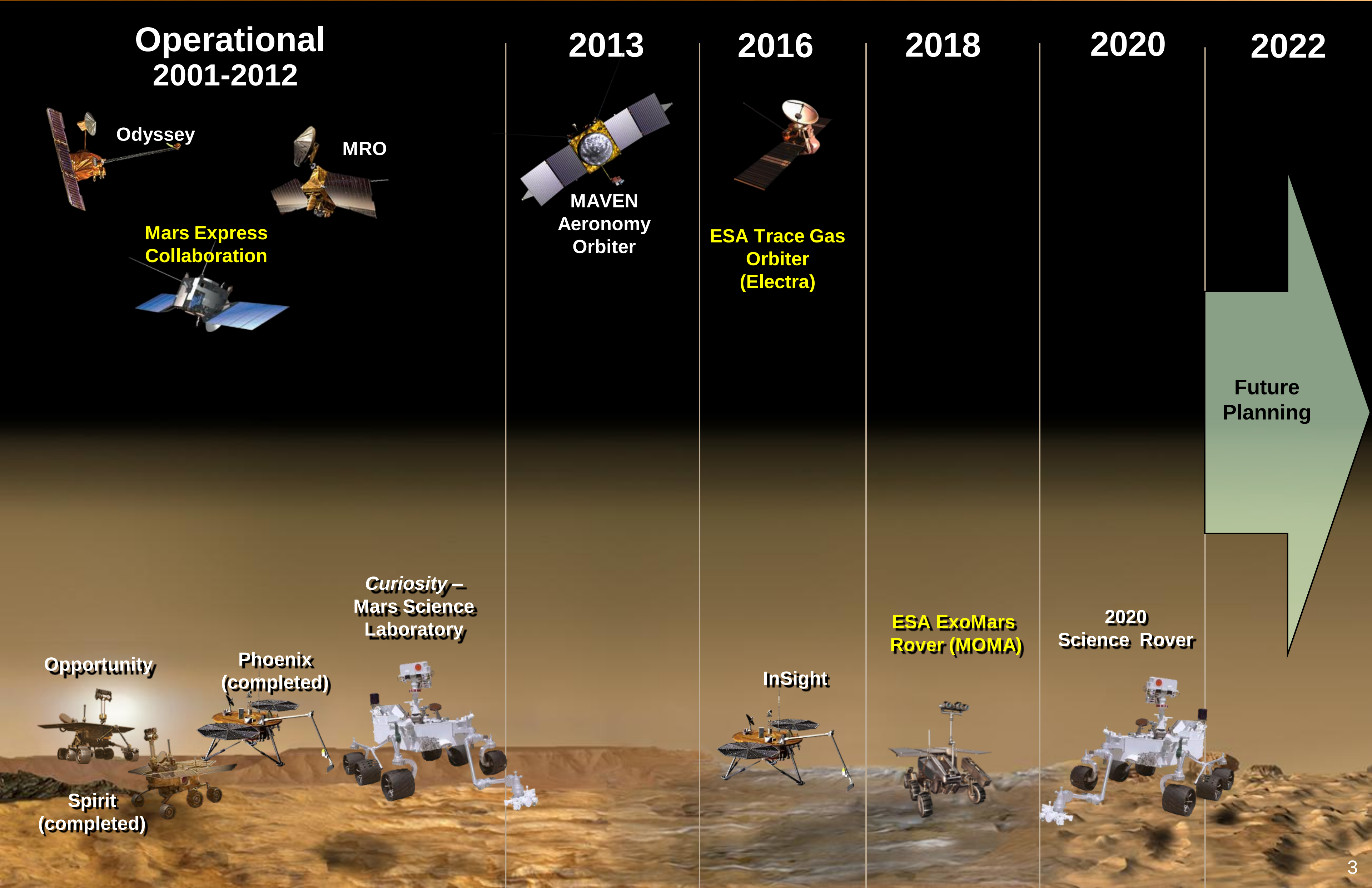
National Aeronautics and Space Administration

Mars Exploration Program
Committee on Astrobiology and Planetary Science
March 7, 2013

Michael Meyer, Lead Scientist
Lisa May, Lead Program Executive
Jim Green, Director (Act.)

- Overview of Mars program
- Future Plans
    - MPPG
    - SDT
    - Timeline
- Status of current missions - review of each mission,
- Highlights from missions & R&A
- Status of mission in devel
    - – MAVEN
- Issues

Mars Exploration
Strategic In-Guide Plan



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 is the most accessible place in the solar system where these highest-priority science questions can be addressed
- 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

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

MEP Highlights

- MSL/Curiosity
  - **Curiosity landed on Mars at 1:32 a.m. on August 6, 2012 EDT!**
  - Completed all First Time Activities
- 2013 MAVEN
  - 8 of 10 payloads delivered
  - On track to ship to the cape in August
- MEP collaborating in ExoMars 2016 (Electra) and ExoMars 2018 rover contributing portion of MOMA payload
- Mars Program Planning Group (MPPG) developed Mars Program reformulation options
- Agency announced Mars 2020 Rover at AGU, 3 Dec. 2012
  - Science Definition Team for Mars 2020 Rover established
    - Kick-off telecon Jan. 24, 2013
    - First face-to-face Feb 27-Mar 1
    - Final Text July 1, 2013
- First all-virtual MEPAG meeting Feb. 27, 2012

Science Definition Team – Statement of Task

The SDT is tasked to formulate a detailed mission concept that is traceable to highest priority, community-vetted scientific goals and objectives (i.e., *Vision and Voyages* NRC Planetary Decadal Survey and related MEPAG Goals/Objectives) that will be formally presented to the Mars Exploration Program and leaders of the Science Mission Directorate (SMD); any and all mission concepts must fit within available resources and associated levels of acceptable risk as provided by the pre-project team.

The SDT report will be essential in formulating the HQ-approved set of 2020 Mars rover mission science goals and measurement objectives suitable for open solicitation via a NASA SMD Payload AO that is to be released for open competition in Summer 2013.

SDT Primary Assumptions and Guidelines

- The mission will launch in 2020.
- The total cost of the instruments has a nominal cost limit of ~$100M (including margin/reserves). This includes the development and implementation costs of US instruments (~$80M) and the estimated costs of any contributed elements (~$20M), but not including surface operations costs. The cost of science support equipment, such as an arm, is budgeted separately and not included in this ~$100M/$80M limit for instruments.
- The mission will employ Mars Science Laboratory (MSL) SkyCrane-derived entry, descent, and landing flight systems, and *Curiosity*-class roving capabilities. Consideration of the scientific value and cost implications of improving access to high-value science landing sites should be provided by the SDT in consultation with the pre-project team.
- The mission lifetime requirement is surface operation for one Mars year (~690 Earth Days).
- Mission pre-project activities will provide additional constraints on payload mass, volume, data rate, and configuration solutions that will establish realistic boundary conditions for SDT consideration.

SDT Charter Mission Objectives

A. Explore an astrobiologically relevant ancient environment on Mars to decipher its geological processes and history, including the assessment of past habitability and potential preservation of possible biosignatures.

B. *In situ science*: Search for potential biosignatures within that geological environment and preserved record.

C. Demonstrate significant technical progress towards the future return of scientifically selected, well-documented samples to Earth.

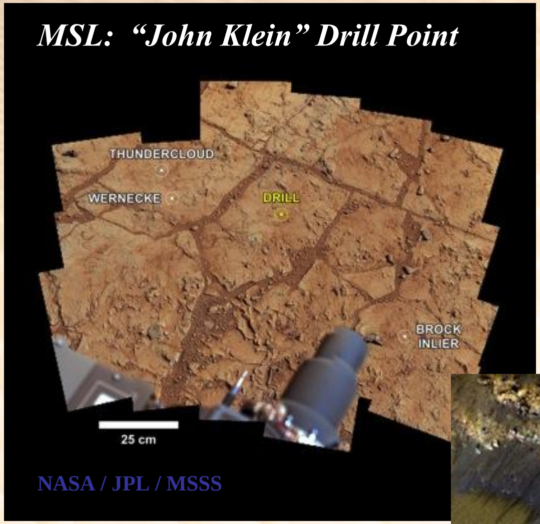
D. Provide an opportunity for contributed HEOMD or Space Technology Program (STP) participation, compatible with the science payload and within the mission's payload capacity.

