National Aeronautics and Space Administration

NRC Committee on Astrobiology and Planetary Science (CAPS)

September 24, 2012

Michael Meyer
Lead Scientist, Mars Exploration Program
Doug McCuistion
Director, Mars Exploration Program

Mars Exploration Program

An Integrated, Strategic Program

2001	2003	2005	2007	2009	2011	2013	2016 & Beyond
Odyssey	Mars Express Collaboration	MRO			MSL/Curiosity	MAVEN	*Mars future planning underway!*
	Spirit & Opportunity		Phoenix (completed)				

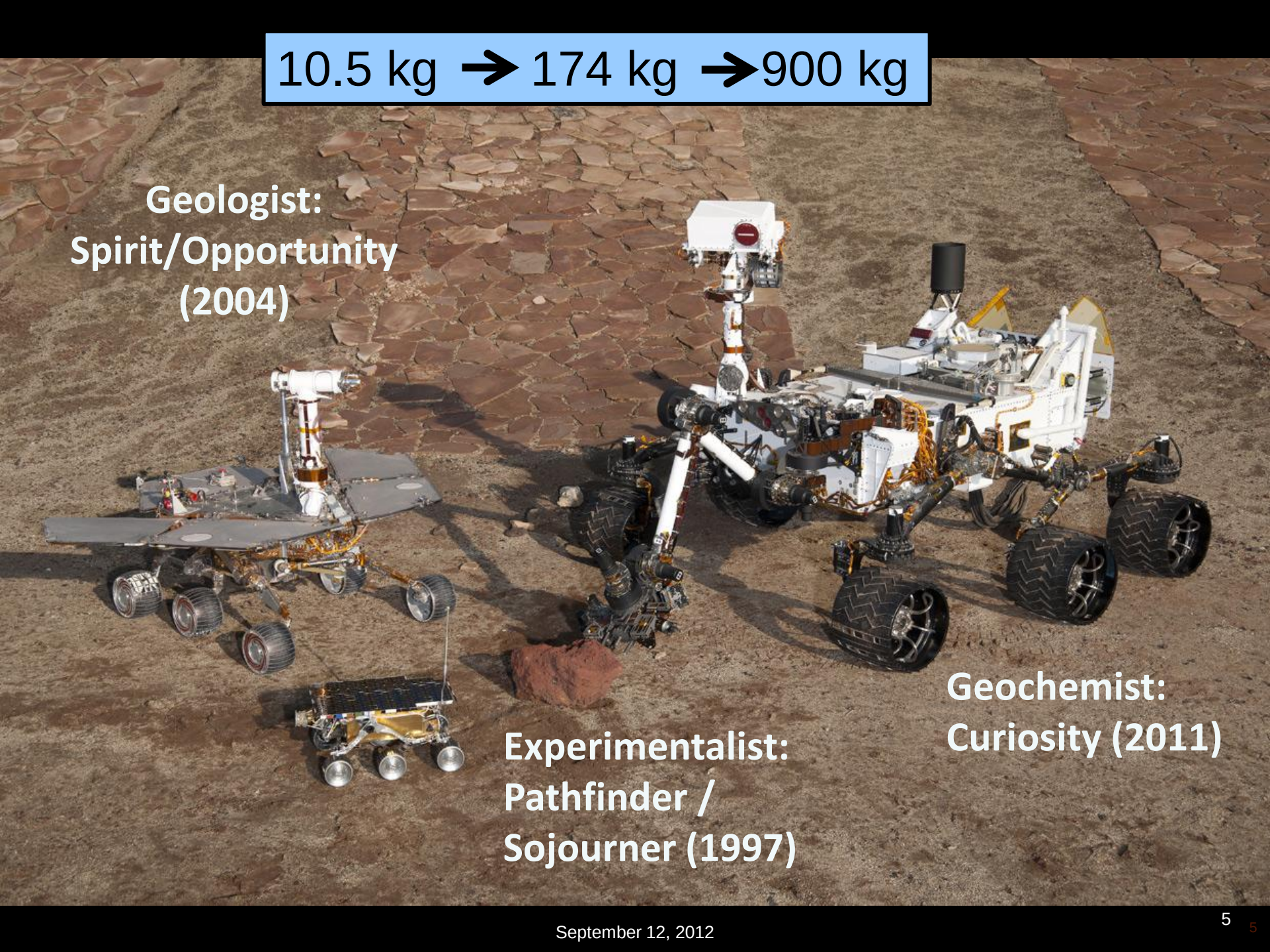
Reasons To Explore Mars

- Many of the key questions in ***solar system science*** can be addressed effectively at Mars:
  - Solar system history
  - Planetary evolution
  - Potential for life
- Mars provides the opportunity to approach, and possibly answer, origin and evolution of life questions
  - Clear potential for past and possibly present biological activity
- Mars has a well-preserved record of its climate and geologic evolution exposed at the surface
  - A comparable record of ancient planetary processes, including those possibly leading to the origin of life, exists on no other terrestrial planet, including Earth
- Mars is the most accessible place in the solar system where these highest-priority science questions can be addressed

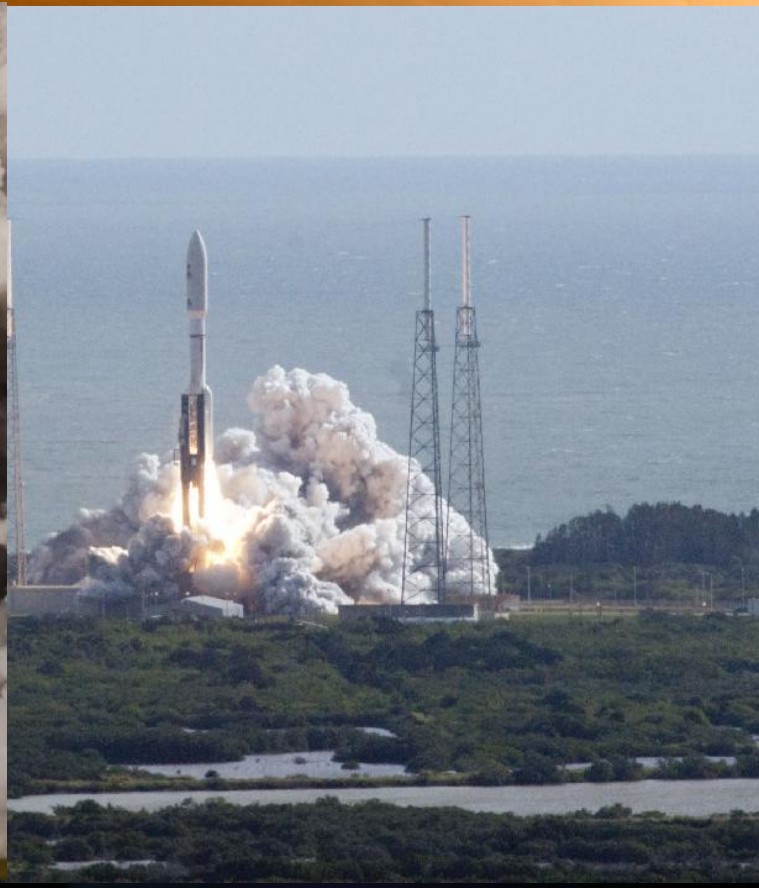
A well-executed program has brought us to where the next major step in exploration can be taken

