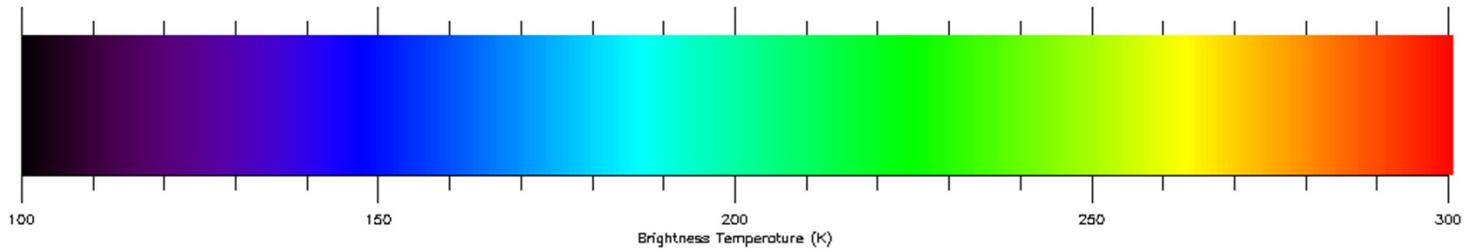
Electra

Hot Mirror-Struts



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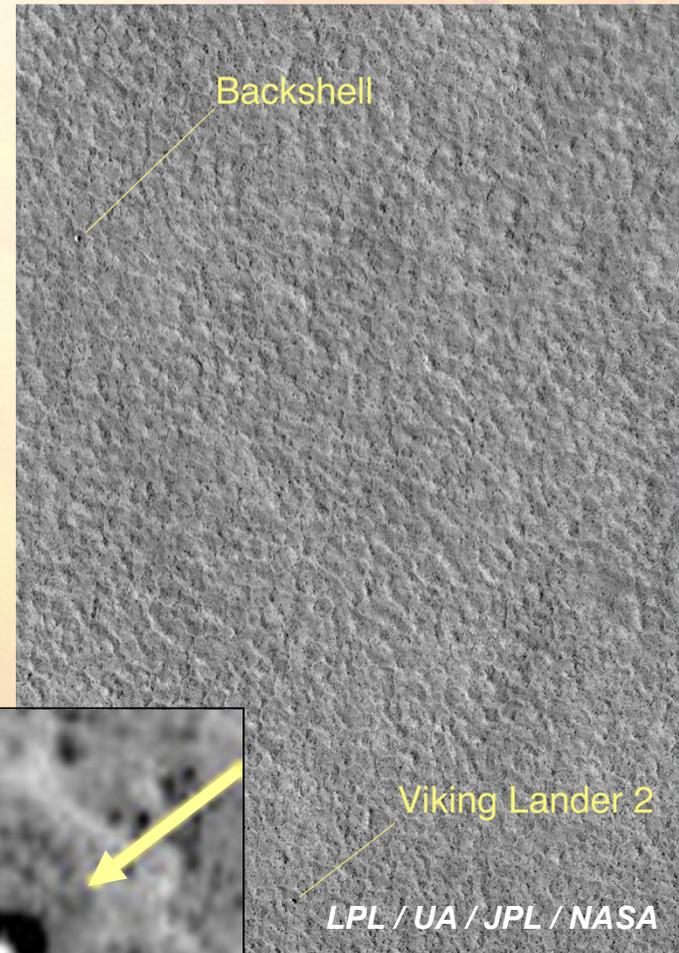
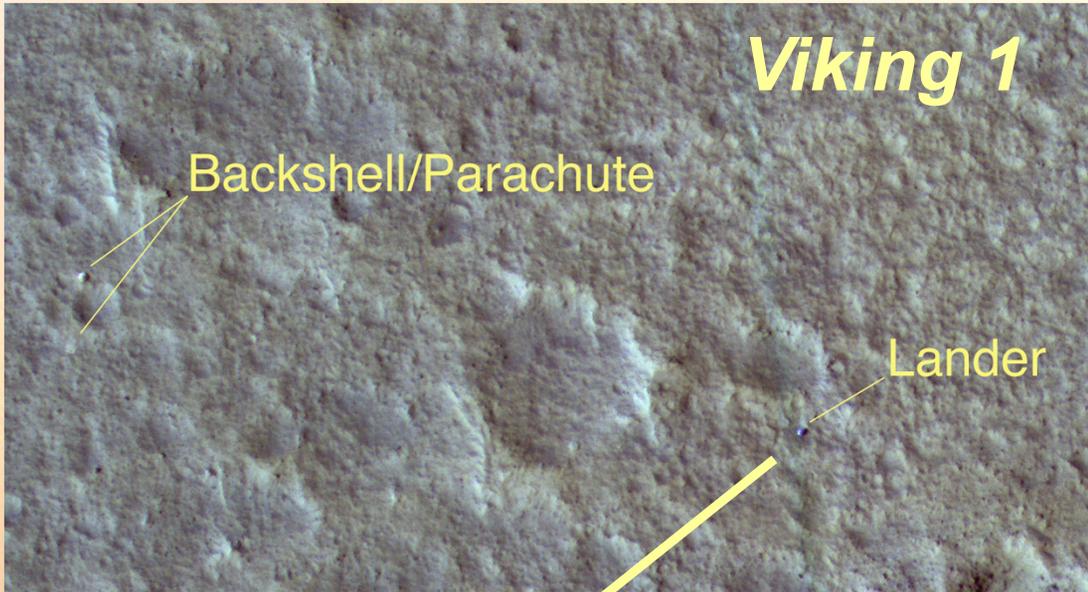
# Channel B1 32.5 microns



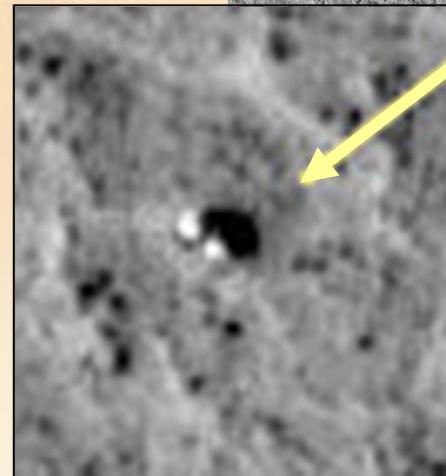
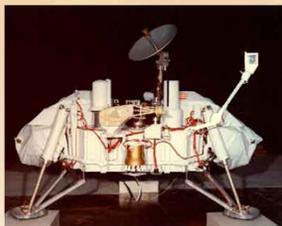


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# Viking Landers Located



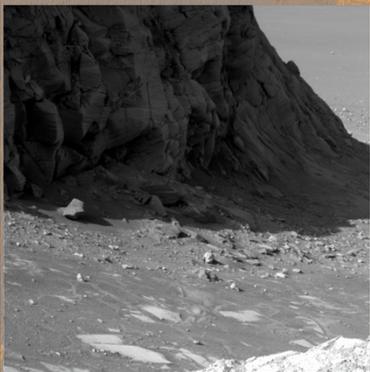
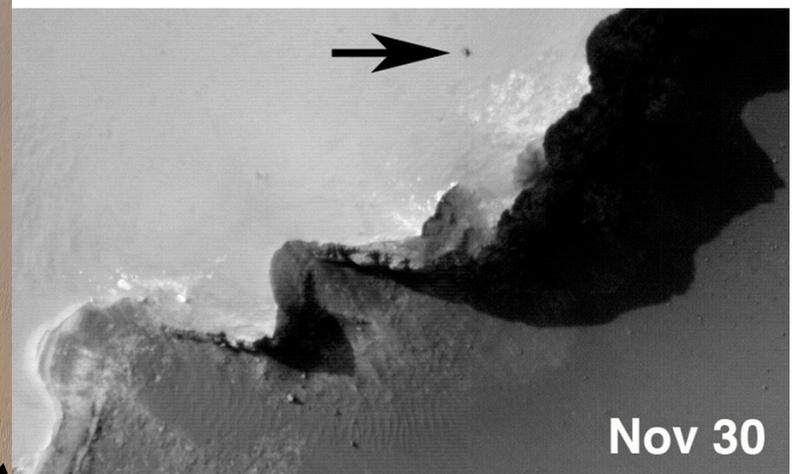
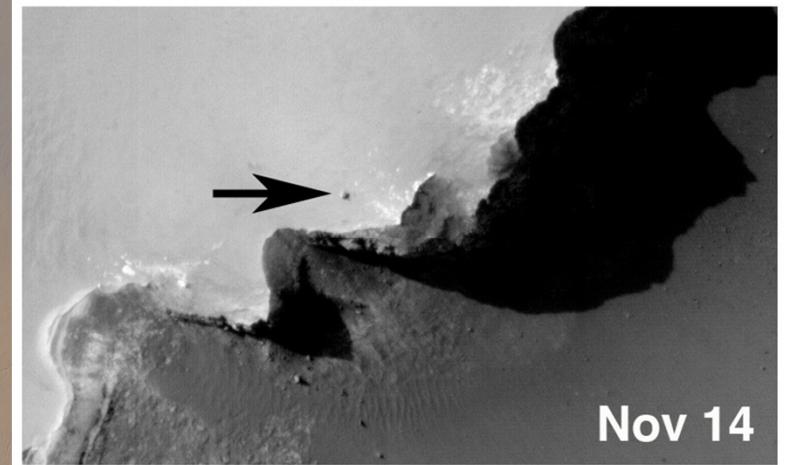
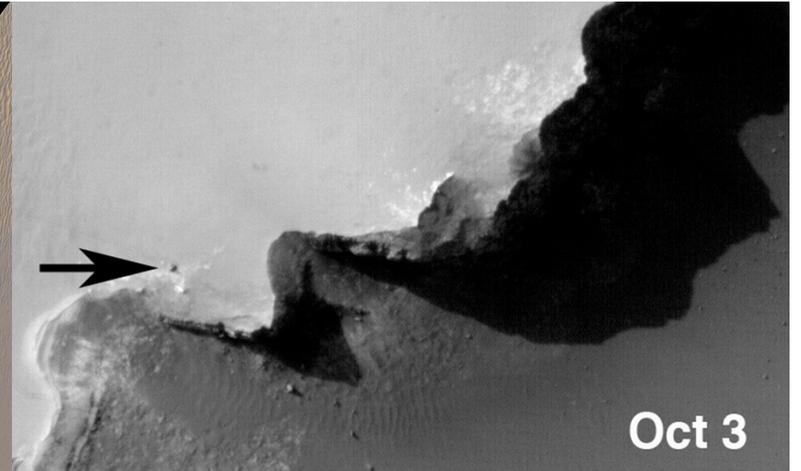
Viking Model - NASM