SDT Roster

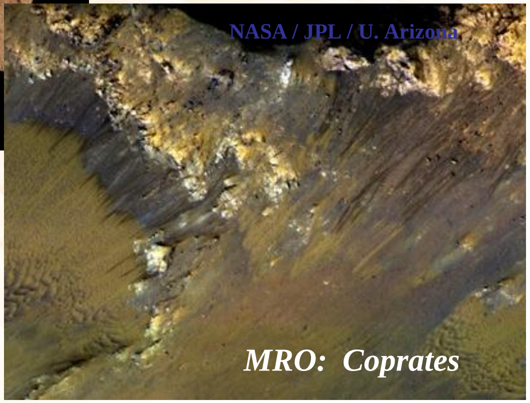
Chair	Professional Affiliation	Interest/Experience
Mustard, Jack	Brown University	Generalist, geology, Remote Sensing, MRO, MEPAG, DS, MSS-SAG
Allwood, Abby	JPL	Field astrobiology, early life on Earth, E2E-SAG, JSWG, MSR
Bell, Jim	ASU	Remote Sensing, Instruments, MER, MSL, Planetary Society
Brinckerhoff, William	NASA GSFC	Analytical Chemistry, Instruments, AFL-SGG
Carr, Michael	USGS, ret.	Geology, Hydrology, ND-SAG, E2E, P-SAG, Viking, MER, PPS
DesMarais, Dave	NASA ARC	Astrobio, field instruments, DS, ND-SAG, MER, MSL, MEPAG
Edgett, Ken	MSSS	Geology, geomorph, MPF, MER, MRO, MSL, MGS, cameras
Eigenbrode, Jen	NASA GSFC	Organic geochemistry, MSL, ND-SAG
Elkins-Tanton, Lindy	DTM, CIW	Petrology, CAPS, DS
Grant, John	Smithsonian, DC	geophysics, landing site selection, MER, HiRISE, E2E, PSS
Ming, Doug	NASA JSC	Geochemistry, MSL (CHEMIN, SAM), MER, PHX
Murchie, Scott	JHU-APL	IR spectroscopy, MRO (CRISM), MESSENGER, MSS-SAG
Onstott, Tullis	Princeton Univ	Geomicrobiology, biogeochemistry
Ruff, Steve	Ariz. State Univ.	MER, spectral geology, MGS (TES), MER, ND, E2E, JSWG
Sephton, Mark	Imperial College	Organics extraction and analysis, ExoMars, Astrobiology, E2E
Steele, Andrew	Carnegie Inst., Wash	astrobiology, meteorites, samples, ND-, P-SAG, AFL-SSG, PPS
Treiman, Allen	LPI	Meteorites, Samples, Igneous Petrology
Adler, Mark	JPL	Technology development, MER, MSR,
Drake, Bret	NASA JSC	System engineering, long-lead planning for humans to Mars
Ex-officio (n = 7)		
Meyer, Michael	NASA	Mars Lead Scientist
Mitch Schulte	NASA	Mars 2020 Program Scientist
George Tahu	NASA	Mars 2020 Program Executive
David Beaty	JPL	Acting Project Scientist, Mars Program Office, JPL
Deborah Bass	JPL	Acting Deputy Proj. Sci, Mars Program Office, JPL
Jim Garvin	NASA	Mars Program Scientist
Jorge Vago	ESA	ESA science representative
Michael Wargo	NASA	HEOMD representative
Supporting resources (n = 2)		
Wallace, Matt	JPL	engineering liason
Sarah Milkovich	JPL	SDT documentarian, logistics

Project Status

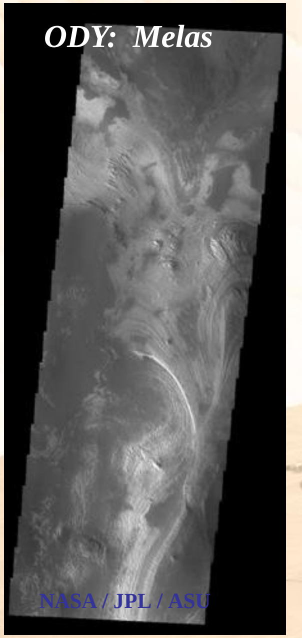
- *MAVEN:*
  - On schedule to launch this fall
  - Now in Environments Testing in Denver
- *MSL:*
  - Analyzing first drilled rock materials in Yellowknife Bay
- *MRO:*
  - Detecting new areas of Recurring Slope Lineae (RSLs), e.g., in Valles Marineris
  - SHARAD returning to operations
- *ODY:*
  - Successful transition to Side B
  - Continuing to fill gores in THEMIS coverage
  - Drifting to later local times
- *MEX:*
  - Finished period of good radar coverage (periapsis in the dark)
- *MER-B:*
  - Finishing Cape York survey
  - Preparing to start move to Solander Point