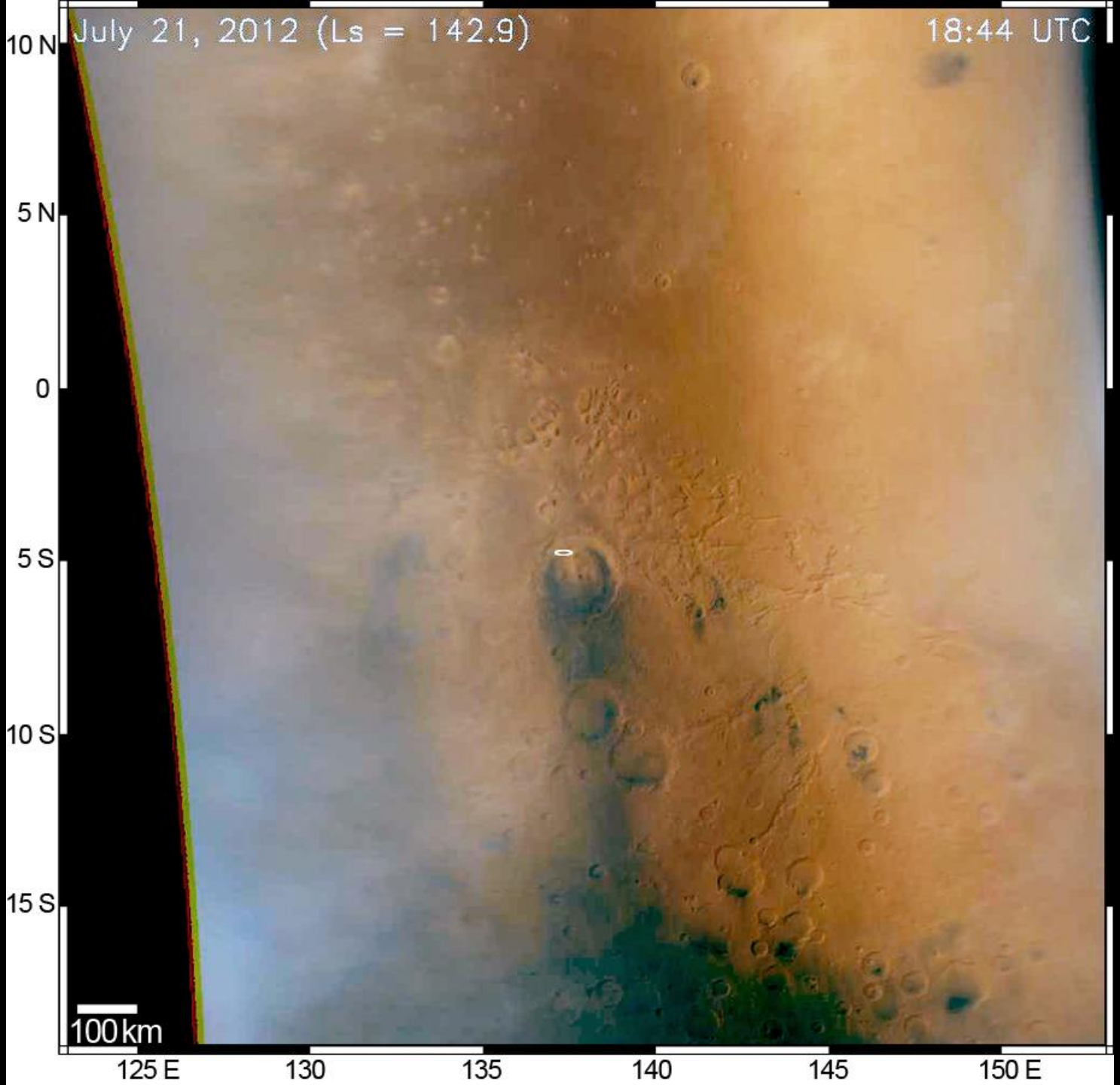
MEP Highlights

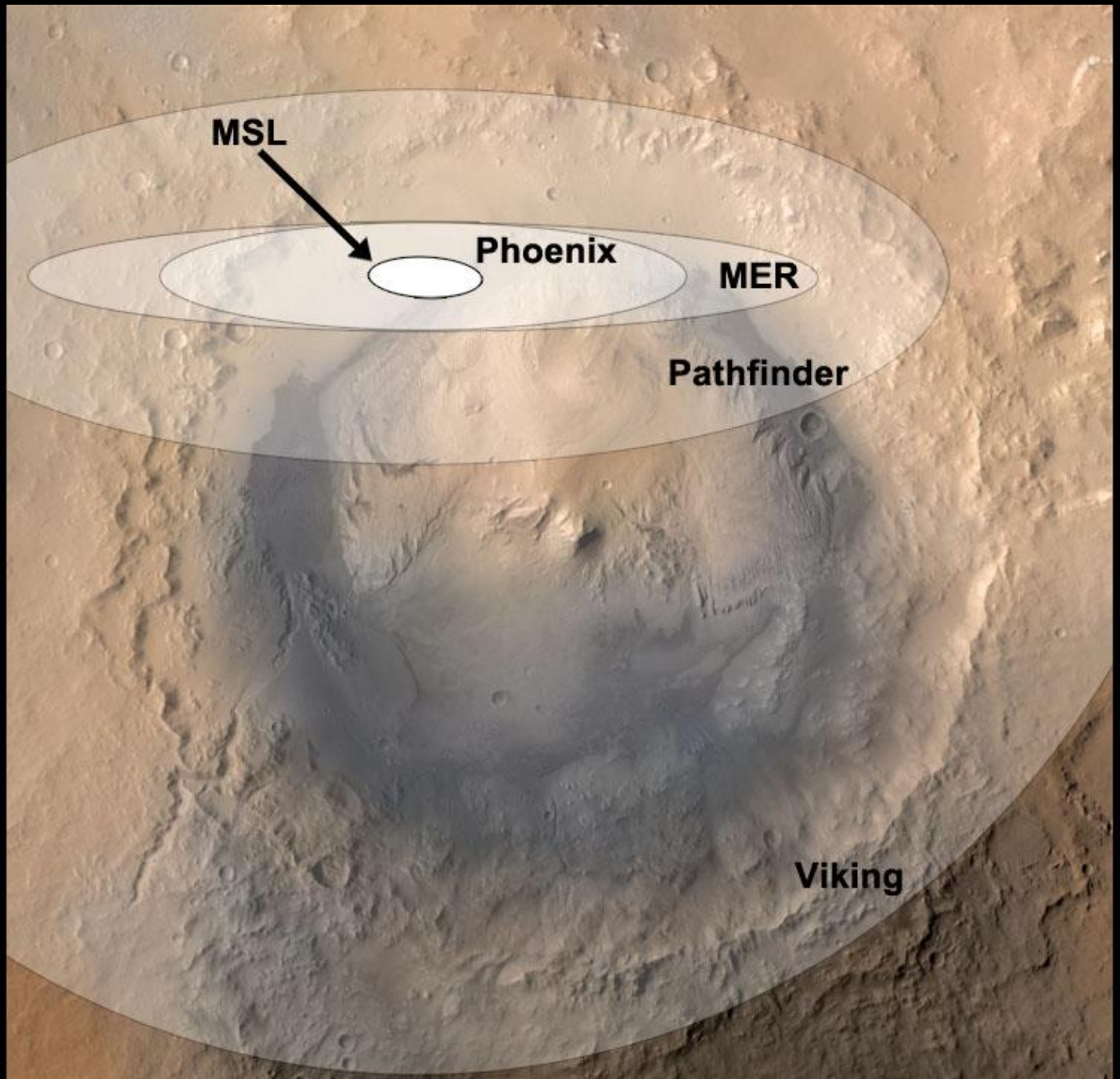
- MSL/Curiosity
  - Launched on November 26, 2012
  - **Curiosity landed on Mars at 1:32 a.m. on August 6, 2012 EDT!**
    - Extensive outreach and educational events in the works nation-wide
  - Mars Reconnaissance Orbiter/Odyssey/Mars Express provided excellent support of the MSL/Curiosity landing – enabling bent-pipe coverage of landing
- 2013 MAVEN
  - KDP-D passed September10, 2012
- Senior review of all Planetary Science Missions
  - All Mars mission were accepted for their next extended mission
- Established independent team, Mars Program Planning Group (MPPG), to develop Mars Program reformulation options after MAVEN in response to FY13 budget and updated Agency priorities
  - Workshop at LPI, June 12-14
  - Final brief from the MPPG Sept. 2012


10.5 kg → 174 kg → 900 kg
Geologist:
Spirit/Opportunity
(2004)
Experimentalist:
Pathfinder /
Sojourner (1997)
Geochemist:
Curiosity (2011)

MSL/Curiosity Launch and Separation

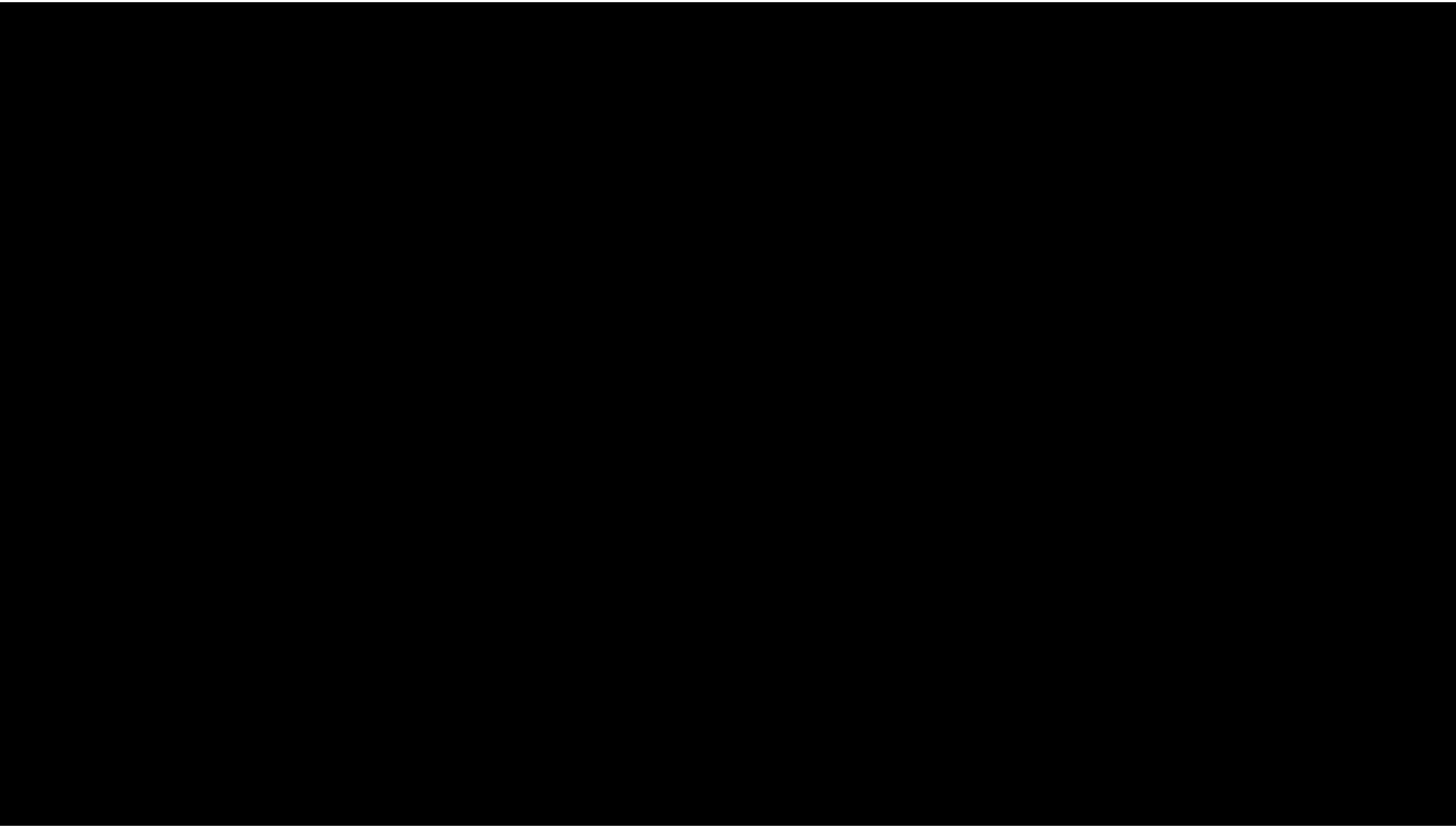



July 21, 2012 (Ls = 142.9)
18:44 UTC
10 N
5 N
0
5 S
10 S
15 S
100 km
125 E
130
135
140
145
150 E