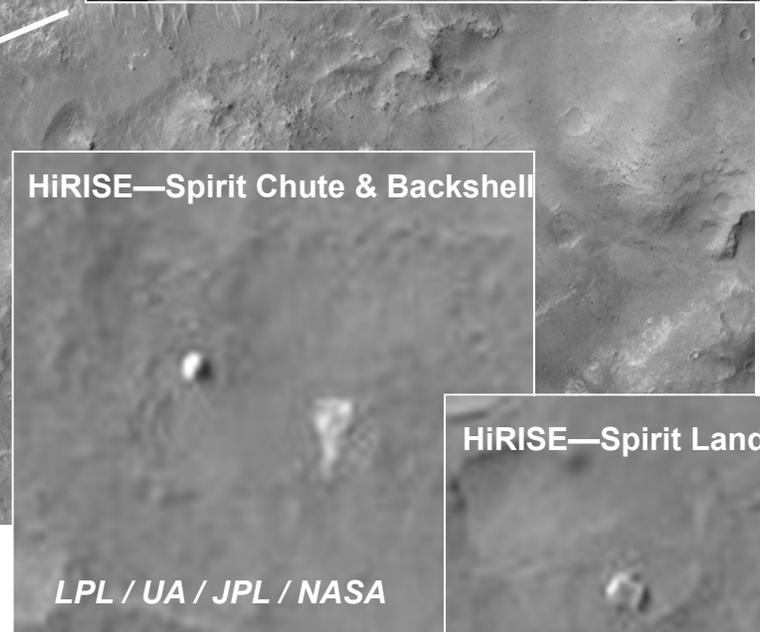
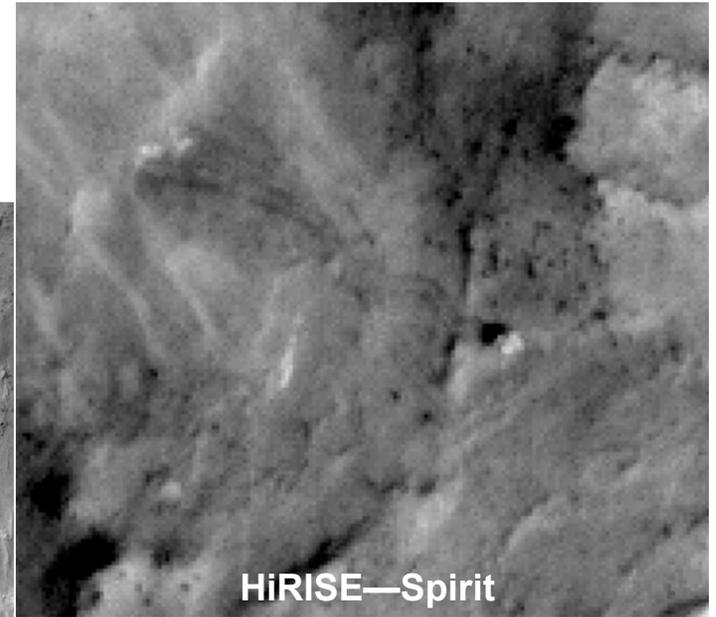
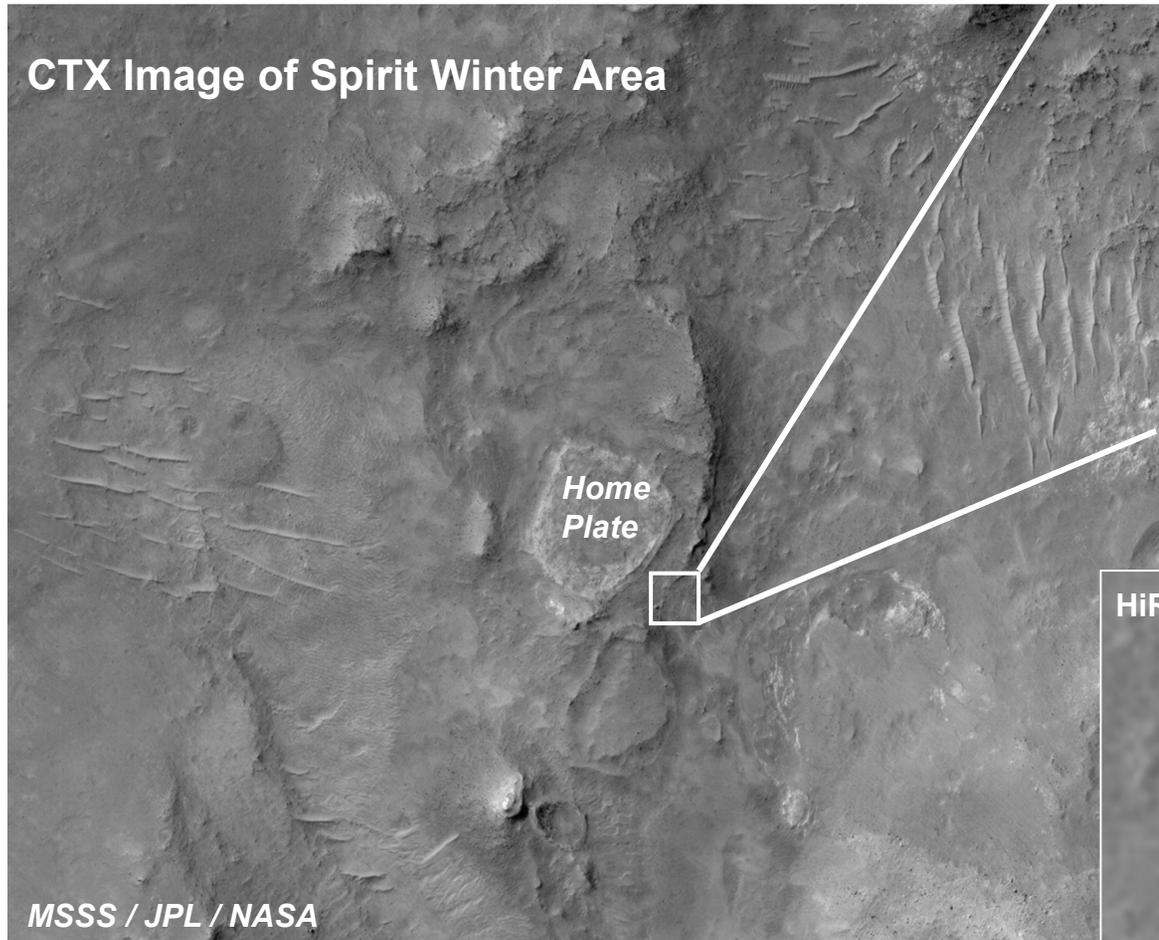
*Opportunity (MER-B) may  
rove, but it cannot hide!*