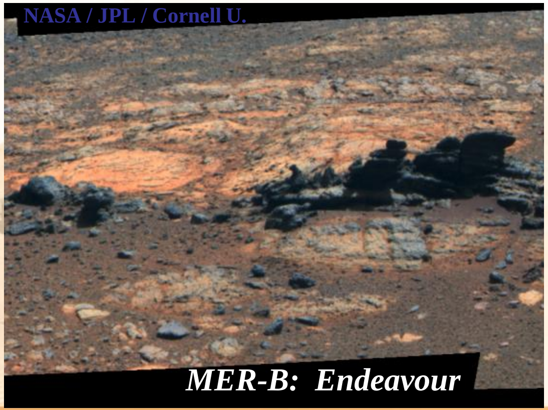
MSL: “John Klein” Drill Point



MRO: Coprates



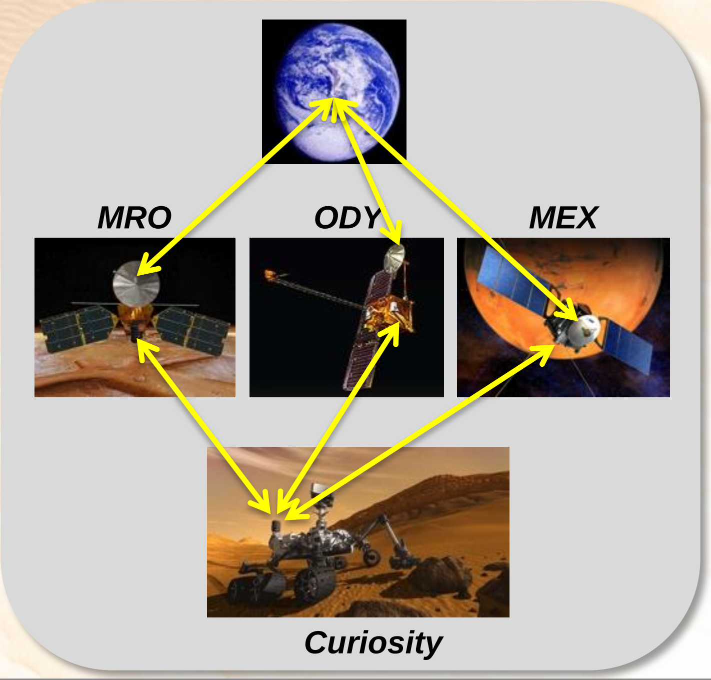
ODY: Melas

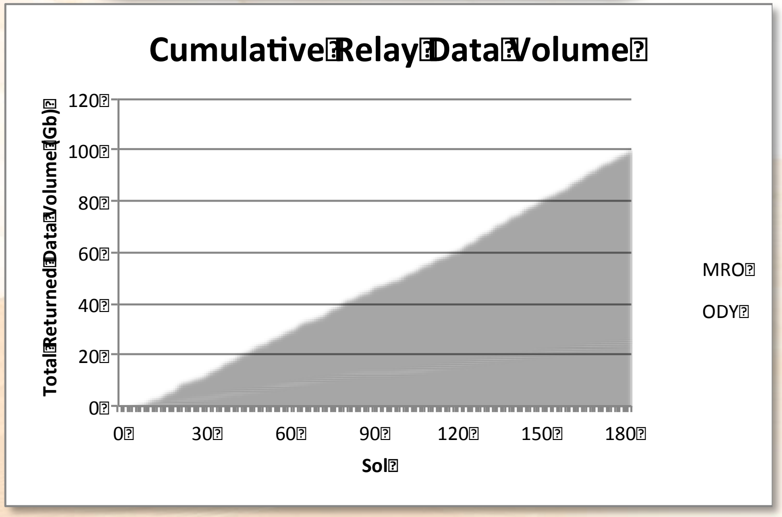


MER-B: Endeavour

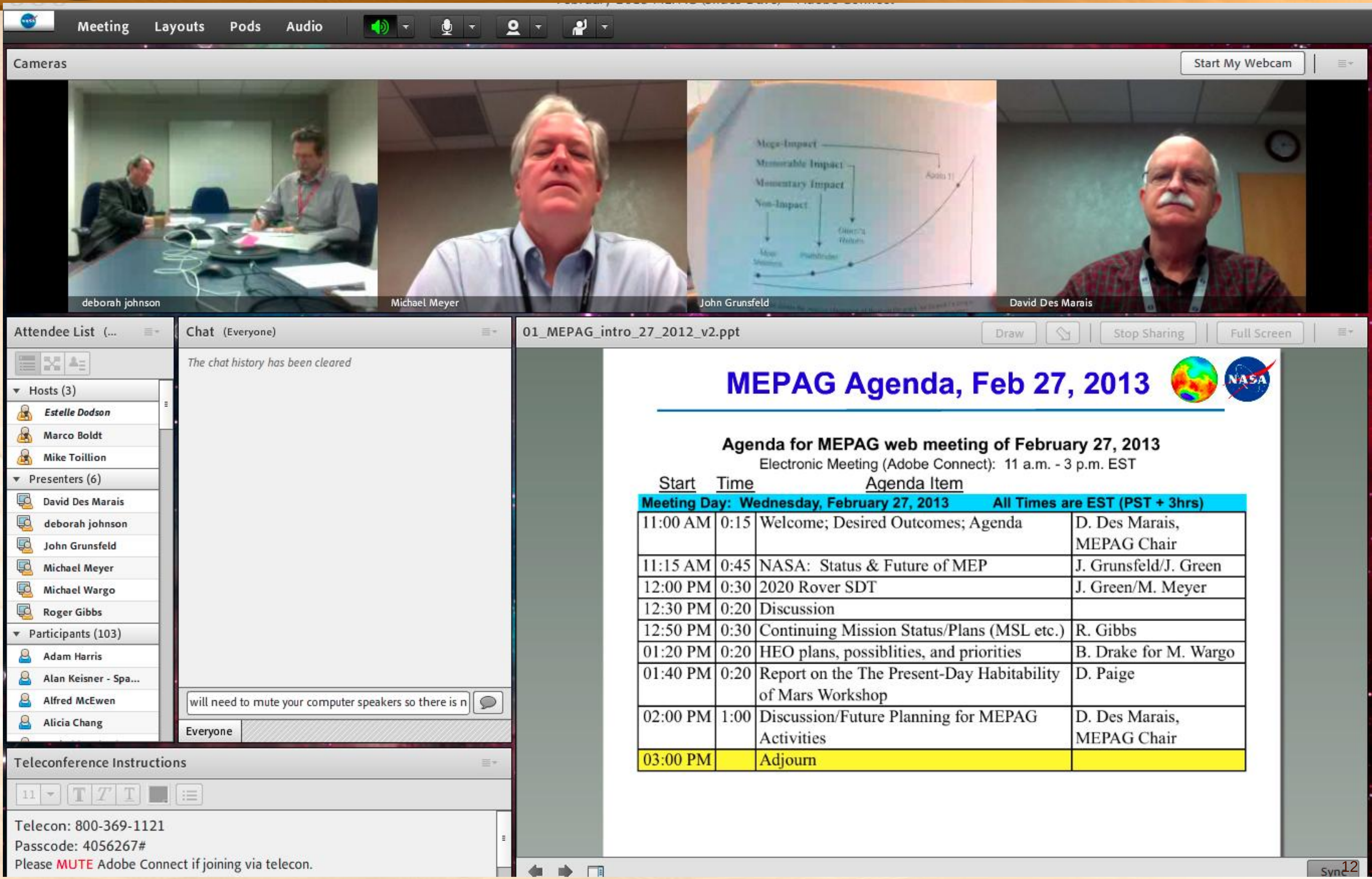
Mars Network Relay Performance

- Curiosity is returning large amounts of science data via an international network of Mars relay orbiters
  - Over **100 Gigabits** of data returned through Sol 184
  - Averaging over **550 Mb/sol**, well above MSL project requirements
- *MRO:*
  - High performance relay based on new Electra UHF Transceiver capabilities
- *ODY:*
  - Real-time data return during MSL EDL
  - Continues to serve as the workhorse relay orbiter for Opportunity
- *MEX:*
  - Tracking of MSL carrier during EDL
  - Backup relay asset for Curiosity surface ops – conducting monthly demonstration relay passes to verify MSL-MEX telemetry and command functions

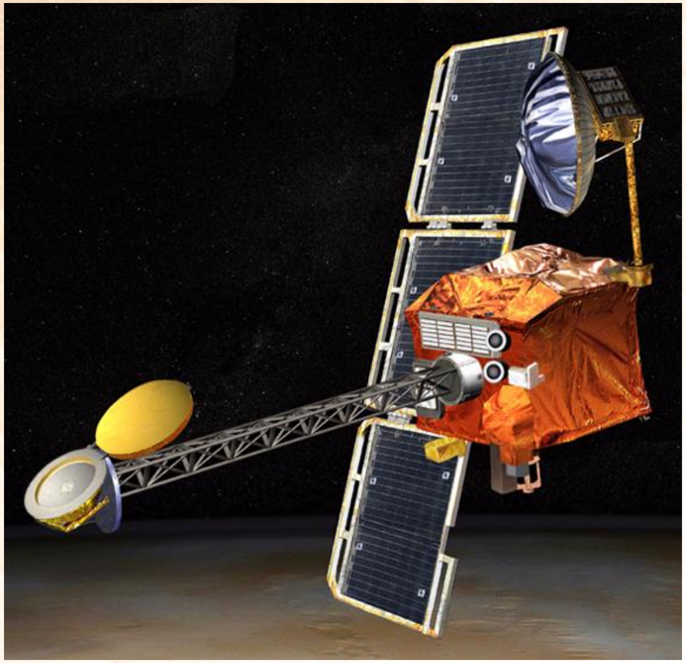




First All-Virtual MEPAG Meeting



Odyssey Project Overview



Salient Features:

Category: 2 Risk Class: B

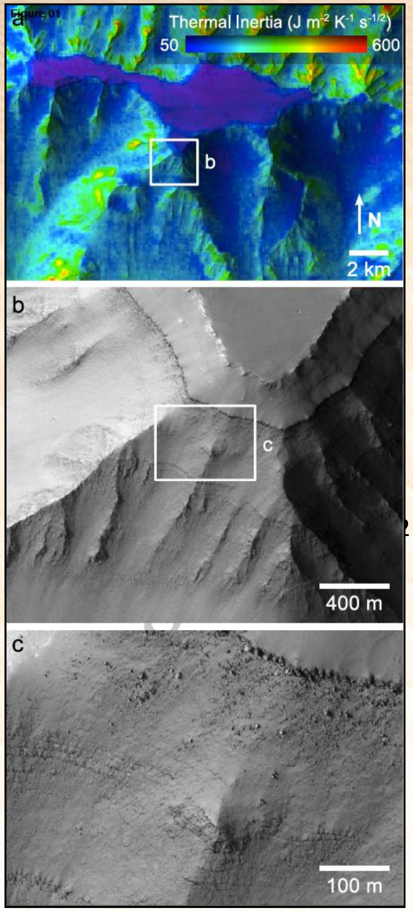
- Mars Orbiter Launched: April 7, 2001
- Science Mission Began: February 19, 2002
- Payload:
  - Thermal Emissions Imaging System (THEMIS)
  - Gamma-Ray Spectrometer (GRS)
  - High Energy Neutron Detector (HEND)
  - Neutron Spectrometer (NS)
  - Martian Radiation Environment Experiment (MARIE)
- Primary 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)

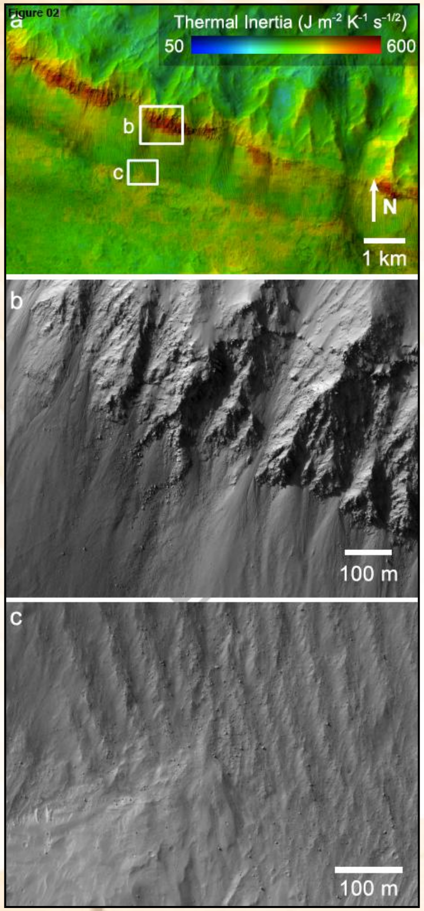
The Dual Nature of the Martian Crust: Young Lavas and Old Clastics

Visible and thermal infrared spacecraft datasets from Mars Odyssey and Mars Reconnaissance Orbiter are used to gain insight into the nature of the surface materials and upper Martian crust, revealing a distinct transition in the physical properties of Martian crustal materials that occurred during the Hesperian era. Contrary to a prevailing view of the Martian crust as primarily composed of lava flows, we find that most older regions of Mars have morphological and thermophysical properties consistent with poorly consolidated fine-particulate materials that may have a volcaniclastic origin. By contrast, younger surfaces contain blocky materials and thermophysical properties consistent with effusive lava flows. Explosive volcanism is likely to have been dominant on early Mars and these findings have implications for the evolution of the volatile content of the crust and mantle and subsequent development of the surface morphology. This dual nature of the crust appears to be a defining characteristic of Martian history.



(a) Thermal inertia data within Coprates Chasma derived from THEMIS data. Thermal inertia values remain low across the 4.5 km elevation range within the image. HiRISE images of layered exposures near the canyon rim(b) and (c). Although boulders are present near the top of the wall, they are not shed from lower layers and do not persist down slope, indicating that they are weakly consolidated and easily disaggregated.

millimeters



(a) Thermal inertia data near the base of Coprates Chasma derived from THEMIS data. Regions of high thermal inertia are similar to an extensive olivine-rich basalt layer. HiRISE images of (b) layered exposures and (c) boulders that have traveled to the base of the canyon wall. The high thermal inertia values and the persistence of boulders indicate that they are composed of well-consolidated and relatively high strength materials.