MSL
Phoenix
MER
Pathfinder
Viking


CURIOSITY

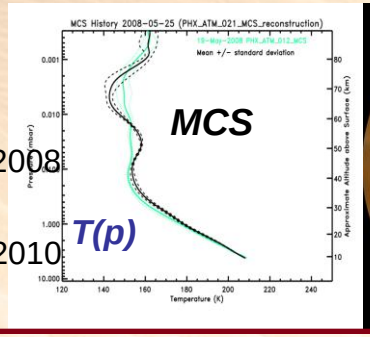
Mars in a Minute

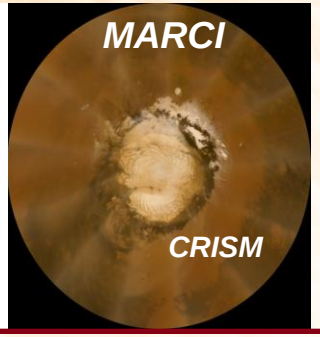


MRO Project Overview

MRO Mission Overview (2006-2012)

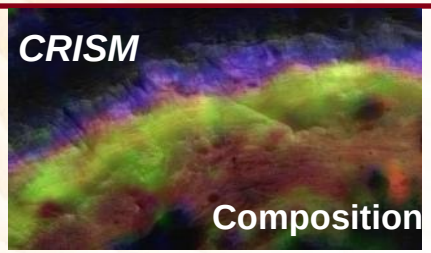
- **Category: II, Risk Class: B**
- Mission Phases
  - Primary Science Phase (PSP): November 2006 to November 2008
  - PHX critical event (EDL) coverage: May, 2008
  - Extended Science Phase (ESP): December 2008-September 2010
  - Extended Mission Phase: October 2010 to September 2012





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

MRO Science Observation Metrics

Investigation	Progress thru end of PSP	By end of ESP	Current EM1
HiRISE	~ 0.6 % of Mars; ~ 964 stereo pairs; ~ 9,550 images	~ 1%; ~ 1955 stereo; ~ 16,745 images	~ 1.72%; ~ 3,054 stereo; ~ 26,728 images
CRISM	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 observations (1.3% of Mars) 2 Mars yrs monitored	78% msp survey[1] 18% hsp survey[1] 21737 targeted observations 2.9 Mars yrs monitored
CTX	18,020 images with ~ 38.5% unique coverage (~8% repeat coverage)	34,596 images with 62% regional coverage	50,185 images with 80.0% regional coverage
SHARAD	~45% of Mars sampled via 5,567 observing strips	~7946 observing strips	12,389 observing strips[2]
MARCI	1 Full Mars year,global DE; 9,670 MARCI images;	97% of 2.1 Mars yrs monitored with 16,566 images	3.1 Mars yrs monitored with 24,964 images
MCS	1 Full Mars year, with GDE >30 x10^6 MCS soundings	84% of 2.1 Mars yrs monitored with 54x10^6 soundings	88% of 3.1 Mars yrs monitored with 82x10^6 soundings
Gravity:	~35% increase in gravity field resolution	Seasonal mass variation	Seasonal mass variation
Accelerometer	Data taken during Aero-braking phase; archived during PSP	Completed	Completed
Science Data Return	~73.4 Tb	~123.2 Tb	~176.0 Tb

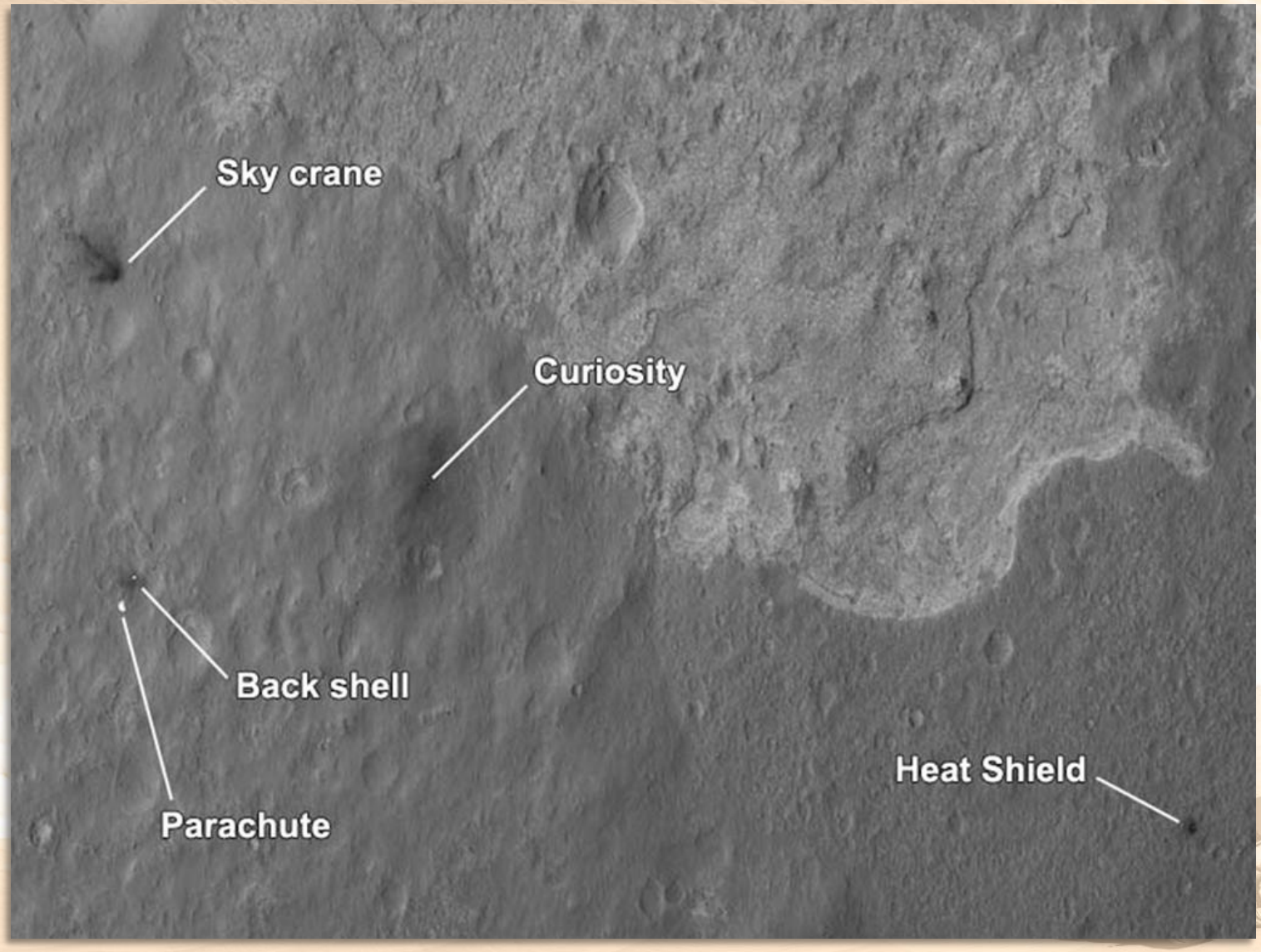
[1]CRISM numbers updated July 2012

MRO Status

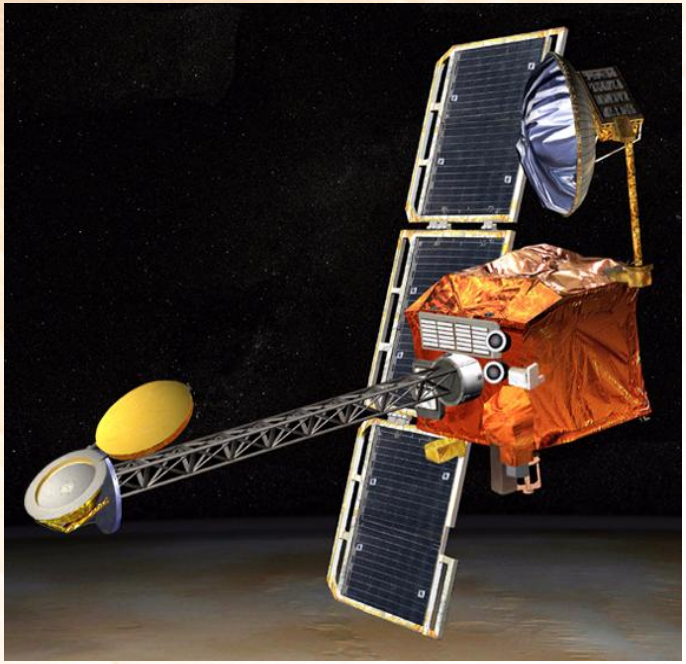
- **Operations—MSL Support:**
  - MRO instruments successfully completed their MSL EDL support functions
    - MCS and MARCI monitored atmosphere during MSL approach
    - MCS profiled atmosphere on orbits immediately before and after EDL
    - HiRISE imaged MSL while deployed on Parachute
    - HiRISE and CTX imaged MSL flight elements after landing
  - HiRISE is filling in color strips close to the actual landing point; these will be used in planning MSL traverses

- **Operations—MRO science**
  - Except for HiRISE (and occasional CTX images on Sols, 1, 6 & 11), MRO instruments were off during characterization of UHF relay performance in various configurations and for different rates; HiRISE operating without competition & MCS rule restrictions
  - CTX & MARCI turned on August 29
  - MCS slated for turn on September 7
  - CRISM and then SHARAD turn-ons to occurred September

MSL Flight Elements: Where are they now?