Victoria Crater

*HiRISE Image of MER-B  
LPL / UA / JPL / NASA*



# *Spirit (MER-A) by Home Plate*



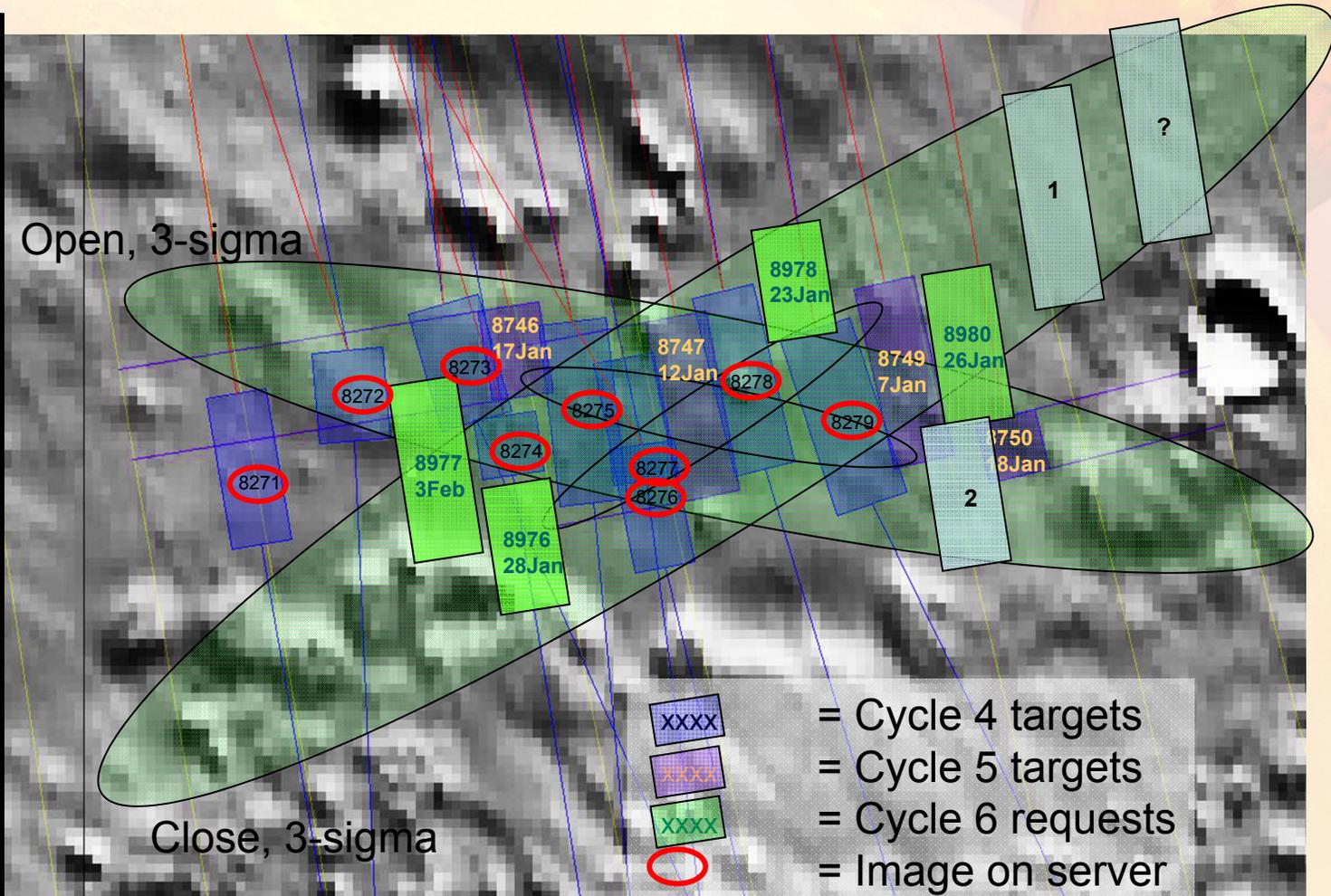


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# Scouting Phoenix Landing Sites

## Box 1 - Region D, Centered on 68.35N, 233.0E

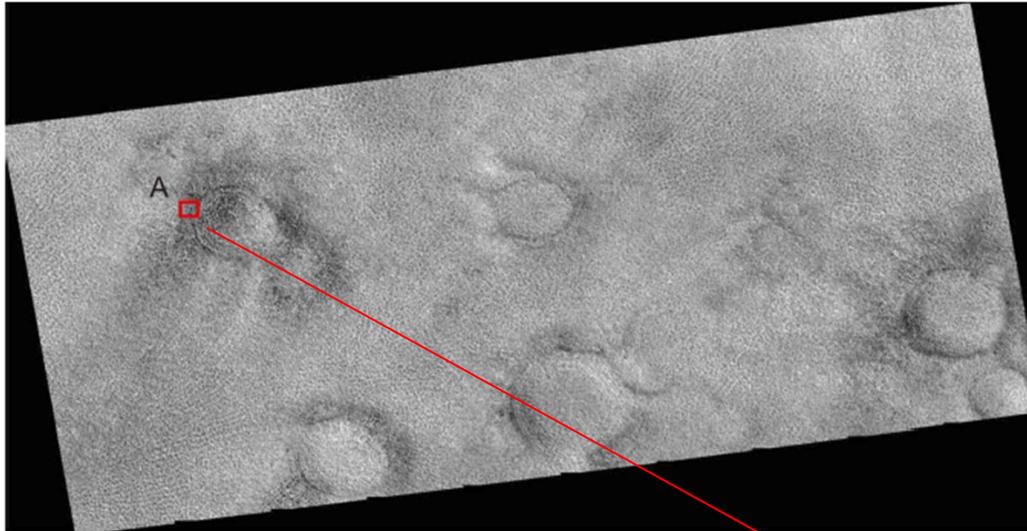
HiW EB	Orbit
8274	1880
8278	1893
8279	1906
8275	1946
8276	1959
8273	1972
8272	2012
8271	2025
8277	2091
8746	2236
8747	2170
8749	2104
8750	2249
8976	
8977	
8978	
8992	





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# Phoenix Region B Image Example



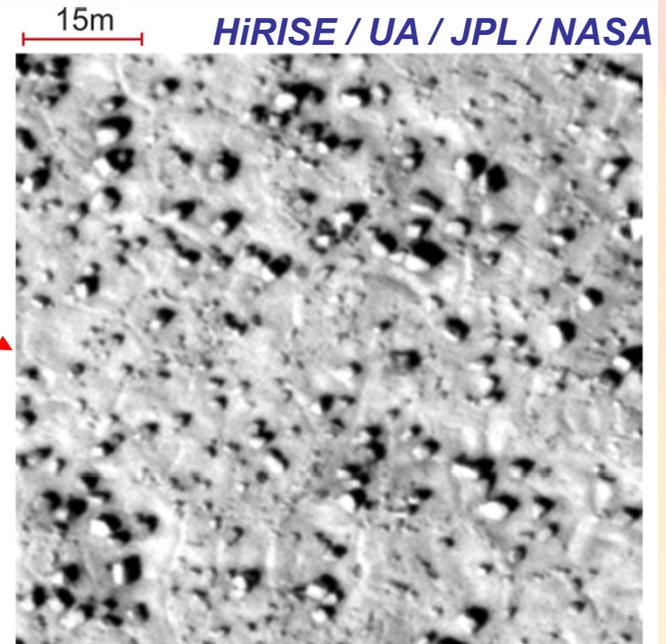
xstart: 5619  
Ystart: 6078

**THEMIS / ASU / JPL / NASA**

**High rock density  
area**

**4-5 m boulders**

**CFA > 50%**



Working Hypothesis -  
THEMIS visibly dark and  
nighttime IR bright areas  
are rocky