J. L. Bandfield, C. S. Edwards, D. R. Montgomery, B. D. Brand, 2012, *Icarus (in press)*.
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Odyssey Status

- The Odyssey spacecraft and its subsystems are performing nominally. Odyssey's science instruments (THEMIS, HEND & NS) are operating nominally.
- Development of a Stop-Gap Thruster Only mode continues. This contingency mode would be used if two reaction wheels failed.   The Project is on track to complete this development in late-March.
- The journal Science announced that the student-focused Mars Student Imaging Project (MSIP) based at Arizona State University was awarded the Science Prize for Inquiry-Based Instruction.
- Odyssey's next Project Science Group (PSG) meeting is tentatively scheduled for 8 May 2013 at JPL.

Students collaborating on Mars image analysis activity (phase 1 of the Mars Student Imaging Project).

S Klug Boonstra, and P Christensen
Science 2013;339:920-921

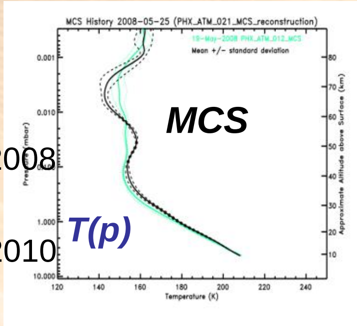
Published by AAAS

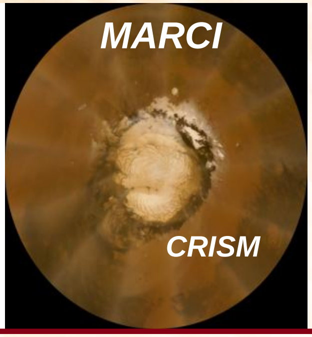
Science AAAS

MRO Project Overview

MRO Mission Overview (2006-2012)

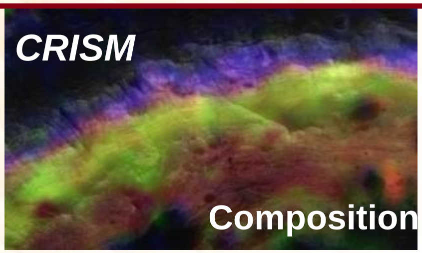
- **Category: II, Risk Class: B**
- Mission Phases
  - Primary Science Phase (PSP): November 2006 to November 2008
  - PHX critical event (EDL) coverage: May, 2008
  - Extended Science Phase (ESP): December 2008-September 2010
  - Extended Mission Phase: October 2010 to September 2012





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.

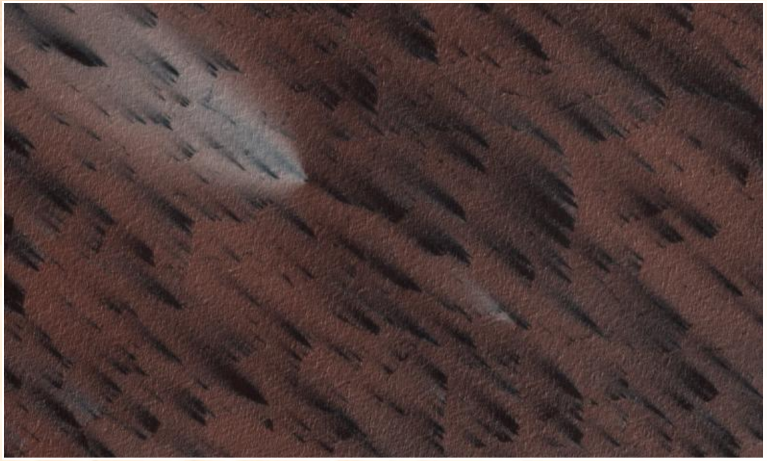
MRO Status

- This was the first week of southern summer on Mars. The MRO spacecraft and its subsystems are performing nominally. All instruments, except SHARAD, are on and acquiring data. The planned SHARAD power on and return to science was delayed by one week to avoid any potential conflict with relay data return during the MSL anomaly investigation. UHF relay support with MSL and MER continues nominally, except for some unfortunate data dropouts due to adverse weather at the DSN. The average MSL data volume returned per pass through the Electra UHF link is 245 Mbits.
- The upload of MSL flight Software Load R10.6.3 through the MRO Electra UHF link was completed.
- The CRISM (cold) focus cycle continues, with a CRISM limb scan planned for next week. CRISM switched from cooler 2 to cooler 3, to get to operating temperatures with good signal to noise in the present warm environment (which occurs in the seasons around Mars perihelion).

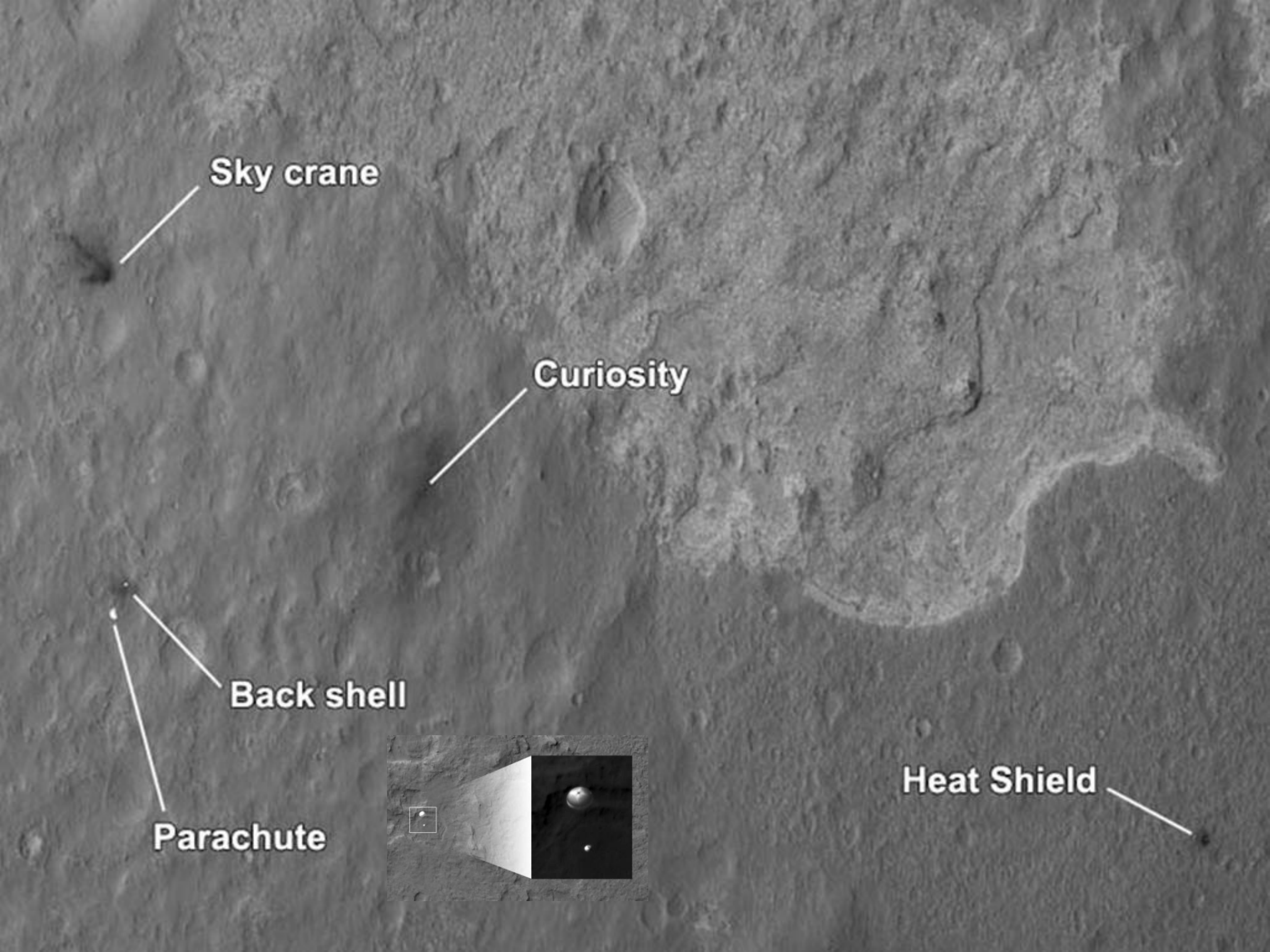
Tens of Thousands of Citizens of Planet Earth Classify Images of Spring on Mars

- Every spring Mars' polar regions are covered with a seasonal layer of frozen CO_2 (dry ice)
- As the ice sublimes in the spring, gas escaping from below the ice carries fine material from the ground up to the top of the ice where it falls into fan-shaped deposits directed by the ambient wind
- These fans are markers for where the seasonal ice cracked and which way the wind was blowing at the time
- The timing, distribution, direction and length of the fans are an important data source for understanding seasonal processes and the martian weather, but there are so many fans that the science team is relying on the public to help with the data analysis