Odyssey Project Overview



Salient Features:

Category: 2 Risk Class: B

- Mars Orbiter Launched: April 7, 2001
- Science Mission Began: February 19, 2002
- Payload:
  - Thermal Emissions Imaging System (THEMIS)
  - Gamma-Ray Spectrometer (GRS)
  - High Energy Neutron Detector (HEND)
  - Neutron Spectrometer (NS)
  - Martian Radiation Environment Experiment (MARIE)
- Primary Mission: 917 Days, Ended August 24, 2004
- Extended Mission: August 25, 2004 to March 31, 2013

Science

- Acquire High Spatial and Spectral Resolution Mapping of Surface Mineralogy
- Provide Information on the Morphology of the Martian Surface
- Observe inter-annual variations and secular changes
- Determine Abundance of Hydrogen in the Shallow Subsurface
- Globally Map the Elemental Composition of the Surface (completed)
- Characterize Specific Aspects of the Martian Near-Space Radiation Environment (completed)

Loss of Reaction Wheel

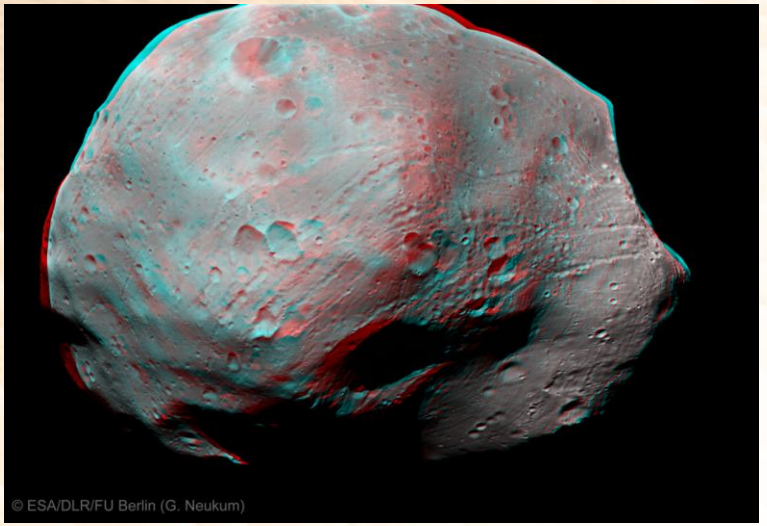
- Description
  - Reaction wheels 1-3 in use nearly continuously since launch (11 years)
  - On 8 June 2012 (UTC), RW1 stiction during a zero crossing caused an X-axis control error and resulted in safe mode entry
  - On 12 June 2012 (UTC), RW1 experienced an additional stiction event at a wheel speed of ~200 rad/s
- Current Status
  - Safe mode exit on 16 June 2012 and replaced RW1 with RW4 at nadir point
  - Spacecraft is operating with reduced control authority due to increased friction and the offset pointing of the skew wheel

Consumables and Lifetime
(as of 31 August 2012)

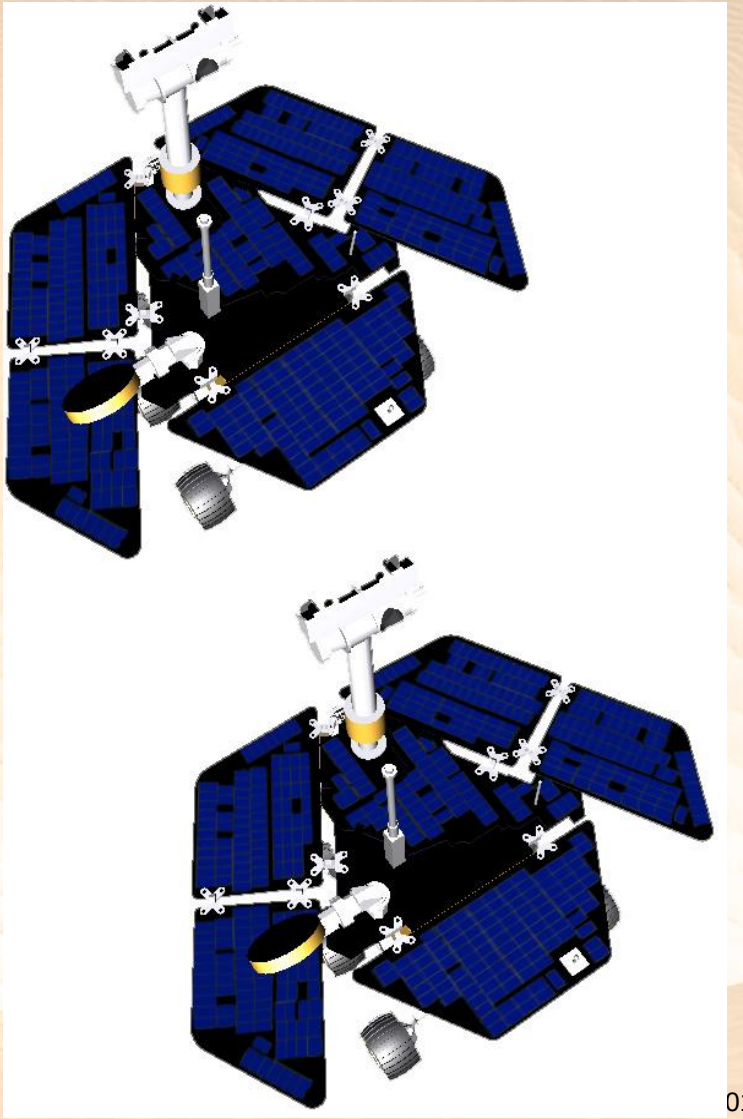
Consumable	Status
UHF Transceiver ('B' side unit available)	Used 9,964 total thermal power cycles of 8K-12K lifetime; based on average 30 cycles/month,12K life and projecting 2 additional cycles per day for MSL, 1.9 years remain
Propellant Remaining	18.90 kg +3/-5 kg; current avg annual usage is 1.3 kg/yr
IMU ('B' side unit available)	Used 98,668 operating hours out of a vendor (Honeywell) predicted operating range of 99,486 – 104,410 hours. Powered on 6/8/2012.
HGA Gimbals	4.6 / 5.4 years of life remaining; recent experience / mission history
Battery	7.6 years remaining of 20 yr life
SSPA ('B' unit available; x-strapped)	16.4 years of life remaining as currently utilized
Solar Array Gimbals	22.1 years of life remaining assuming periodic vector tracking
Power Supplies ('B' side unit available)	Both C&DH power supplies (Side-A & Side-B) nominal

ESA Press Release - 20 August 2012
Fantastic Phobos

Mars Express continues to image the sides of Phobos that are never seen by the other Mars orbiters, which orbit much closer to Mars. Once every 5 months, the orbits of Phobos and Mars Express align in such a way that Mars Express gets up to 12 close (within a few hundred kilometers) flybys of Phobos. These close flybys have enabled observations by the entire Mars Express payload. Radar sounding has probed the Phobos interior to help determine its origin. Radio science data taken during these multiple flybys would determine the mass and low-order gravitational moments, giving additional insight into the Phobos interior and composition. Also, these multiple close flybys provide a wide longitudinal coverage for HRSC, OMEGA, SPICAM, and PFS to build up high–spatial resolution global coverage as well as long–time baseline orbital, topographic, cartographic, rotational, albedo, mineralogical, compositional, and multispectral coverage to address the current state of the interior and surface. Also, ASPERA has probed the Phobos dust environment during these flybys. No other spacecraft in the past or in the planned future can provide these unique and revolutionary observations and results. Special sessions at the joint European Planetary Science Congress / Division of Planetary Sciences meeting in 2011 produced a consensus that a large Martian cratering event (rather than captured asteroids) is the origin of Phobos and Deimos based upon Mars Express data.