Less rocky areas in Region  
B: CFA ~20%

# *Phoenix Site Characterization*

*Site in Region D*

*HiRISE / UA / JPL / NASA*

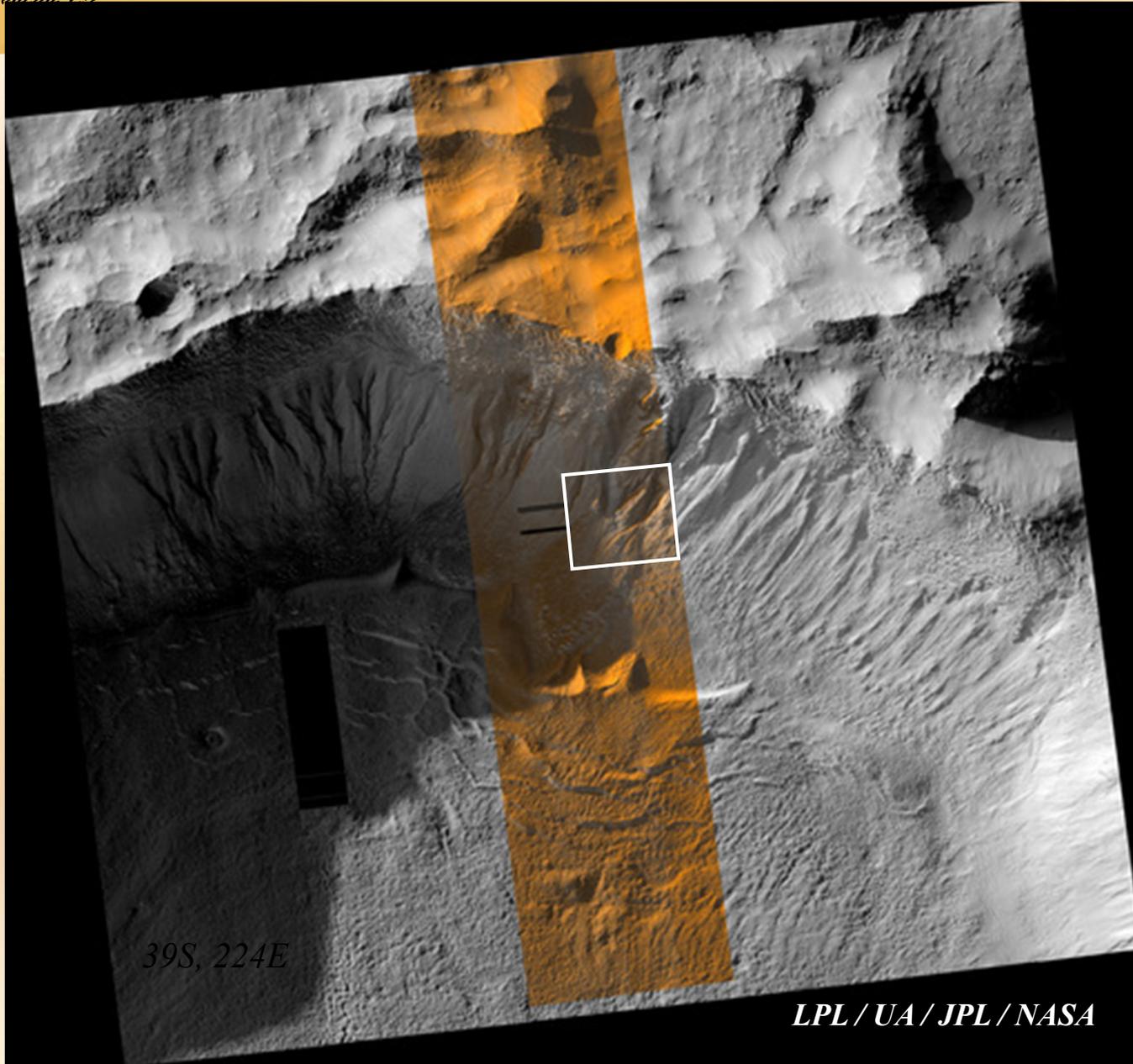
100 m

**Rock  
Abundance  
CFA  
< 5%**



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# HiRISE: Crater with Gullies in Terra Sirenum



*HiRISE*

**Details of  
Gullied  
Crater  
In  
Terra  
Sirenum**

*39S, 224E*



~ 250 m  
51 cm/pixel

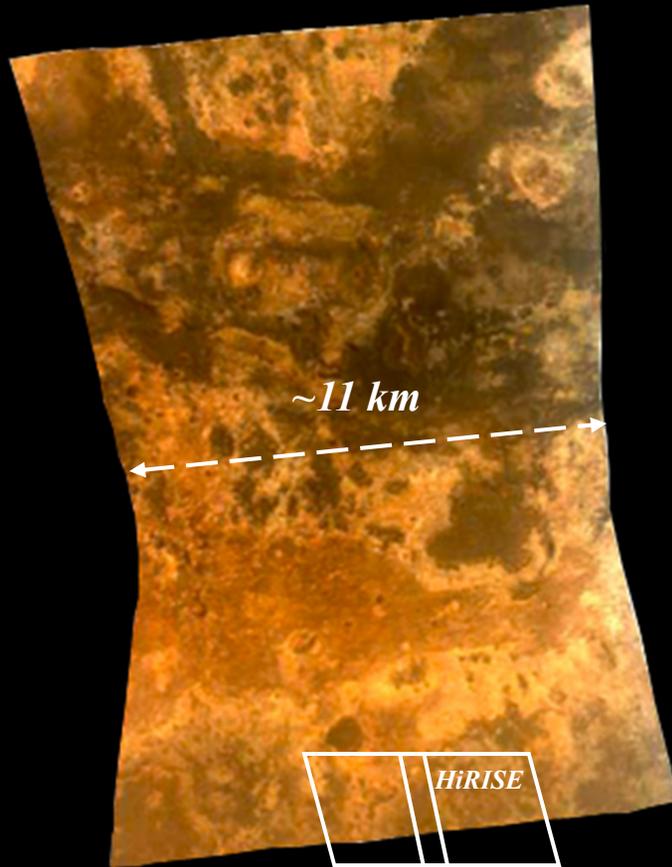
*LPL / UA / JPL / NASA*



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# CRISM: Mawrth Vallis

True color



False color infrared image

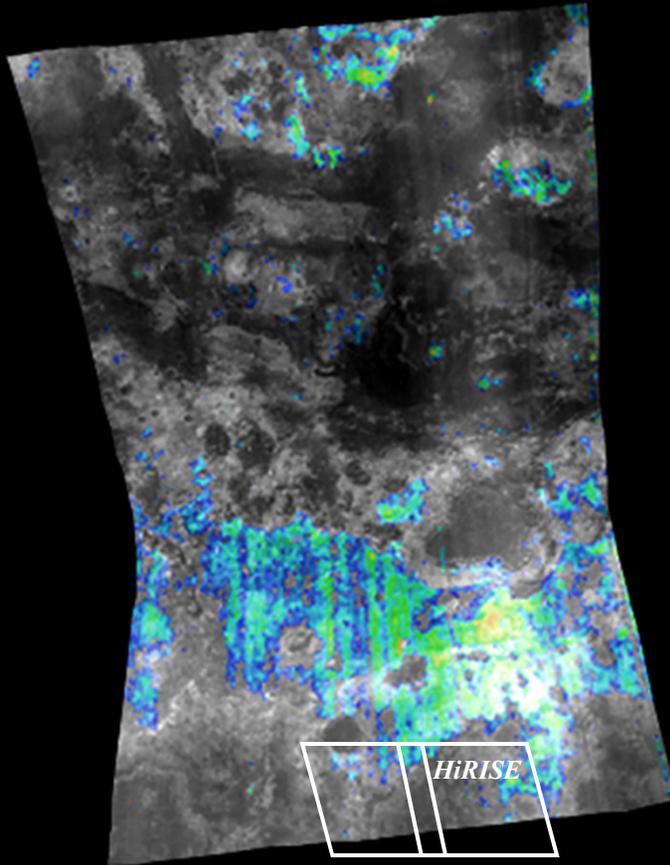




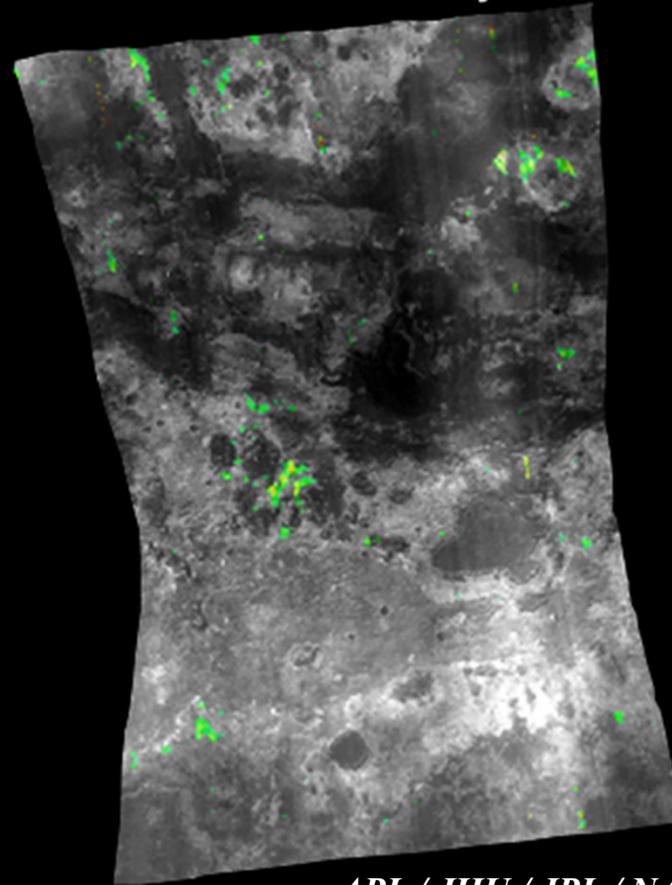
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# CRISM: Mawrth Vallis

Iron-rich clay



Aluminum-rich clay



APL / JHU / JPL / NASA



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## *MRO Project*

- MCO / MPL (Mars '98) failures in 1999
- July 2000 – 2003 Mission selected for implementation
- October 2000 – 2005 Mission was identified
- November 2000 – MRO PM selected
- December 2000 & January 2001 – Science Definition Teams