2 millimeters

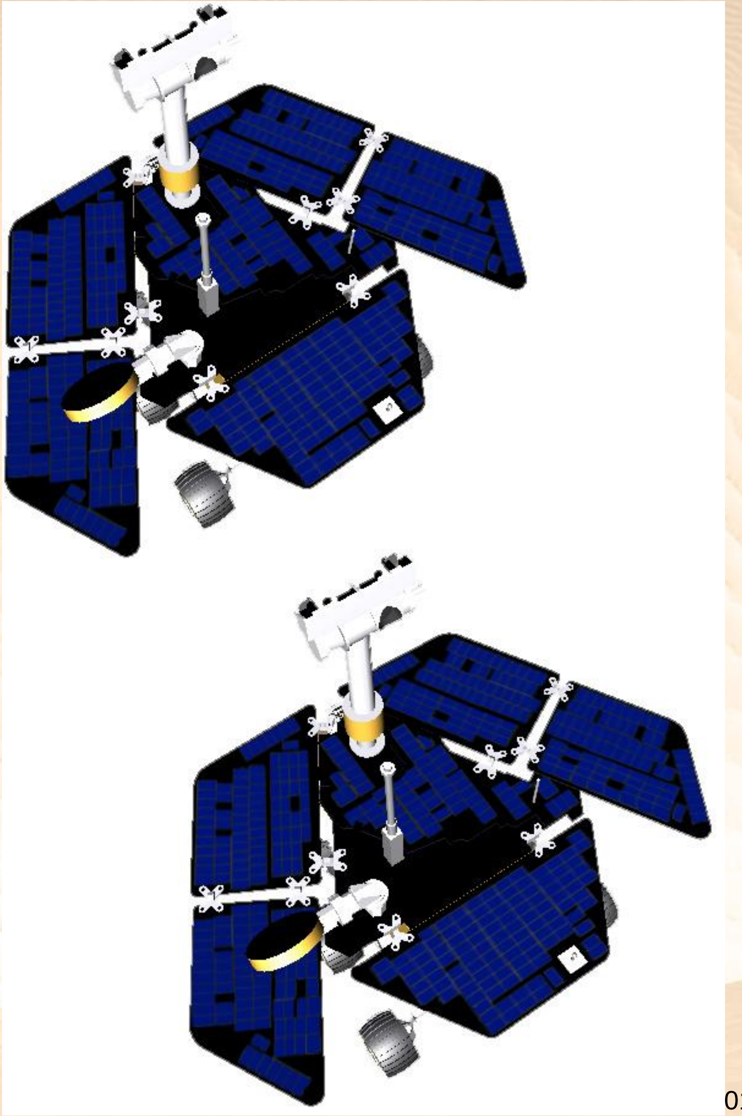


- To that end the Zooniverse project has set up a website, planetfour.org, for citizen scientists to contribute their time to identify and measure fans
- Volunteers are currently locating fans imaged by the HiRISE camera on the Mars Reconnaissance Orbiter, in the second and third springs – soon springs 1 and 4 will be added to the data set
- This is a dynamic (ongoing) project, but a snapshot on January 17, 2013 shows that over 59,000 people have participated and nearly 3 million image tiles have been analyzed



Sky crane
Curiosity
Back shell
Parachute
Heat Shield

Mars Exploration Rover



Spirit at Gusev

Last Contact Sol 2210

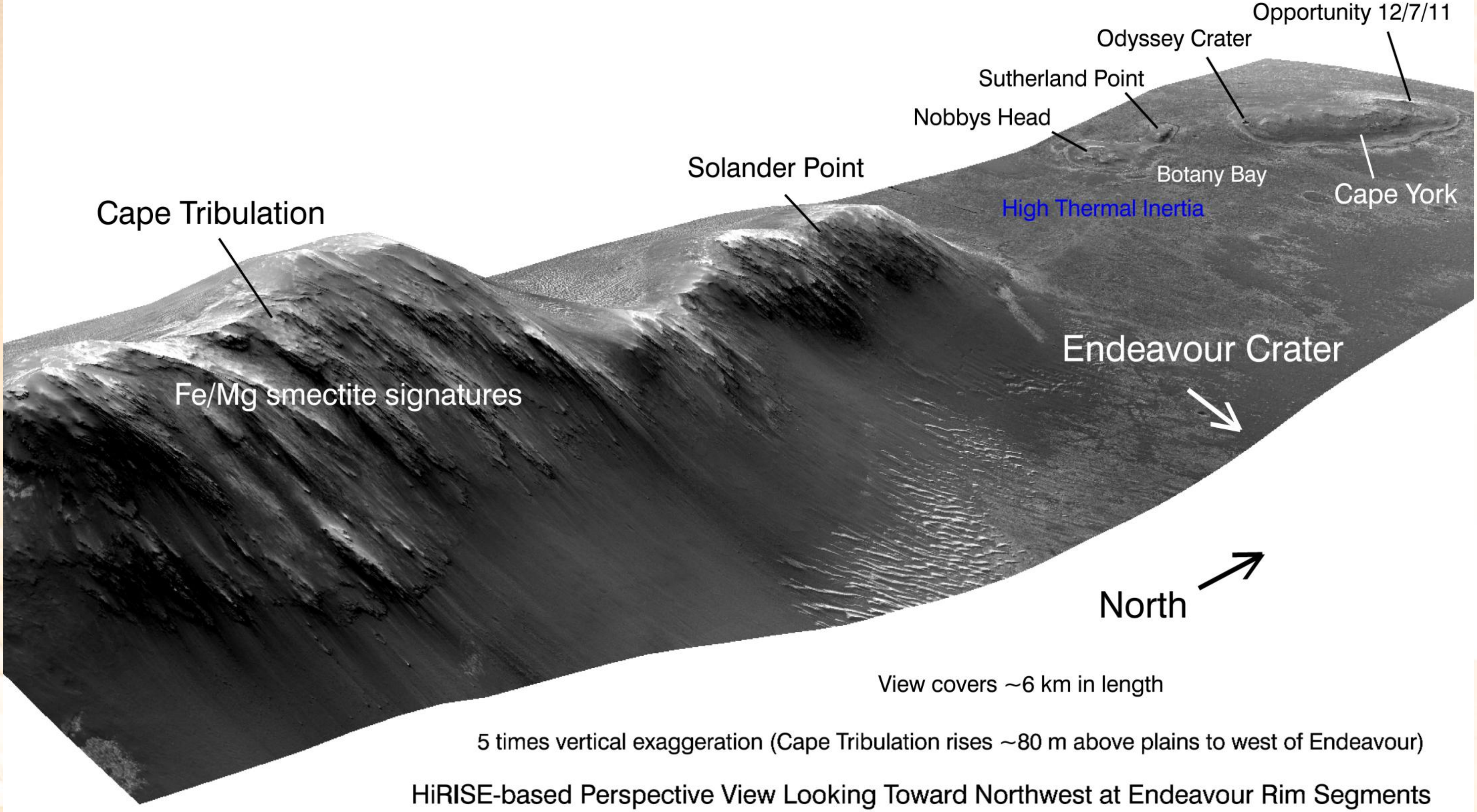
7.730 km

Opportunity at Meridiani

Sol 3241

Opportunity has exceeded 35 kilometers!

Endeavour Rim Perspective



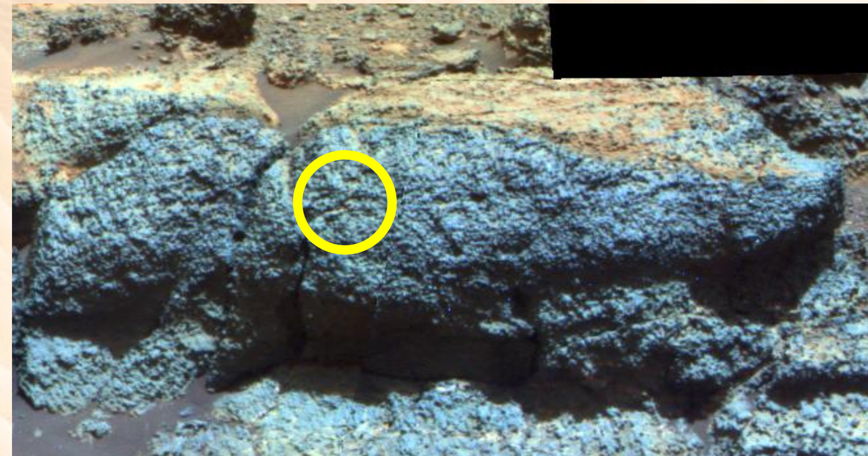
View covers ~6 km in length

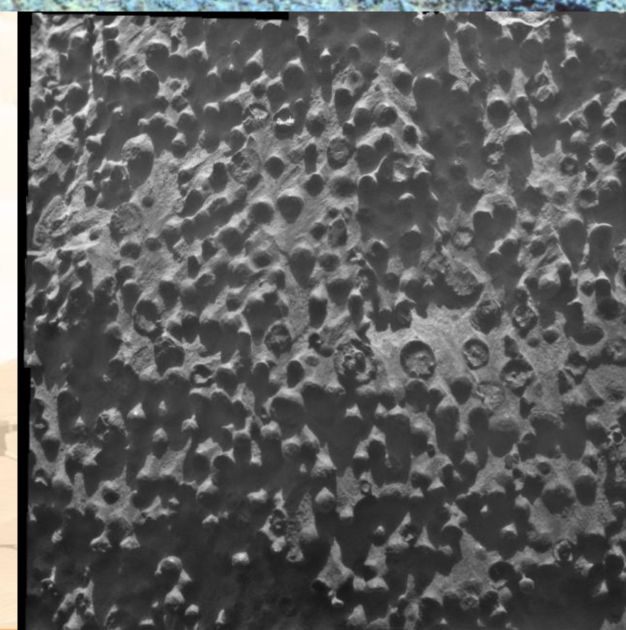
5 times vertical exaggeration (Cape Tribulation rises ~80 m above plains to west of Endeavour)

HiRISE-based Perspective View Looking Toward Northwest at Endeavour Rim Segments

Mars Exploration Rover Opportunity

Opportunity began its 10th year of operation on Mars in January 2013 and is currently exploring the area of Endeavour crater known as Matijevic Hill where it recently documented the discovery of rocks with unusual textures, similiar to the 'blueberries' discovered earlier, but with a very different composition and likely a different origin.