Mars Exploration Rover



Spirit at Gusev

Last Contact Sol 2210

7.730 km

Opportunity at Meridiani

Sol 3064

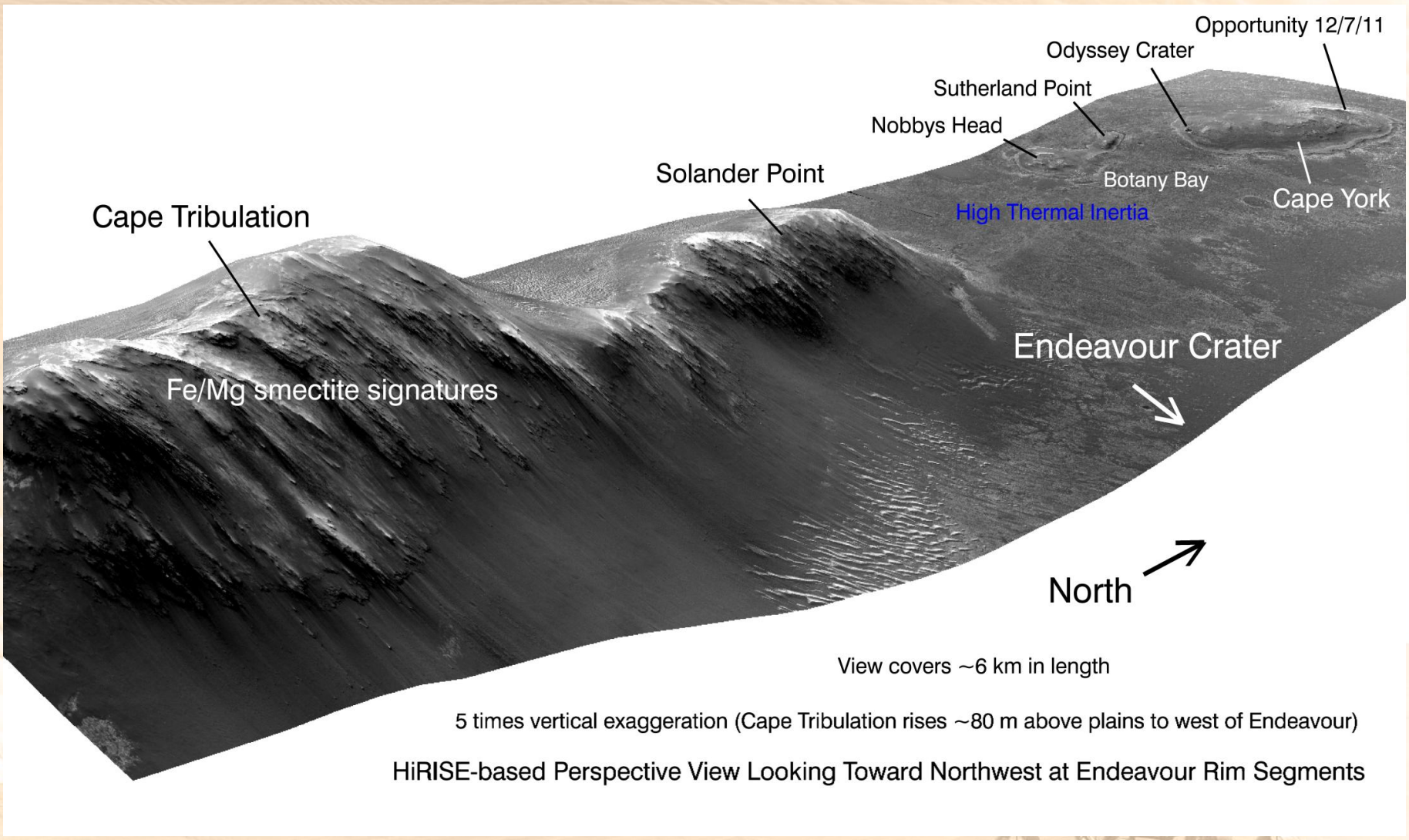
35.035 km to date

Opportunity has exceeded 35 kilometers!

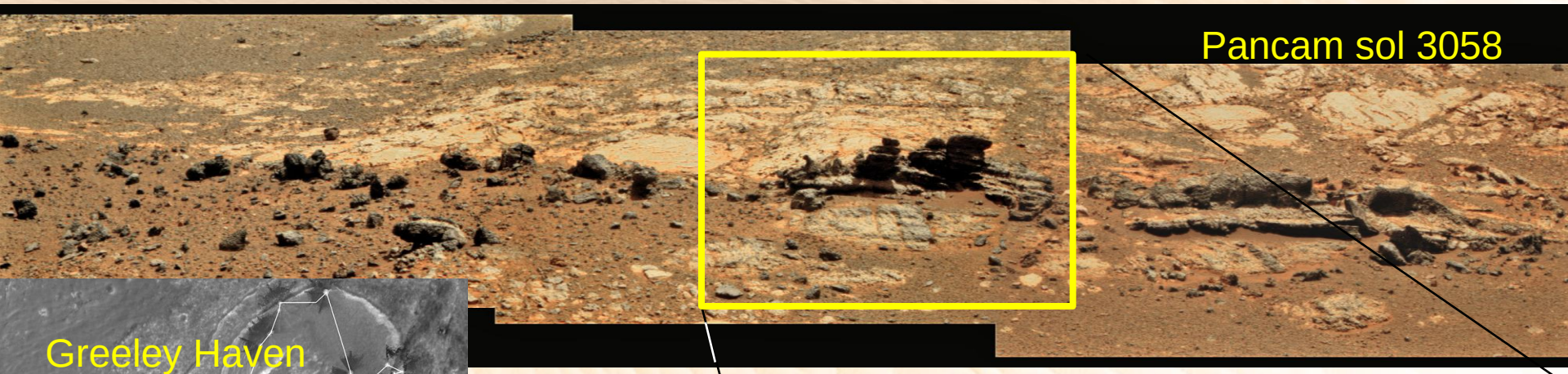
Assessment

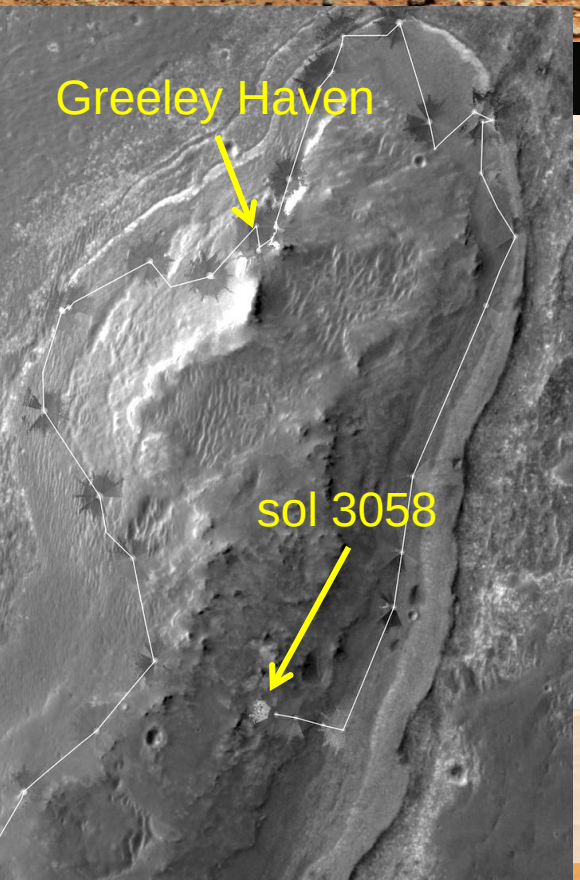
- Opportunity has exceed 35 kilometers of odometry.
- Opportunity is in good health with ample energy production as spring and summer approach.
- Opportunity is exploring Cape York on the rim of Endeavour Crater with the near-term science objective to explore the in-board (eastern) side where orbital data suggest the presence clay minerals.
  - Opportunity is likely near the putative clay minerals.
  - An in-situ (contact) science campaign is already being implemented.