(Results of the Decadal Survey (2013-2022) guide the future direction of planetary exploration [http://solarsystem.nasa.gov/docs/Squyres\\_2013\\_Decadal\\_Rollout\\_at\\_LPSC.pdf](http://solarsystem.nasa.gov/docs/Squyres_2013_Decadal_Rollout_at_LPSC.pdf))



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## *MRO Major Components*

- Launch Vehicle [selected by NASA-KSC through the NASA Launch Services (NLS) Contract - LSTO Competitive Procurement]
  - *Lockheed Martin Commercial Launch Services (LMCLS) selected [Jun 2002]*
  - *Atlas V-401 - Intermediate-class expendable launch vehicle*  
*[NASA exercised its option for Atlas V-401, Flight Planning Board approval 3/2003]*
- Spacecraft [selected by JPL through an RFP process]
  - *Lockheed Martin Astronautics (LMA) - Denver selected [Oct 2001]*
- Science Investigations [selected by NASA-HQ through the AO process]
  - *Reflight of MCO Investigations (MARCI-WA and MCS)*
  - *SHARAD - ASI-provided, shallow sub-surface radar [Jan 2001]*
  - *New Investigations [Nov 2001]*
    - *2 PI Instruments and 4 Facility Teams formed*
- Engineering Payloads [specified by the Mars Program Office and JPL]
  - *Electra Telecom/Nav Relay, OpNav Camera Demo, Ka-Band Demo*



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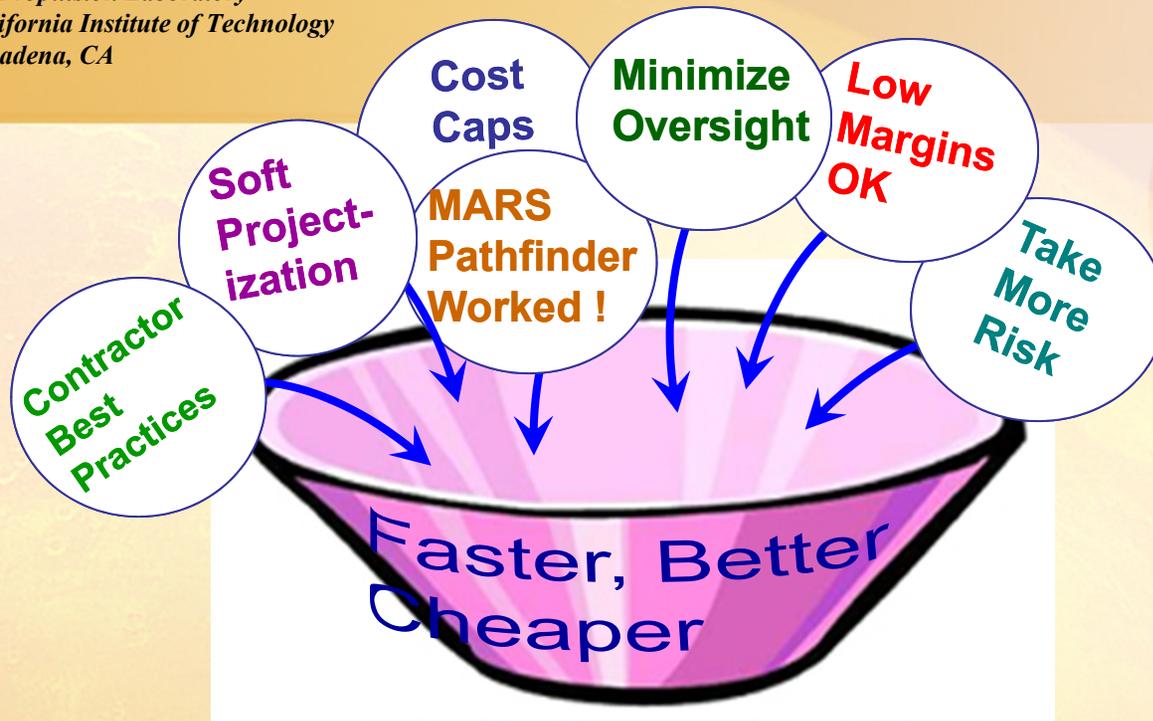
# *Science and Engineering Payload Suite*

- **Scientific Investigations**
  - *Reflight of the MCO Investigations*
    - *MCS (McCleese/JPL) and MARCI (Malin/MSSS)*
  - *MRO Science Investigations*
    - *Hi-RISE (McEwen/UA) and CRISM (Murchie/APL)*
  - *MRO Facility Experiments/Teams*
    - *SHARAD (Phillips), CTX (Malin/MSSS), Gravity Science(Zuber/MIT),*
    - *Atmospheric (Accelerometer) Science (Keating/GWU)*

*=> Targeted, Regional, and Mapping Investigations*
- **Engineering Payload**
  - *Electra Telecom/Nav Relay*
  - *OpNav Camera Demo*
  - *Ka-Band Demo*



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MARS '98  
Failures

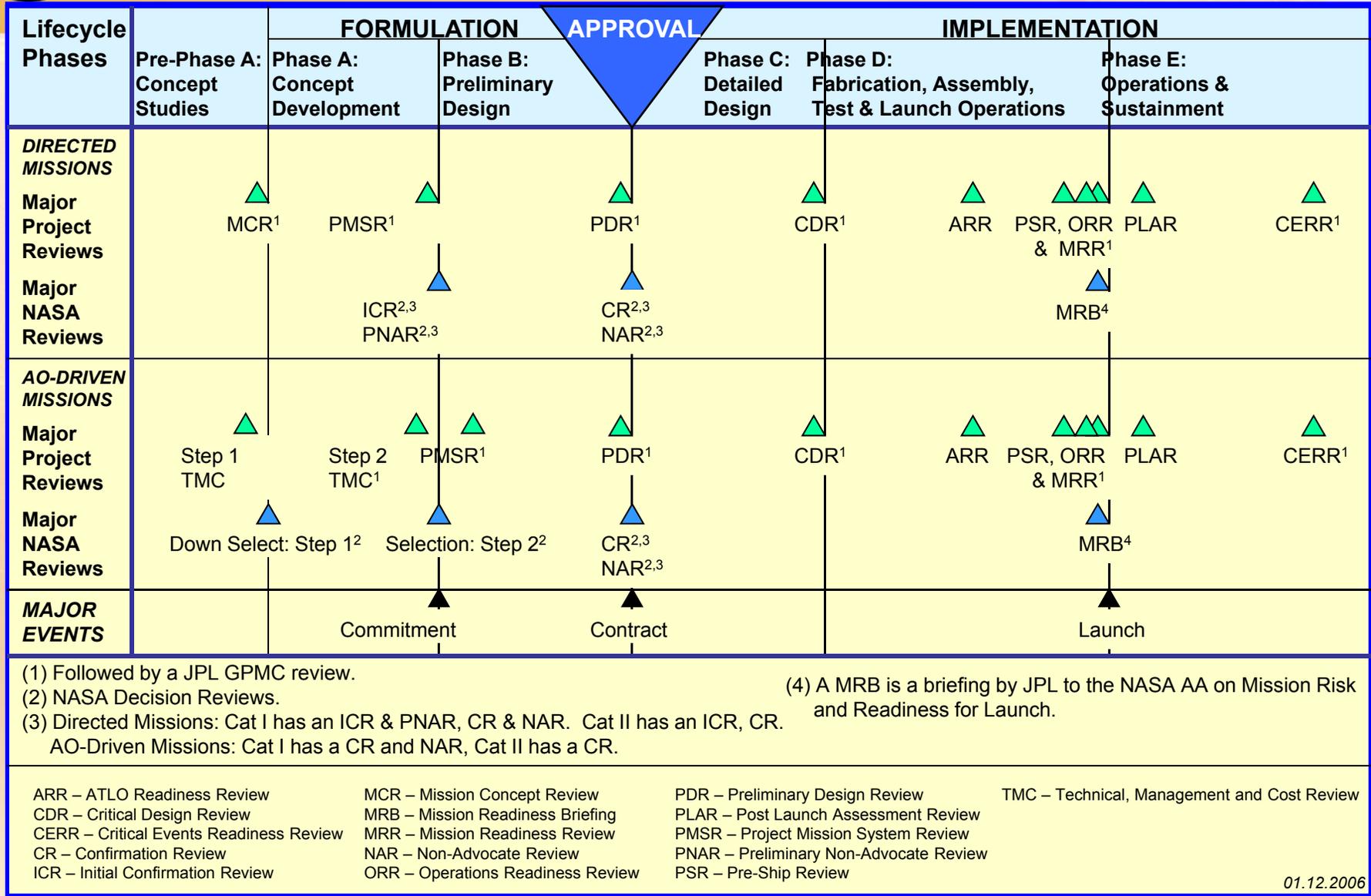
- Stephenson Report
- Young Report
- Casani Report

Faster, .....,  
Cheaper

Risk Balance



# The JPL Project Life Cycle







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# MRO Project Organization (Development Org)

- Technical Margins
- Schedule Margin
- Resource Margins

Jim Graf  
Manager  
Richard Zurek  
Project Scientist

Project Science Group  
PIs

MEP

MPIB, MPTCT  
W Va  
KSC

Ross Jones, Project Engineer  
Tom Fouser Project Software Mgr  
Arden Acord, Launch Vehicle Liaison

Walt Boyd, Finance & Resource Mgr  
Janis Norman, Secretary  
Erica Beam, Scheduler  
Marty Scarbrough, Acq. Rep.