The MER team is currently making plans to suspend science operations during the upcoming conjunction period and to drive south to Solander Point on the rim of Endeavour Crater. There, Opportunity will be in terrain favorable for surviving the upcoming martian winter...the rover's 6th on Mars!

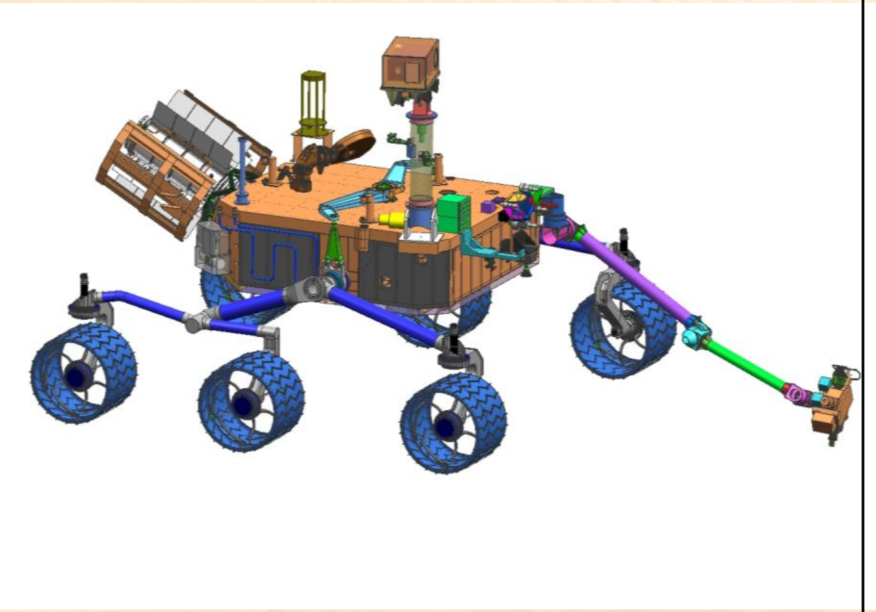
Opportunity Status

- Opportunity is conducting the post-walkabout in-situ (contact) science campaign at different locations around the inboard edge of Cape York on the rim of Endeavour Crater. Some in-situ work with a target called "Lihir" in the area are planned with the instruments on the end of the robotic arm.
- No "amnesia" events with the Flash file system have occurred since Sol 3183 and the rover is otherwise in good health.

- Total odometry as of Sol 3241: 35582 meters

Mars Science Laboratory Project Overview

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

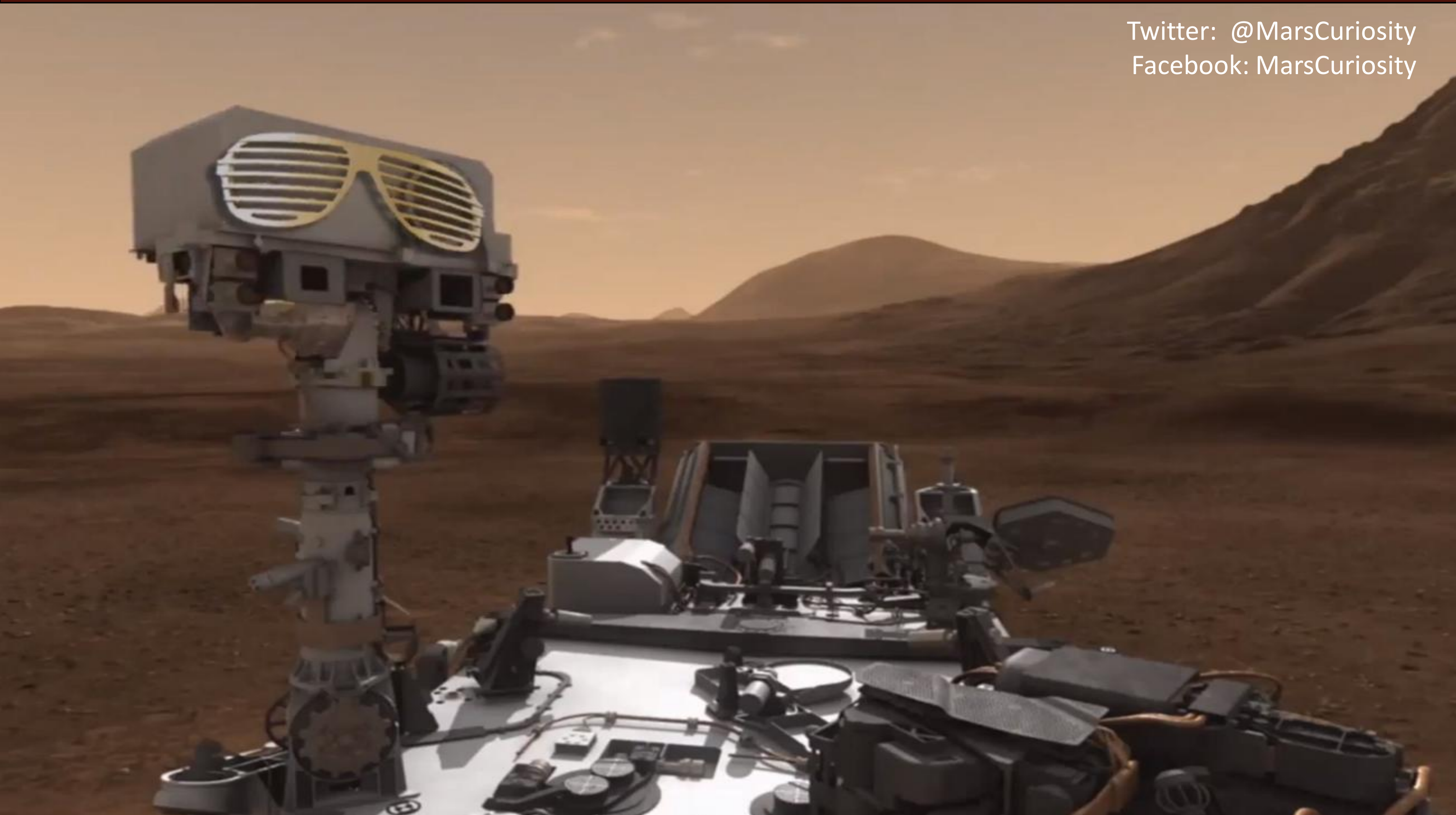


<u>Technical Capabilities</u>
Category 1
Risk Class A
One Mars Year surface operational lifetime (669 sols/687 days)
Discovery Responsive over wide range of latitudes and altitudes
Precision Landing via Guided Entry
Skycrane Propulsive Landing
Long Distance Traverse Capability (20 km)
Flexible & Robust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