Endeavour Rim Perspective

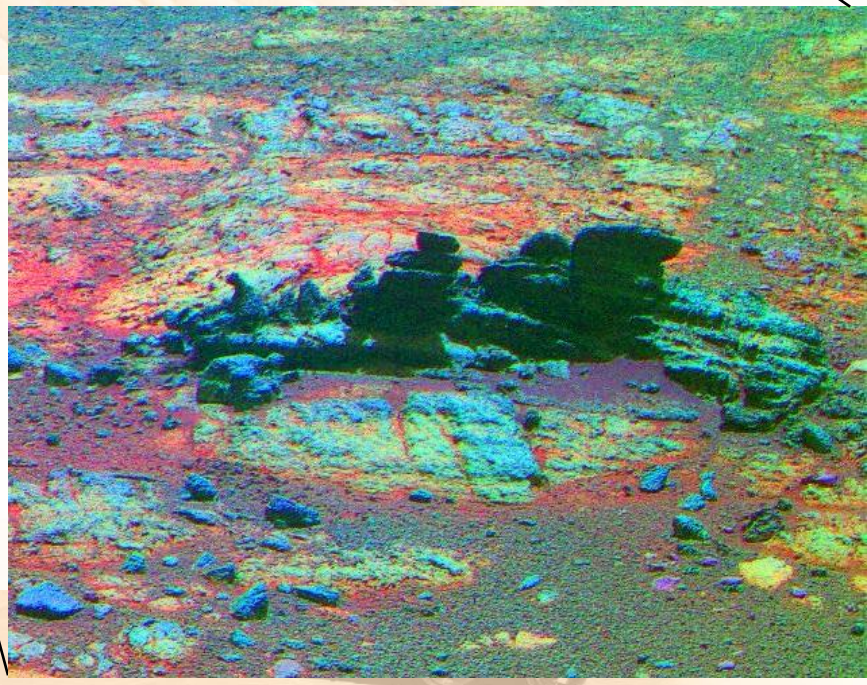


Searching for Phyllosilicates on Cape York

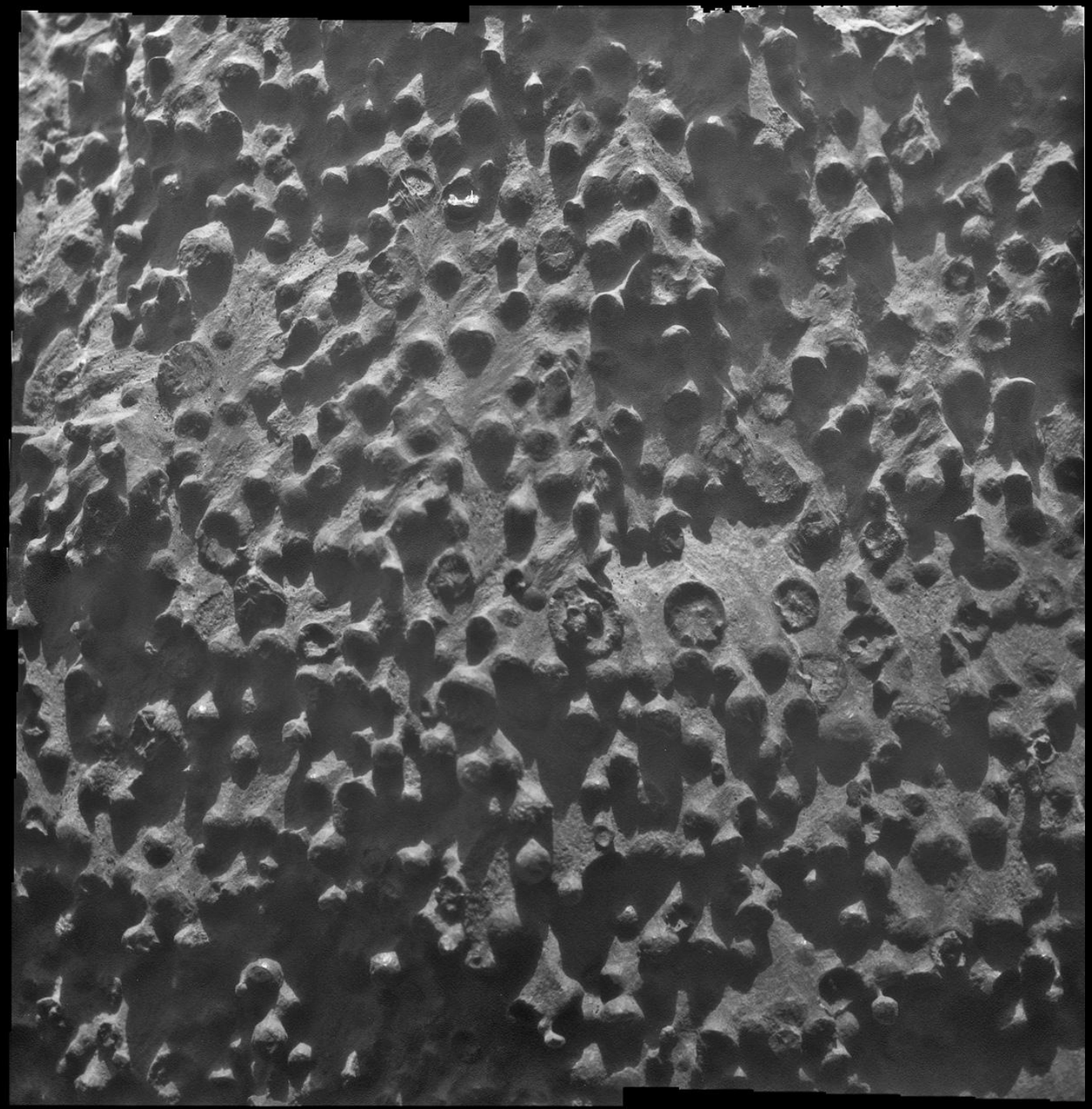




Opportunity has nearly completed its survey of the Cape York region containing CRISM clay signatures, and is ready to perform detailed IDD investigations of candidate targets.



spectral principal component stretch – W. Farrand



Mars Science Laboratory Project Overview

Science

Focus on Past & Present Habitability of Mars
Highly Capable Analytical Laboratory
Next Generation Remote Sensing & Contact Investigations
Suite of Environmental Monitoring Instruments

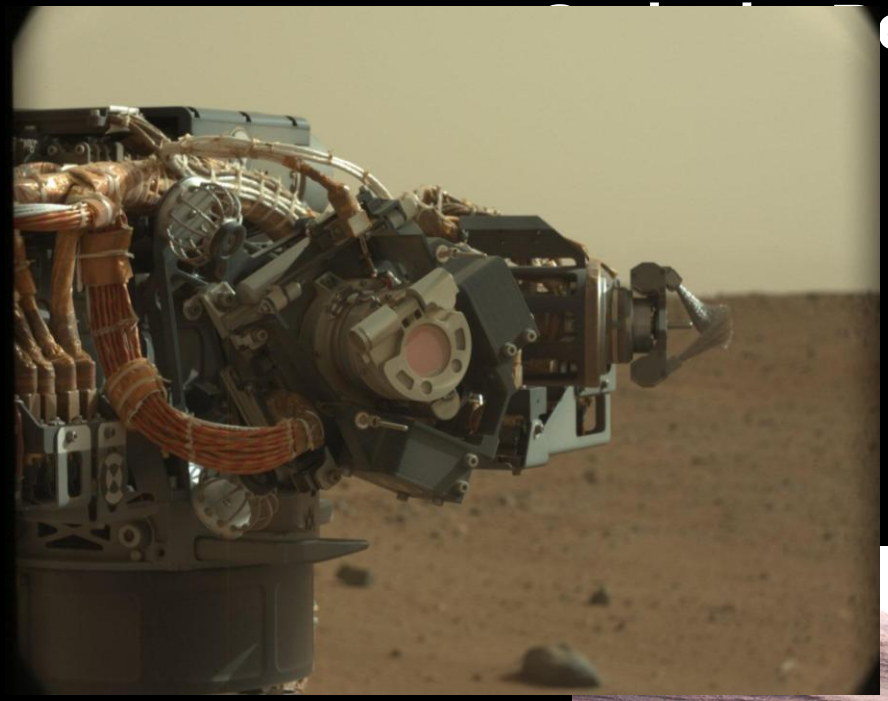
Technical Capabilities

Category 1
Risk Class A
One Mars Year surface operational lifetime (669 sols/687 days)
Discovery Responsive over wide range of latitudes and altitudes
Precision Landing via Guided Entry Skycrane Propulsive Landing
Long Distance Traverse Capability (20 km)
Flexible & Robust Sample Acquisition & Processing

Recent Accomplishments

- Landing
- Completion of CAP 1A, R10.5.6 FSW Transition, and CAP 1B activities
- Initial MRO-MSL UHF Characterization
- First traverses
- First SAM atmospheric measurements
- First ChemCam LIBS measurements
- Recent completion of CAP 2 activities
- Curiosity proceeding toward first science destination, “Glenelg”

ecent Accomplishments



Images from Curiosity

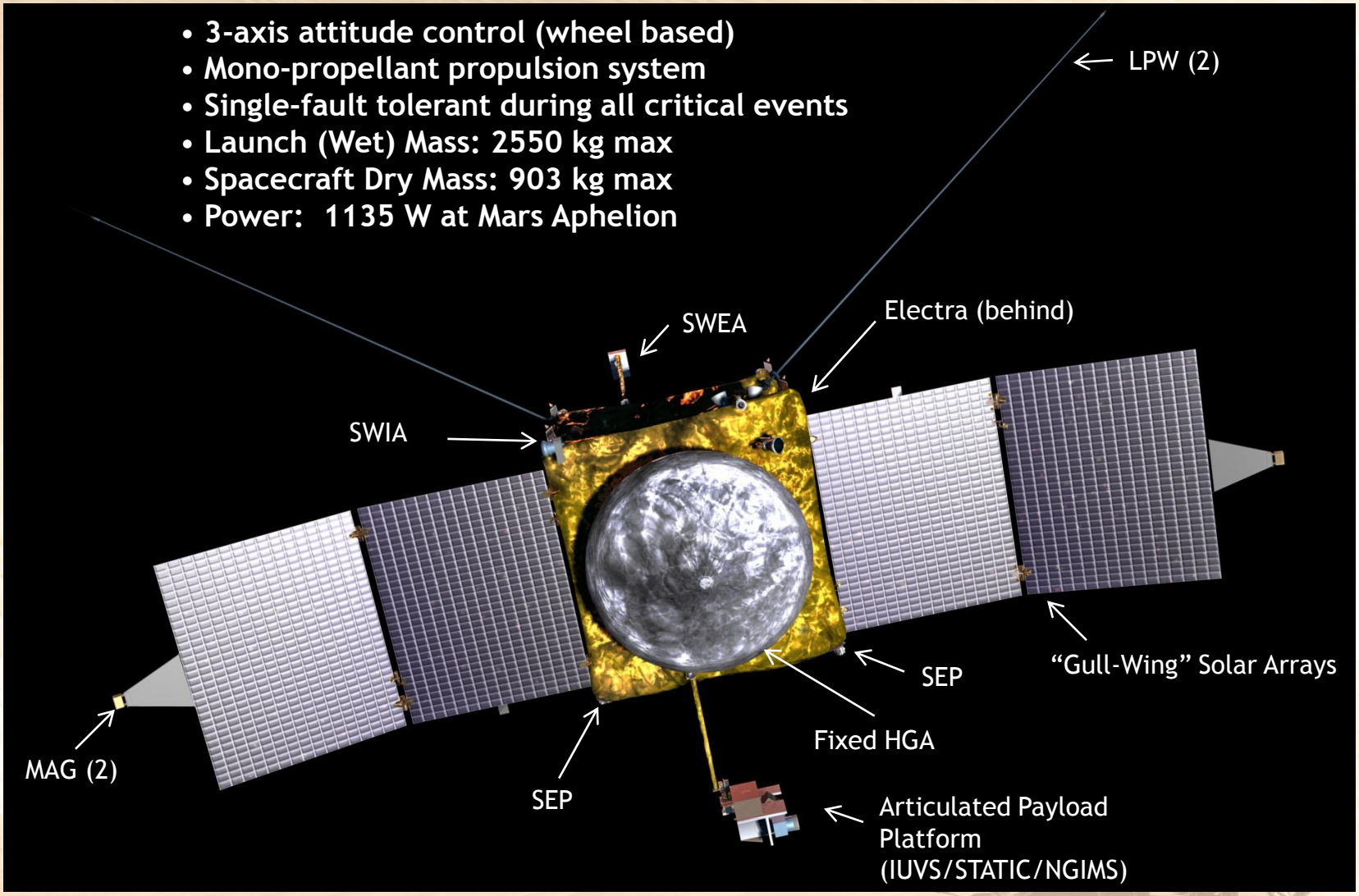
Key Upcoming Activities

- Initial contact science (APXS/MAHLI)
- Additional SAM atmospheric measurement
- Complete MRO-MSL UHF Characterization
- Additional drives towards Glenelg
- Initial scoop sample acquisition

- Post-Landing Assessment Review (Sept 18)

The MAVEN Spacecraft

- 3-axis attitude control (wheel based)
- Mono-propellant propulsion system
- Single-fault tolerant during all critical events
- Launch (Wet) Mass: 2550 kg max
- Spacecraft Dry Mass: 903 kg max
- Power: 1135 W at Mars Aphelion



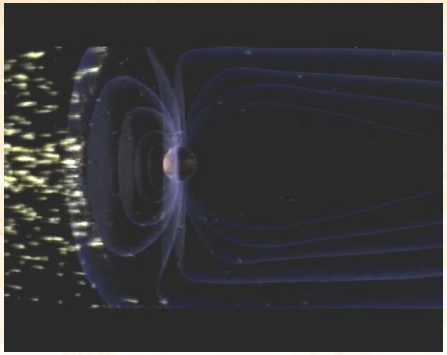
Science and Mission Summary: Science Overview (1 of 2)

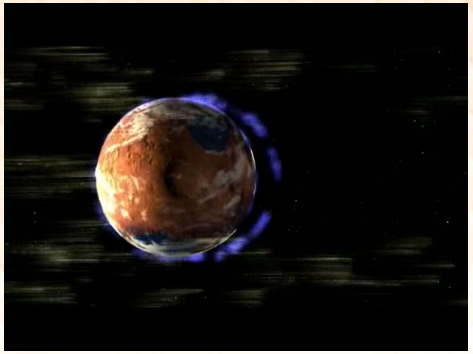
Ancient Valleys

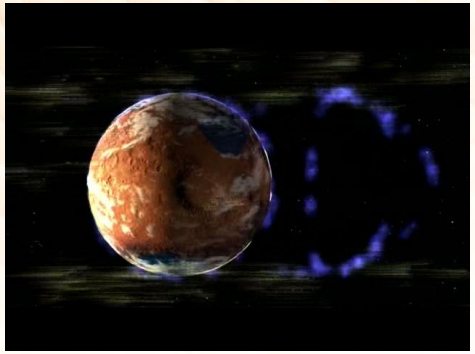
Mars' atmosphere is cold and dry today, but there was once liquid water flowing over the surface.