IPN-ISD  
'07 MISSIONS  
MTP

## Project Systems (System Managers)

H. Eisen  
Flight System Mgr  
G. Beutelschies  
CTM

J. Duxbury  
Sci/Payload Mgr  
W. Mateer  
Dep. P/L Mgr

D. Johnston  
Mission Design  
Mgr

B. Jai  
Mission Ops/GDS  
Mgr

P. Barela  
Mission Assurance  
Mgr

LMA- Orbiter  
Kevin McNeill  
Orbiter Mgr

MTP

LaRC

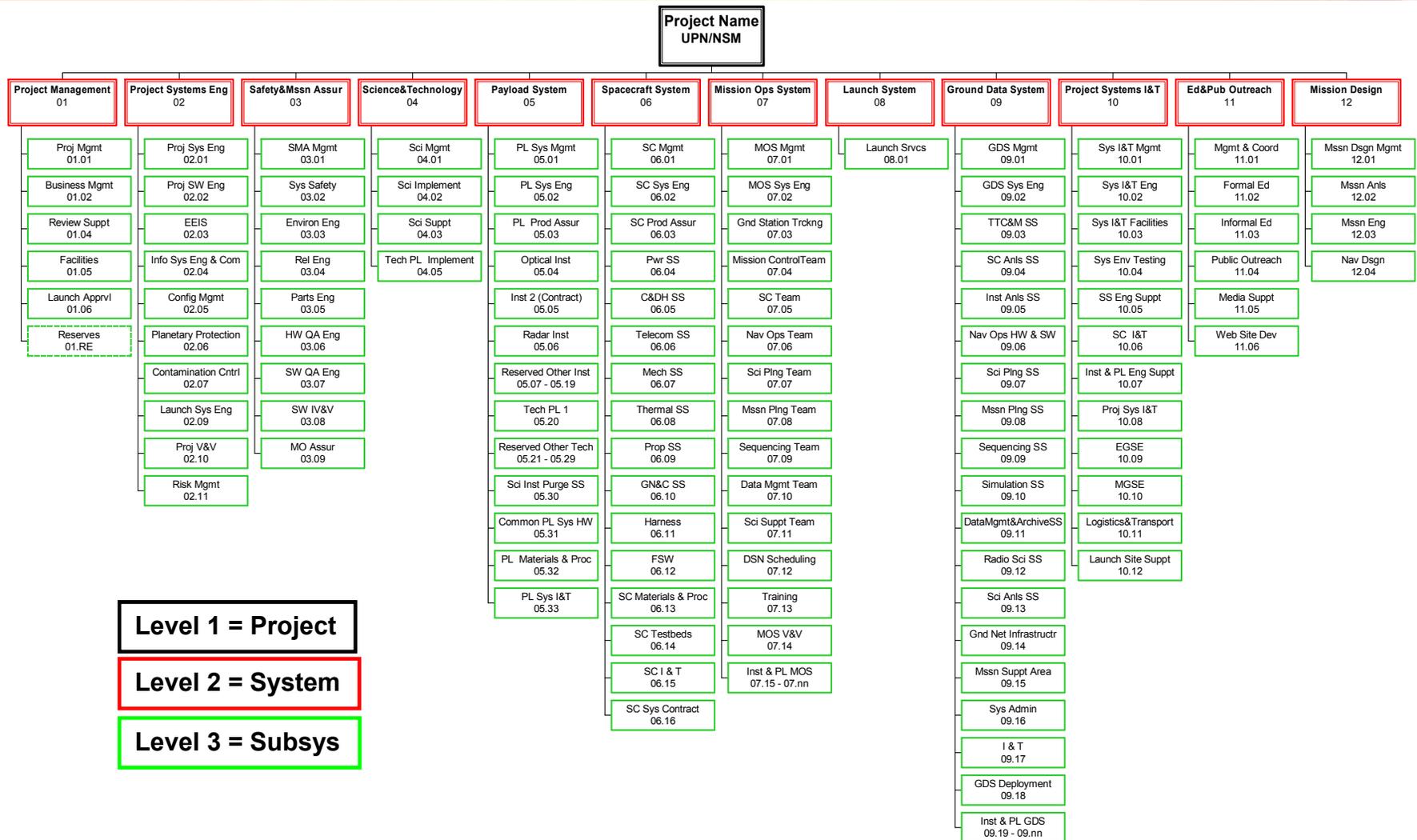
IPN-ISD  
PDS  
MMO

External Organizations



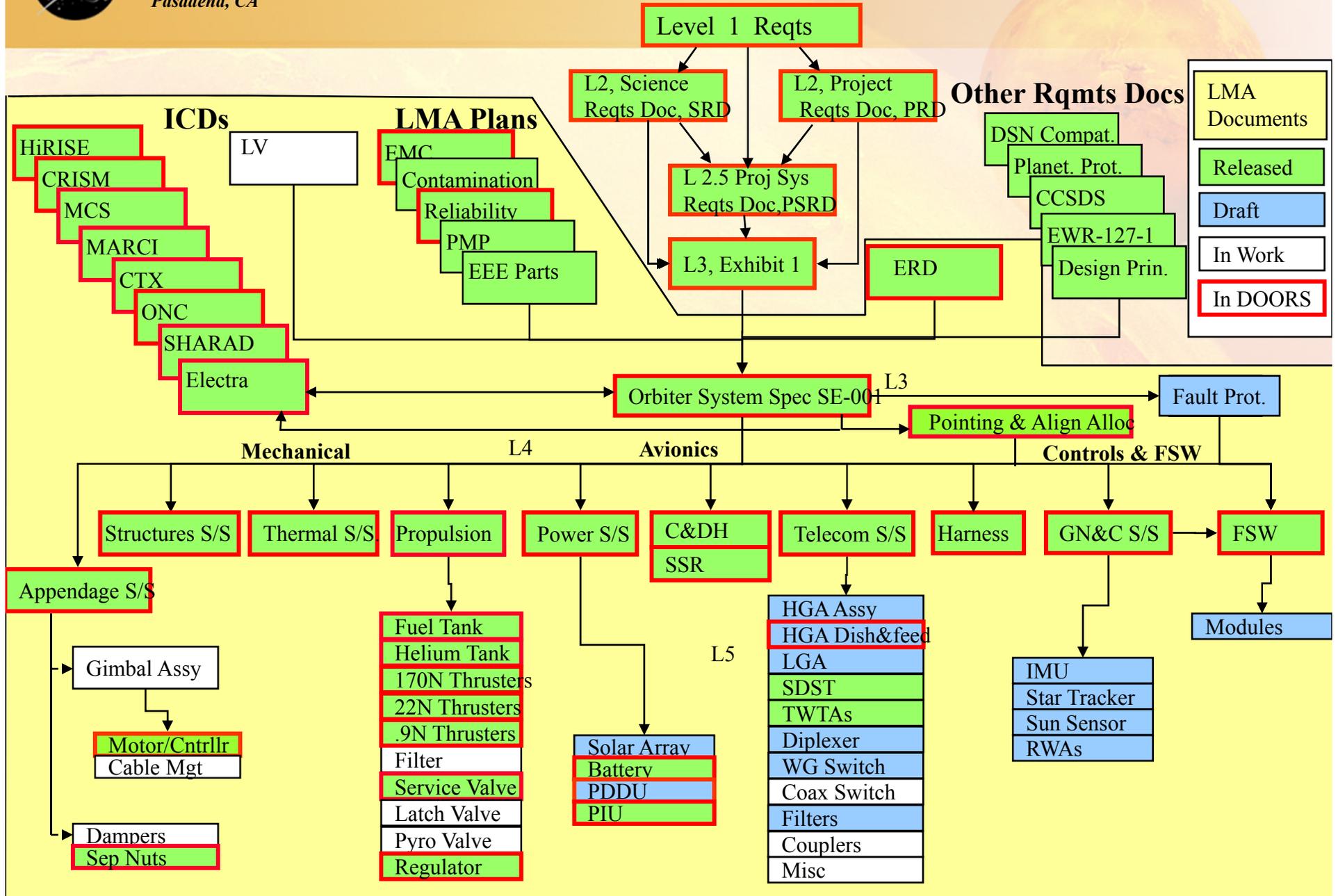
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# Graphic View of Standard Flight Project Work Breakdown Structure To Level 3