I'm Curiosity…

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

Twitter: @MarsCuriosity
Facebook: MarsCuriosity



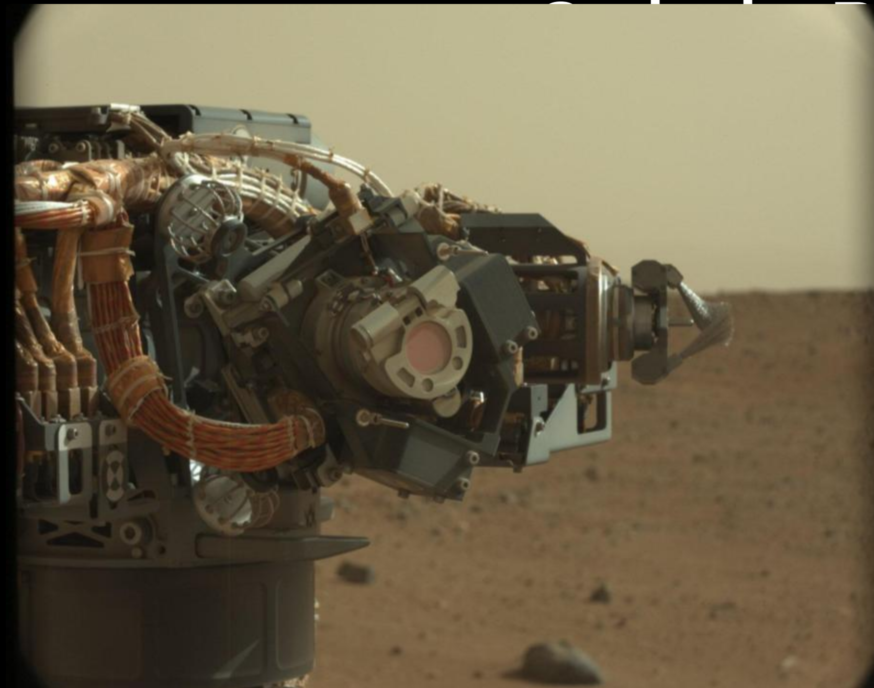
Credit: YouTube/Satire

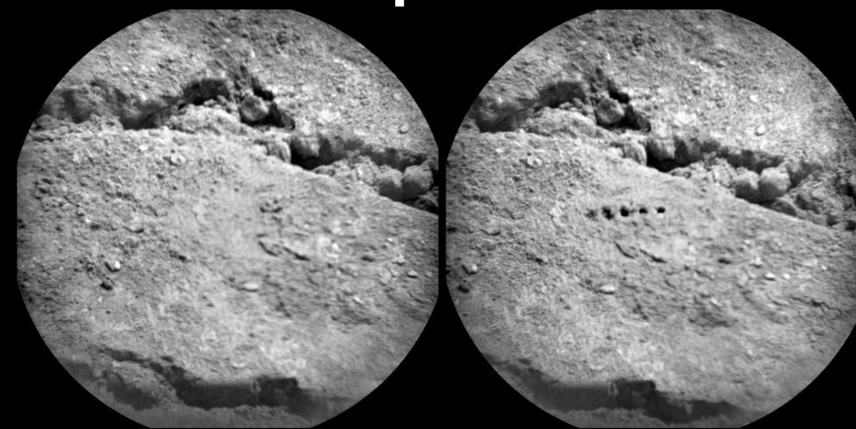
…and I know it!

Recent Accomplishments

- **Landing**
- Evidence of ancient riverbed
- Initial results presented at AGU
- All First time activities accomplished, including first time drill sample and analysis on another planet
- Currently exploring Yellowknife Bay

ecent Accomplishments

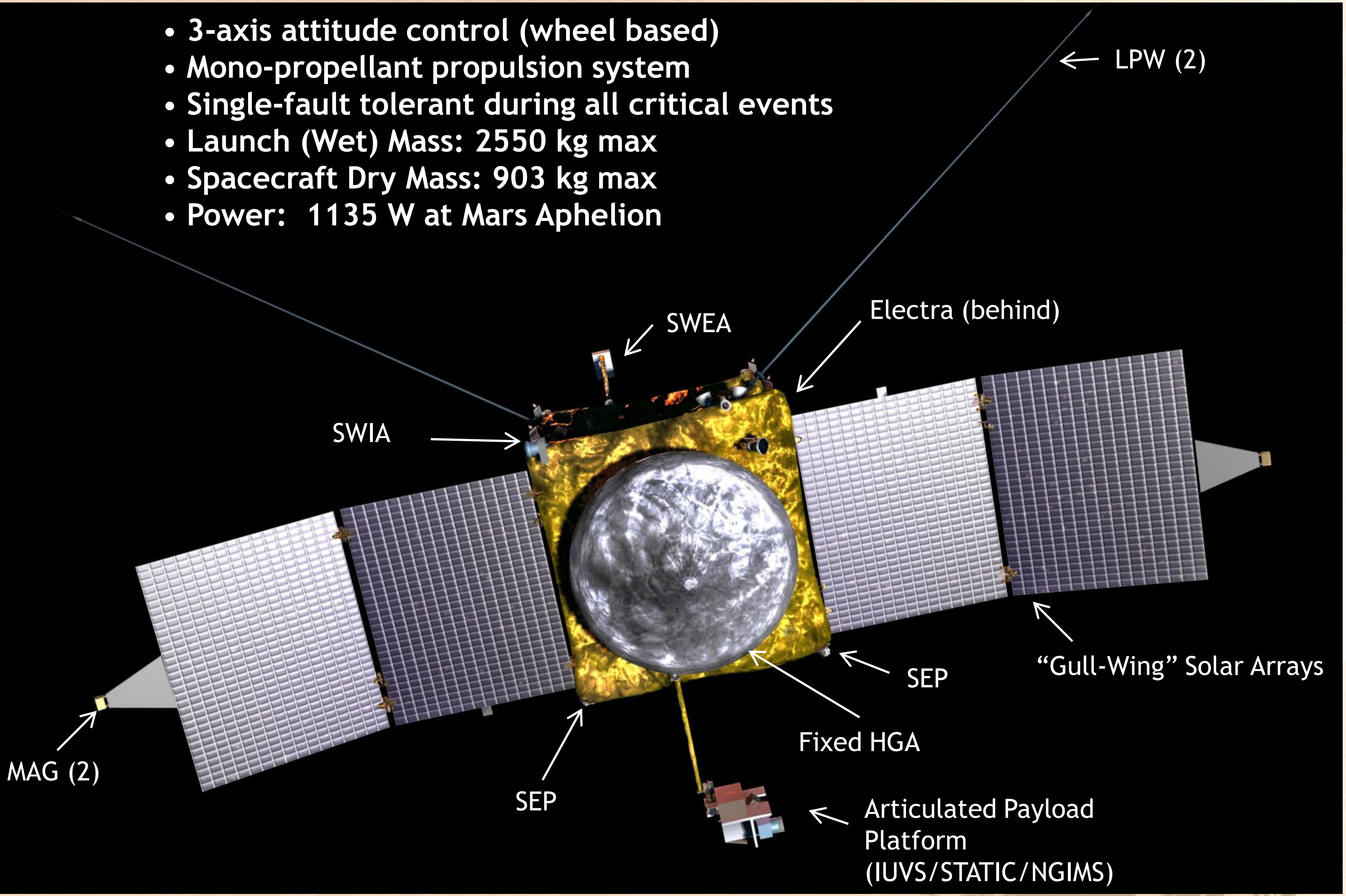




Images from Curiosity

The MAVEN Spacecraft

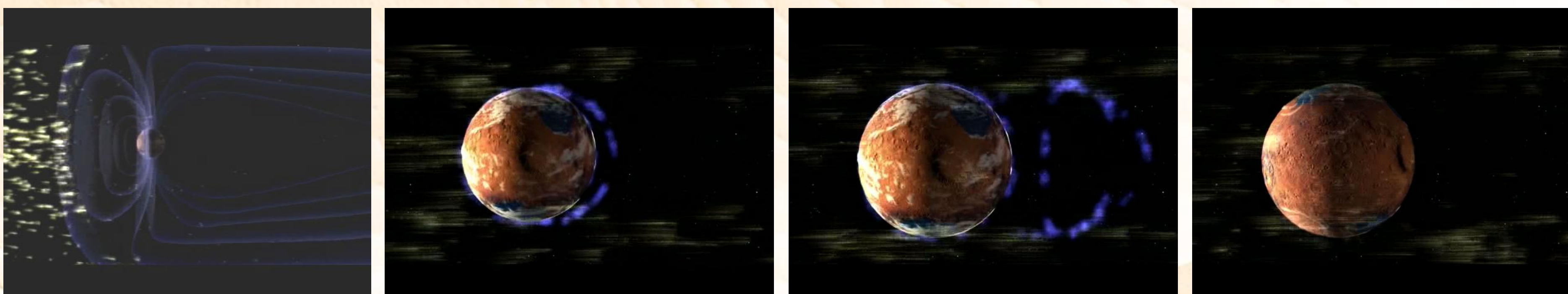
- 3-axis attitude control (wheel based)
- Mono-propellant propulsion system
- Single-fault tolerant during all critical events
- Launch (Wet) Mass: 2550 kg max
- Spacecraft Dry Mass: 903 kg max
- Power: 1135 W at Mars Aphelion



What Will MAVEN Do?