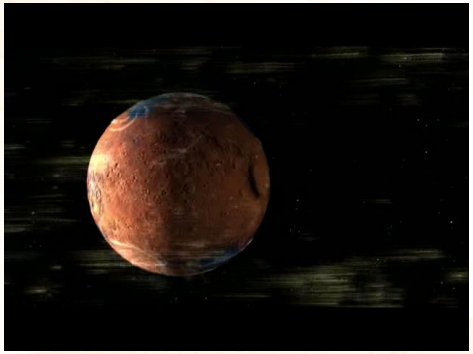
Where did the water and early atmosphere go?

- *H_2O and CO_2 can go into the crust or be lost to space*
- *MAVEN will focus on volatile loss to space*





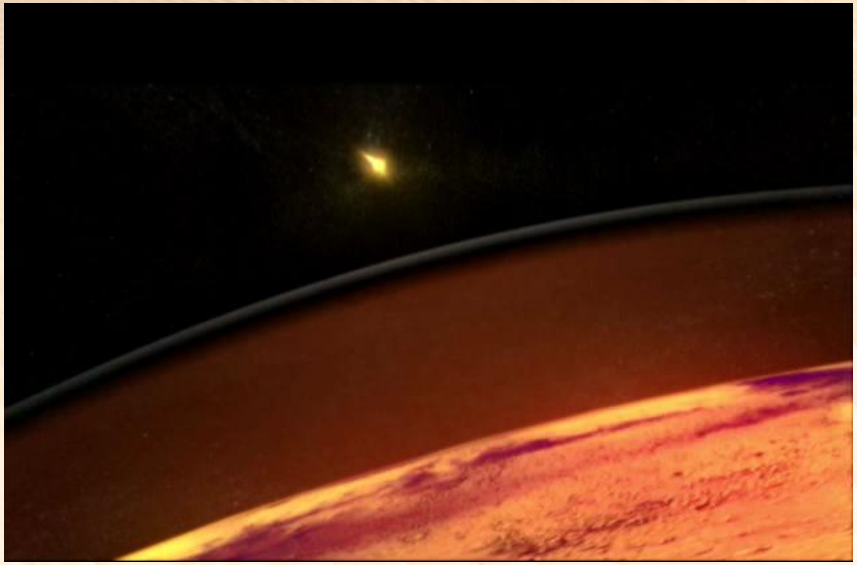




Turn-off of the Martian magnetic field allowed turn-on of solar-EUV and solar-wind stripping of the atmosphere approximately 3.7 billion years ago, resulting in the present thin, cold atmosphere.

Science and Mission Summary: Science Overview (2 of 2)

MAVEN will:



- Determine the structure and composition of the Martian upper atmosphere today
- Determine rates of loss of gas to space today
- Measure properties and processes that will allow us to determine the integrated loss to space through time

MAVEN will answer questions about the history of Martian volatiles and atmosphere and help us to understand the nature of planetary habitability.

MAVEN Top Stories

Significant Accomplishments

- Passed KDP-D
- Spacecraft command and telemetry links to the Test Control Center were verified.
- NGIMS high temperature bake-out of the Quadrupole Mass Spectrometer (QMS) sensor is complete; no leaks were observed.
- Electra was delivered to LM and completed mag testing.
- PFP completed EMC testing

Cost and Schedule

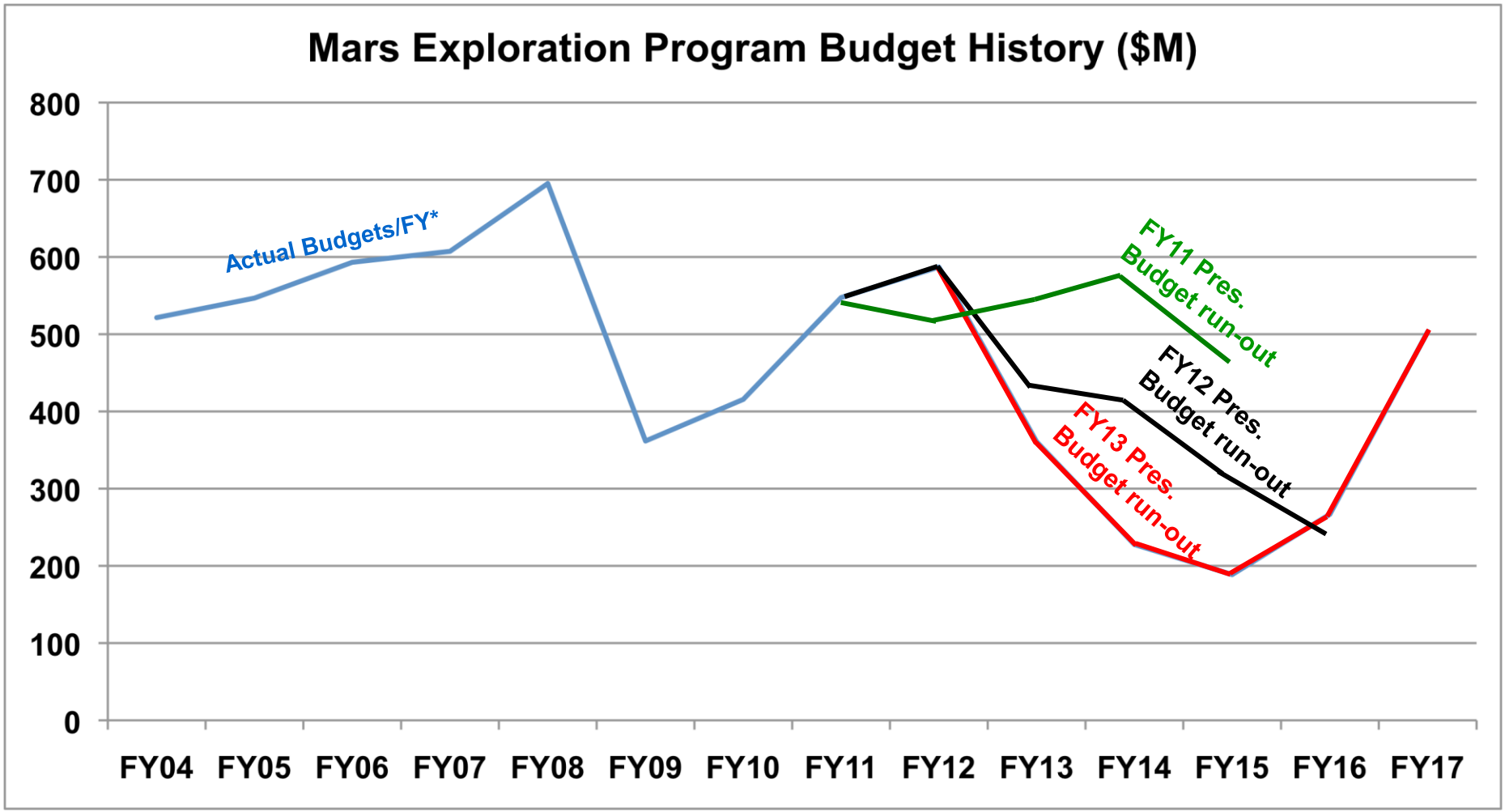
- Project is using funded schedule margin as required. Will use reserves to buy weekend work or other schedule mitigation as the FSR drops towards the GSFC guidelines. NGIMS descopes/replans in progress. December delivery unlikely

President's FY13 Budget – Planetary Science

	FY 11	FY 12	FY 13	FY 14	FY 15	FY 16	FY 17
Planetary Science	$1,450.8	$1,501.4	$1,192.3	$1,133.7	$1,102.0	$1,119.4	$1,198.8
Planetary Science Research	$158.8	$174.1	$188.5	$222.5	$233.4	$231.7	$230.3
Lunar Quest Program	$130.2	$139.9	$61.5	$6.2			
Discovery	$192.0	$172.6	$189.6	$242.2	$235.6	$193.8	$134.3
New Frontiers	$213.2	$160.7	$175.0	$269.8	$279.6	$259.9	$155.1
Mars Exploration	$547.4	$587.0	$360.8	$227.7	$188.7	$266.9	$503.1
Outer Planets	$91.9	$122.1	$84.0	$80.8	$78.8	$76.2	$76.3
Technology	$117.3	$144.9	$132.9	$84.6	$85.9	$90.9	$99.6

- Grey region is a "notional" budget – top line remains the same but details within may change

MEP Budget History
Including President's FY13 Request



(*) actual based on last Op Plan of each Fiscal Year

FY13 Budget – Looking Forward

- The FY13 budget
  - Ramp down of existing 2016 and 2018 miss activities with ESA continue
    - Plan to provide Electra for 2016 TGO mission, and some telecom and engineering support for 2016 landing demonstrator and 2018 rover missions
  - A 2018 small-class mission (per Decadal definitions) may be supportable
    - However some rephasing will be required--TBD