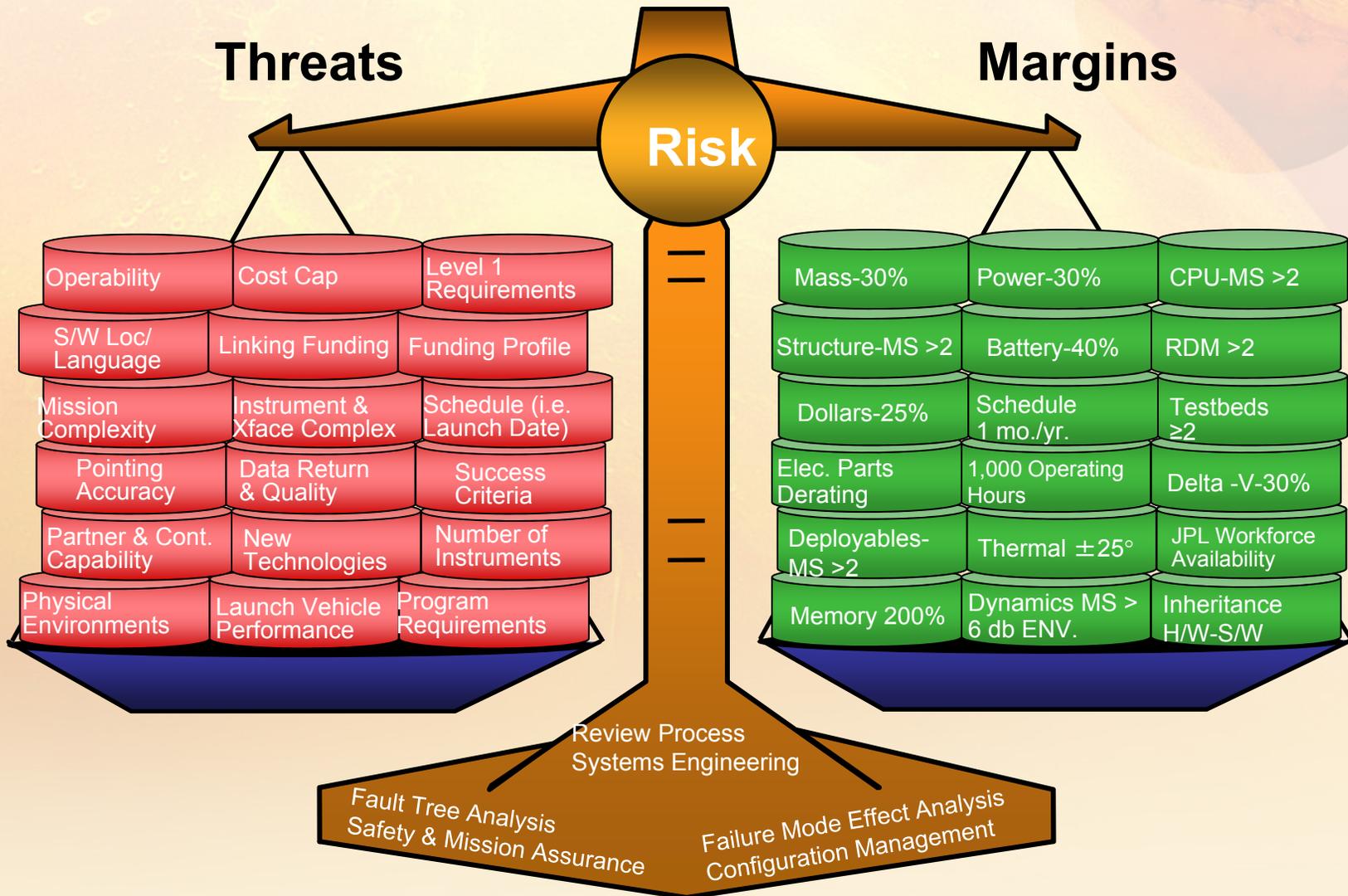


# MRO Spec Tree Status -Flight Hardware





# Achieving Balanced Risk

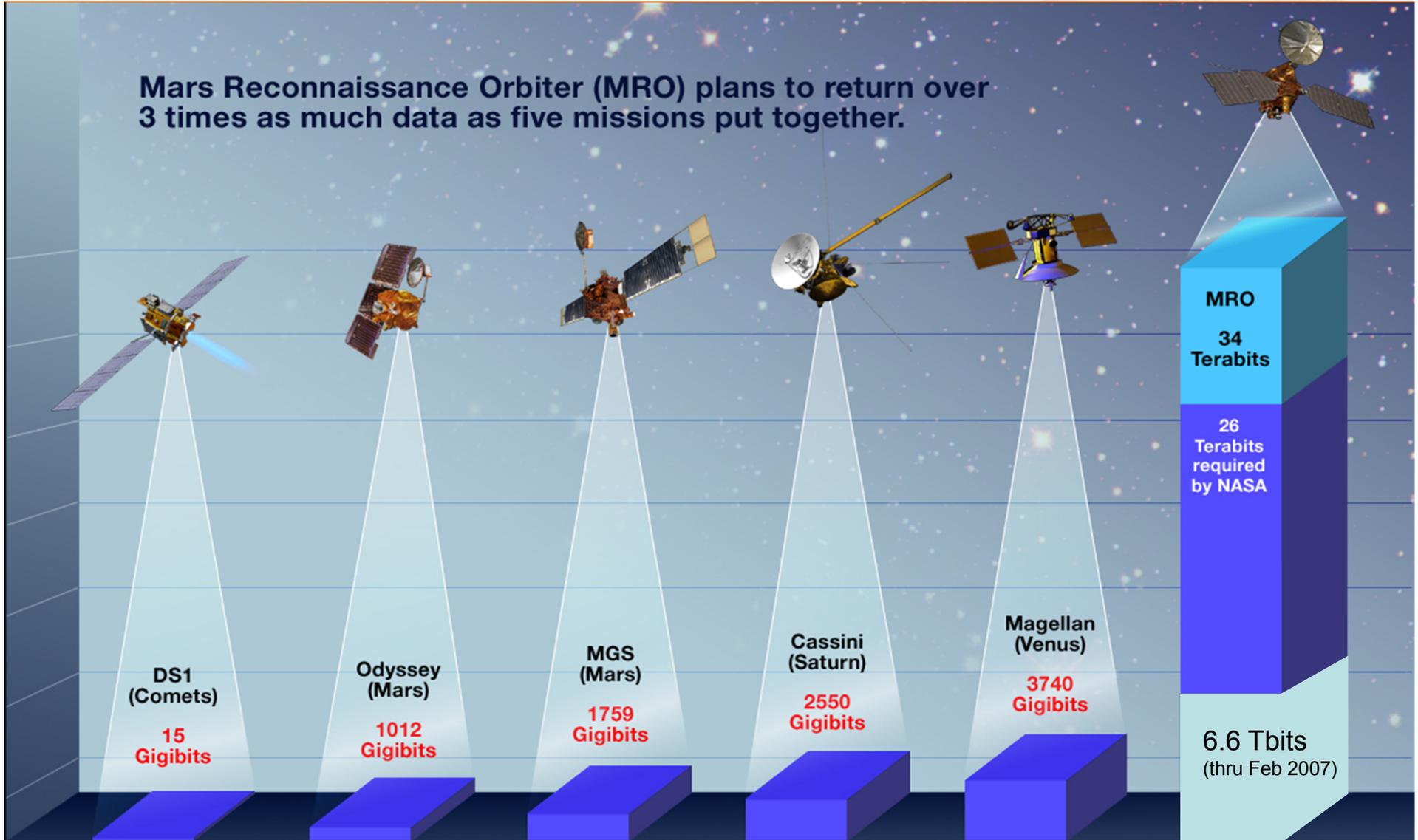




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# Higher Resolution => More Data

Mars Reconnaissance Orbiter (MRO) plans to return over 3 times as much data as five missions put together.