- The Mars Program Planning Group (MPPG) was established by the Agency/SMD, to develop options for the next step in Mars Exploration
  - Terms of Reference signed on March 19, 2012 by SMD AA, HEOMD AA, Chief Technologist, Chief Scientist
  - Report will be released publically after this session of CAPS

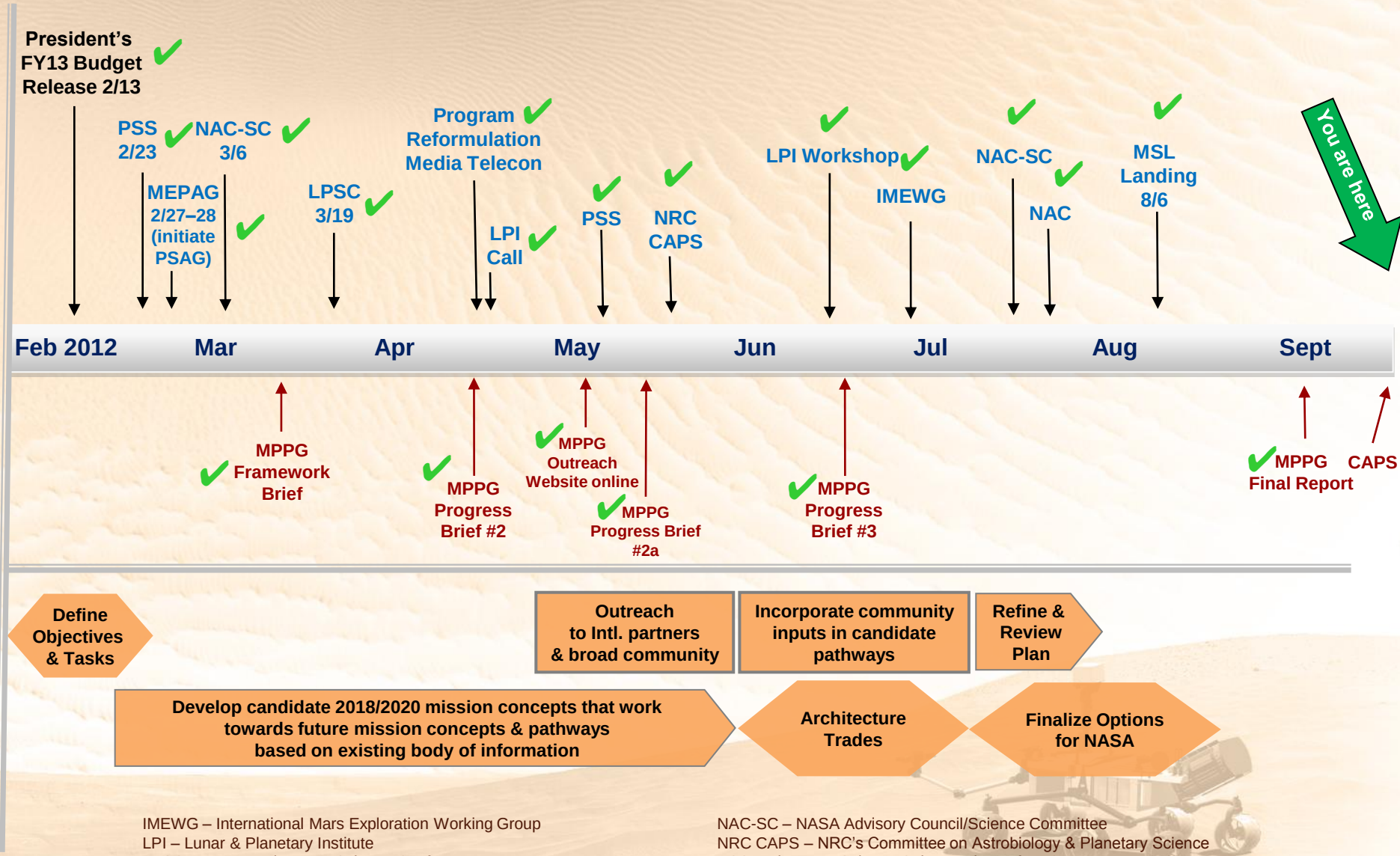
How NASA will Reformulate the Mars Exploration Program (MEP)

- NASA will incorporate the input from the MPPG findings into NASA's broader planning process for the future mission set for the MEP, beginning with the 2018 launch opportunity
- With HEO/OCT/OCS, a collaborative strategy for robotic and human Mars Exploration will be developed that infuses high payoff technologies
- The reformulated Mars Exploration Program will be recommended to OMB during the FY14 PPBE process
  - It is likely that the final program architecture will not become public until the President's FY14 budget is release in February '13

- Next Steps:
  - Sept – MPPG briefing to CAPS (first public roll-out)
  - Sept-Oct - Develop NASA's strategy for the reformulated Mars Exploration Program
  - Mid Oct - Brief OMB on reformulated Mars Exploration Program
  - Late Nov - OMB Passback
  - End of Nov - Brief Congress on reformulated Mars Exploration Program
  - Feb 2013 - Roll-out revised Mars Exploration program in FY14 President's Budget Request
  - Feb/Mar – Engage Community on reformulated MEP (PSS, NRC, MEPAG, etc.)

Mars Exploration Program Reformulation

FY12 Timeline & Milestones (dates are approximate)



IMEWG – International Mars Exploration Working Group
LPI – Lunar & Planetary Institute
LPSC – Lunar & Planetary Science Conference
MEPAG – Mars Exploration Program Analysis Group

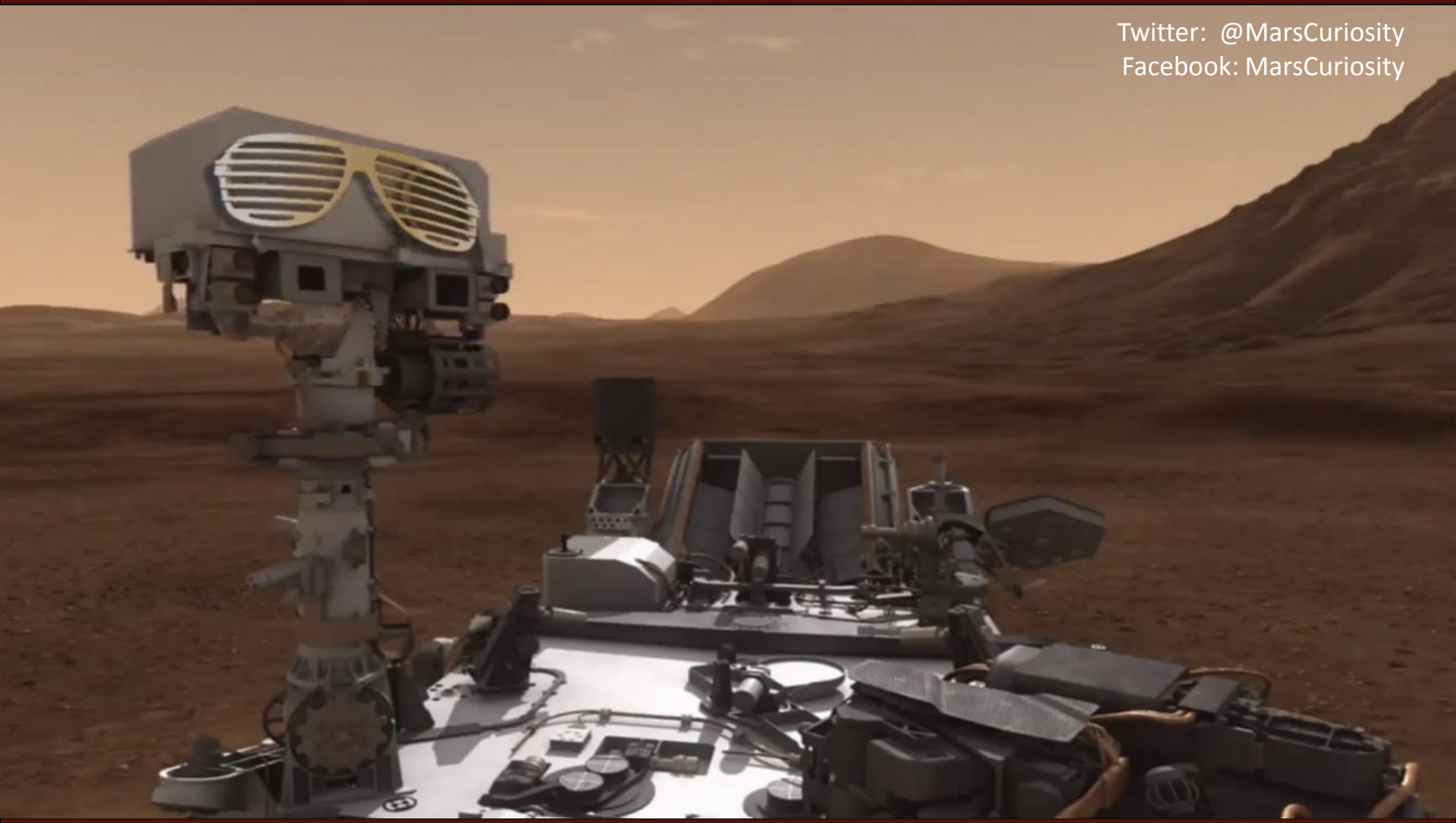
NAC-SC – NASA Advisory Council/Science Committee
NRC CAPS – NRC's Committee on Astrobiology & Planetary Science
PSS – Planetary Science Subcommittee of NAC
NRC – National Research Council


MARS IS HARD!
EARTH
HALF-TIME SCORE:
MARS
24
16

I'm Curiosity…

www.nasa.gov/msl
mars.jpl.nasa.gov/msl

Twitter: @MarsCuriosity
Facebook: MarsCuriosity



Credit: YouTube/Satire

…and I know it!