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# Navigation Strategy

## Preliminary Dates of OTM, OSM and OCM Maneuvers

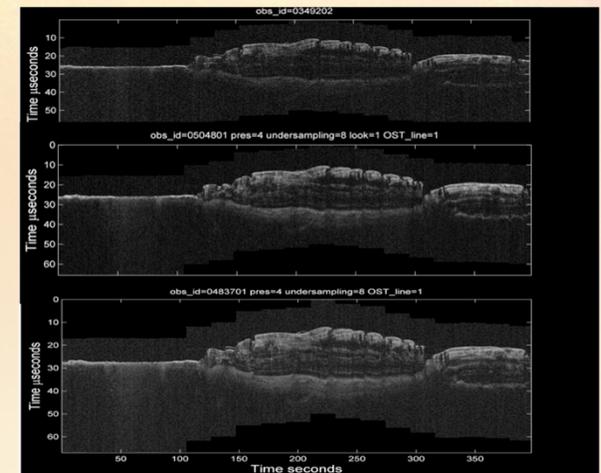
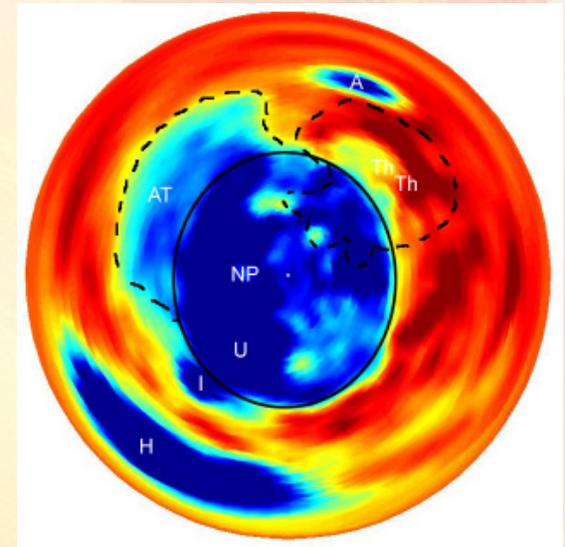
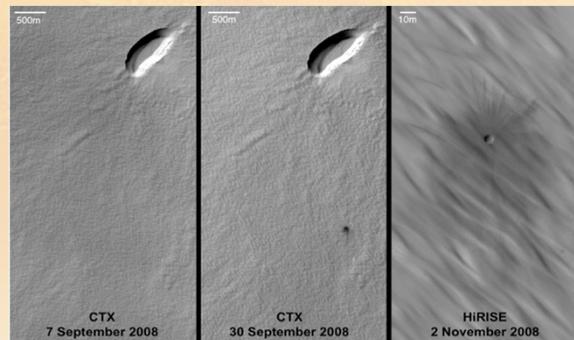
Name	Maneuver Type	Anticipated Date	Notes	Conditions Requiring Maneuver
OTM	GTW Control	October 12, 2011	Nominal GTW control maneuver	GTW exceeds nominal control bands
OCM or OSM or OTM	Orbit orientation change / Orbit Period Change	February 1, 2012 (EDL-187d)	Inclination change maneuver performed to change LMST from 3:00pm PSP orbit towards node requested for MSL EDL; maneuver may also include, or may strictly be, a period correction. Maneuver may be used to change ground-track walk off nominal -32.5 km / 211 orbits to remove initial large phasing bias (depending on target conditions).	MRO LMST target below predicted value time of EDL; EDL phasing errors > 30 seconds and phasing correction > error sources
OSM	Orbit period change	April 25, 2012 (EDL-103d)	Maneuver used to synchronize orbit to fly over MSL EDL. Will remove a majority of the phasing error at the time of MSL EDL.	EDL phasing errors > 30 seconds and phasing correction > error sources
OSM	Orbit period change	July 18, 2012 (EDL-19d)	Maneuver used to synchronize orbit to fly over MSL EDL. This is nominally the final phasing correction.	EDL phasing errors > 30 seconds
OSMC	Orbit period change (contingency)	July 25, 2012 (EDL-12d)	Maneuver used to synchronize orbit to fly over MSL EDL. This is a contingency maneuver only (MRO safeing, etc). A "canned" maneuver may be used.	EDL phasing errors > 30 seconds
-	-	August 6, 2012	MSL EDL event	-
OCM or OSM	Orbit orientation change / Orbit Period Change	August 29 / September 12, 2012 (EDL+23/37d)	Inclination change maneuver performed to go from LMST following MSL EDL back to nominal 3:00pm PSP orbit. A period correction component may also be included for a "quick return" to nominal GTW.	Launch date requires MRO LMST below 3:00pm at EDL
OCM or OSM or OTM	Orbit orientation change / Orbit Period Change	November 7, 2012 (EDL+93d)	Inclination change maneuver performed to level off LMST at 3:00pm. A period correction component may also be included. <b>NOTE:</b> if MRO LMST @ MSL EDL is < 02:52 PM, inclination change should be performed at next OTM opportunity (December 19, 2012).	Launch date requires MRO LMST below 3:00pm at EDL

*A total of 6 (+1 contingency) maneuvers are planned between November 2011-November 2012. Epoch of maneuvers will be dependent on the MSL-requested phasing conditions.*



# Science Status

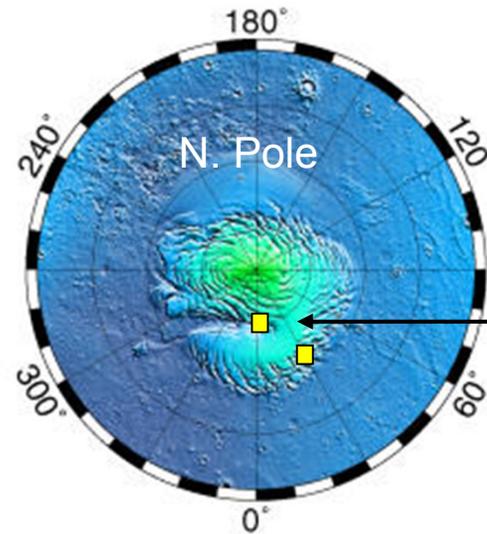
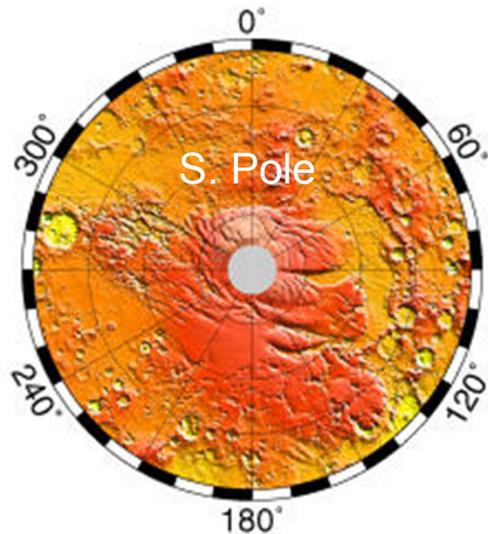
- HiRISE
- CRISM
- CTX
- MARCI
- MCS
- SHARAD
- Gravity
- Upper Atmospheric Structure



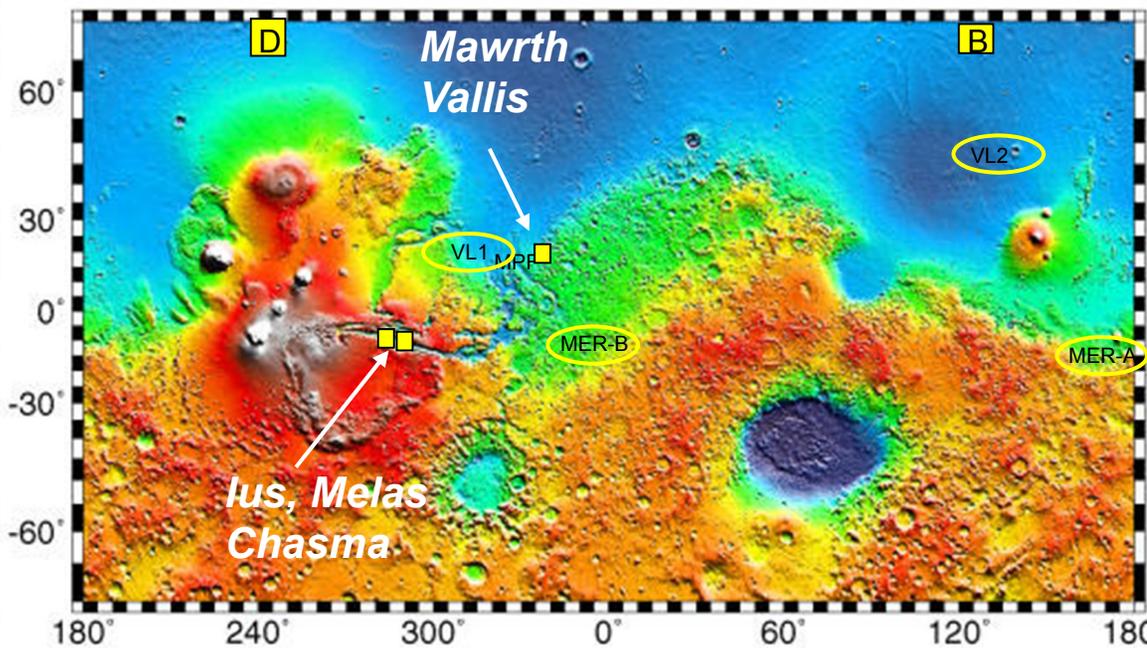


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# Mars Topography



**Chasma  
Boreale**



**CREDIT:  
NASA /  
JPL /  
GSFC**

**MGS  
MOLA**