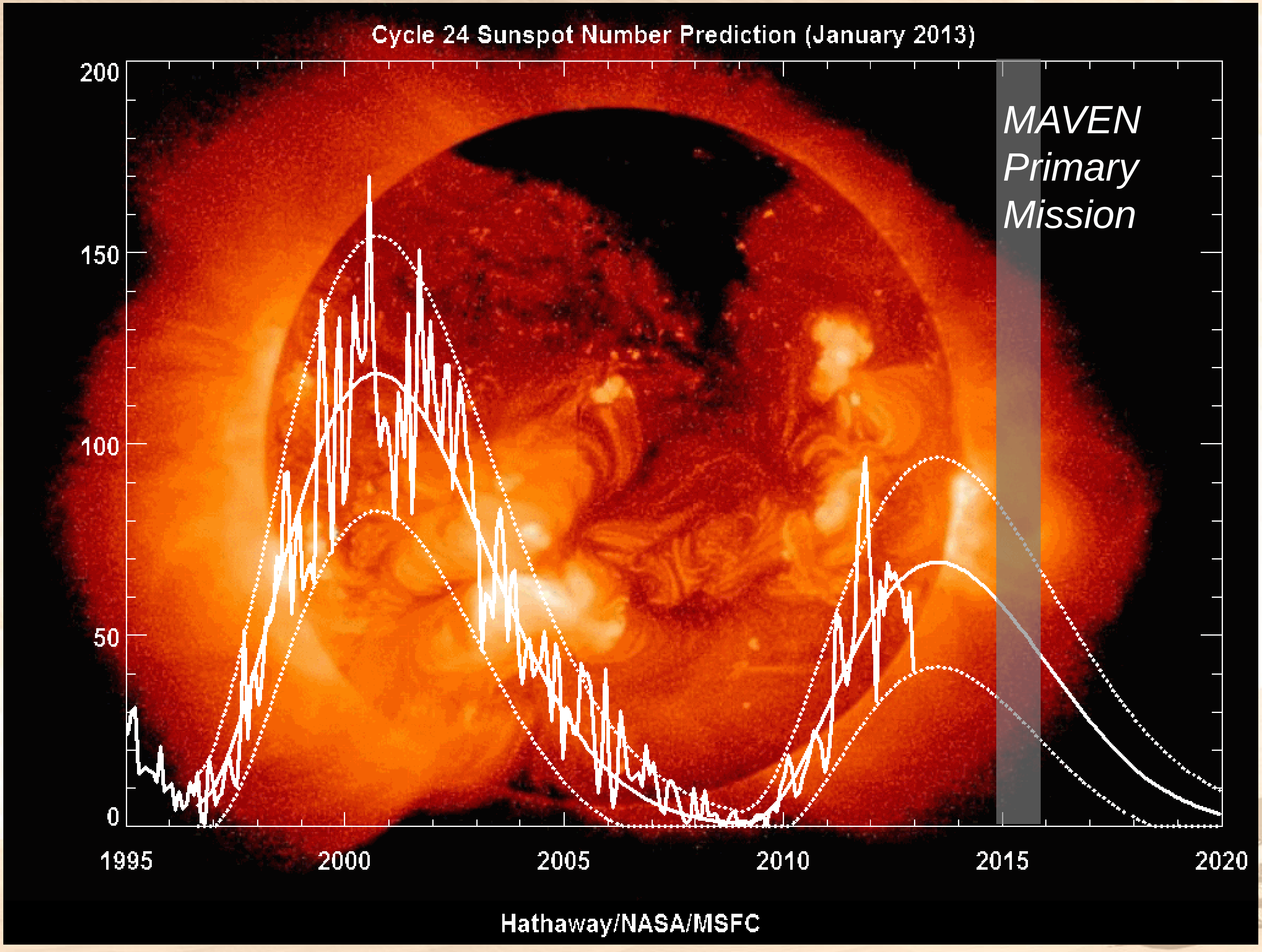
MAVEN will answer questions about the history of Martian volatiles and atmosphere and help us to understand the nature of planetary habitability.

- 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



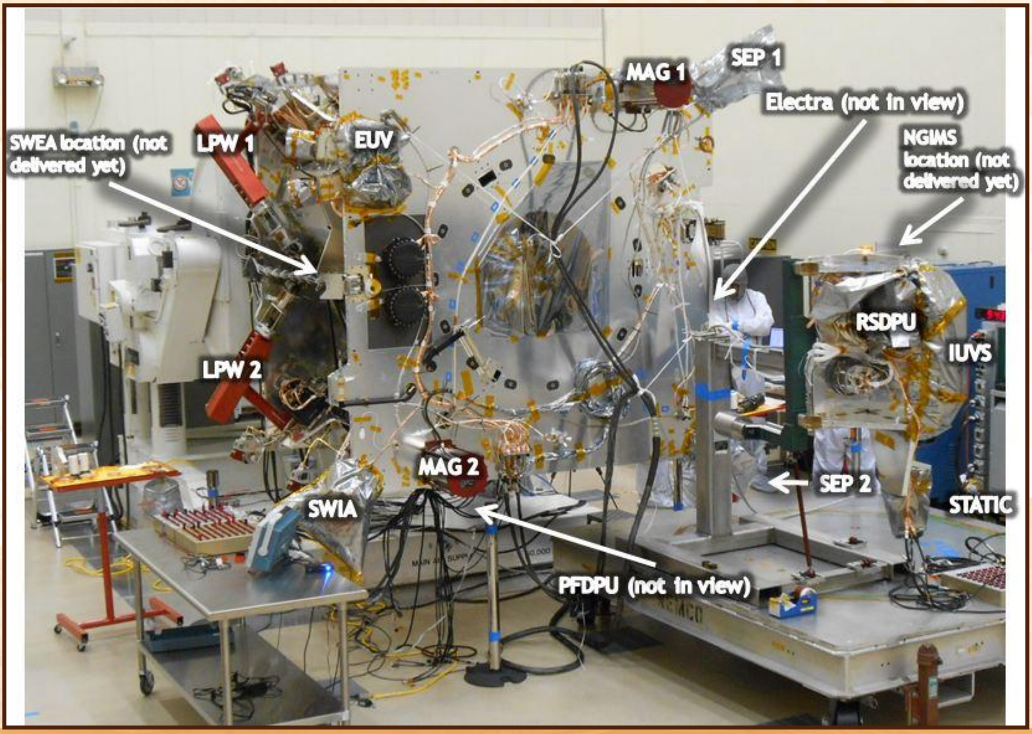
Turn-off of the Martian magnetic field allowed turn-on of solar-EUV and solar-wind stripping of the atmosphere approximately 3.7 billion years ago, resulting in the present thin, cold atmosphere.

MAVEN's Timing in the Solar Cycle

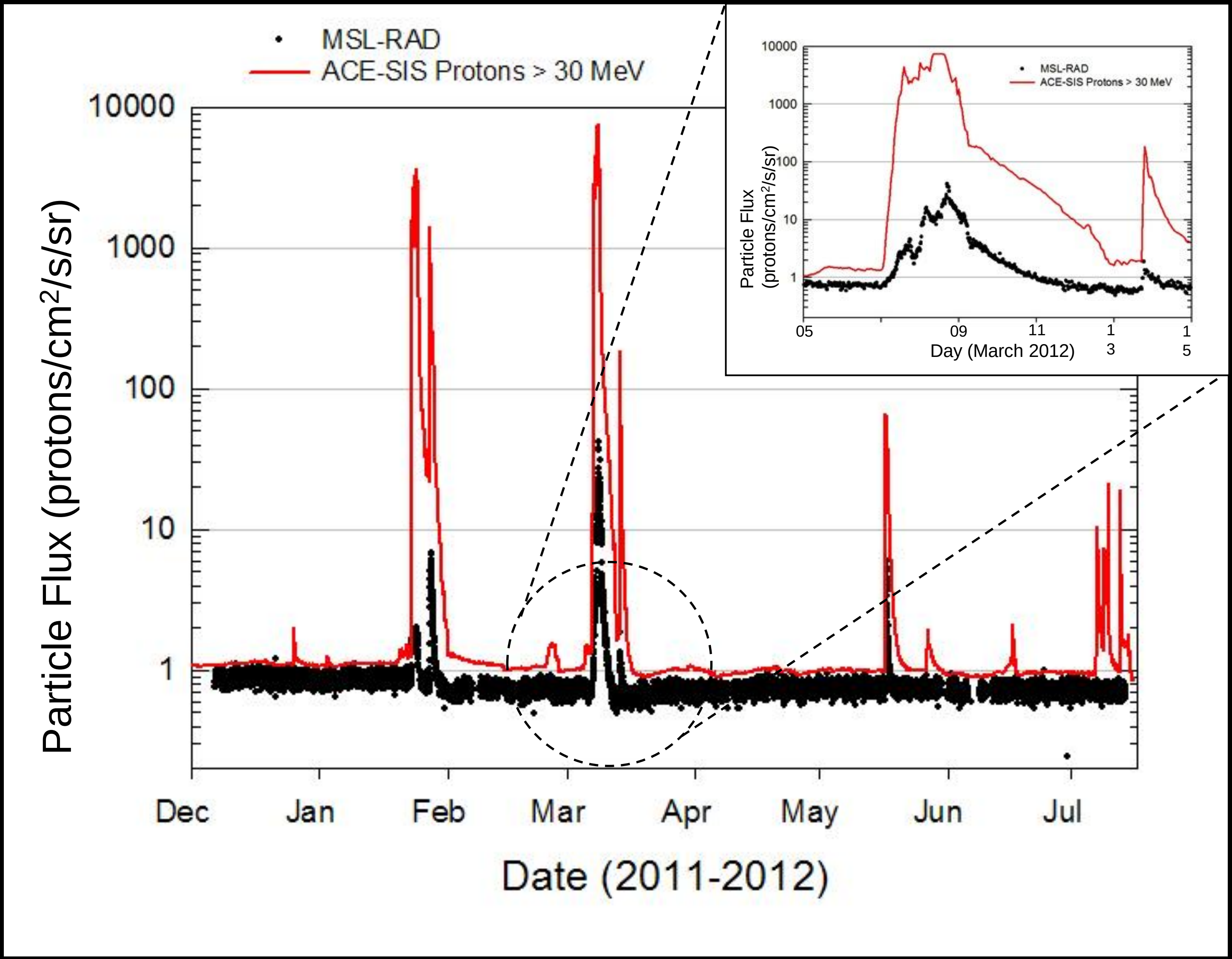


MAVEN in ATLO

- Eight of ten payloads integrated.
  - SWEA shipping this week
- Testing
  - Magnetic swing, modal survey and acoustics complete
  - Sine-vibe in progress
- On track for August ship to CCAFS



MAHLI
Self Portrait



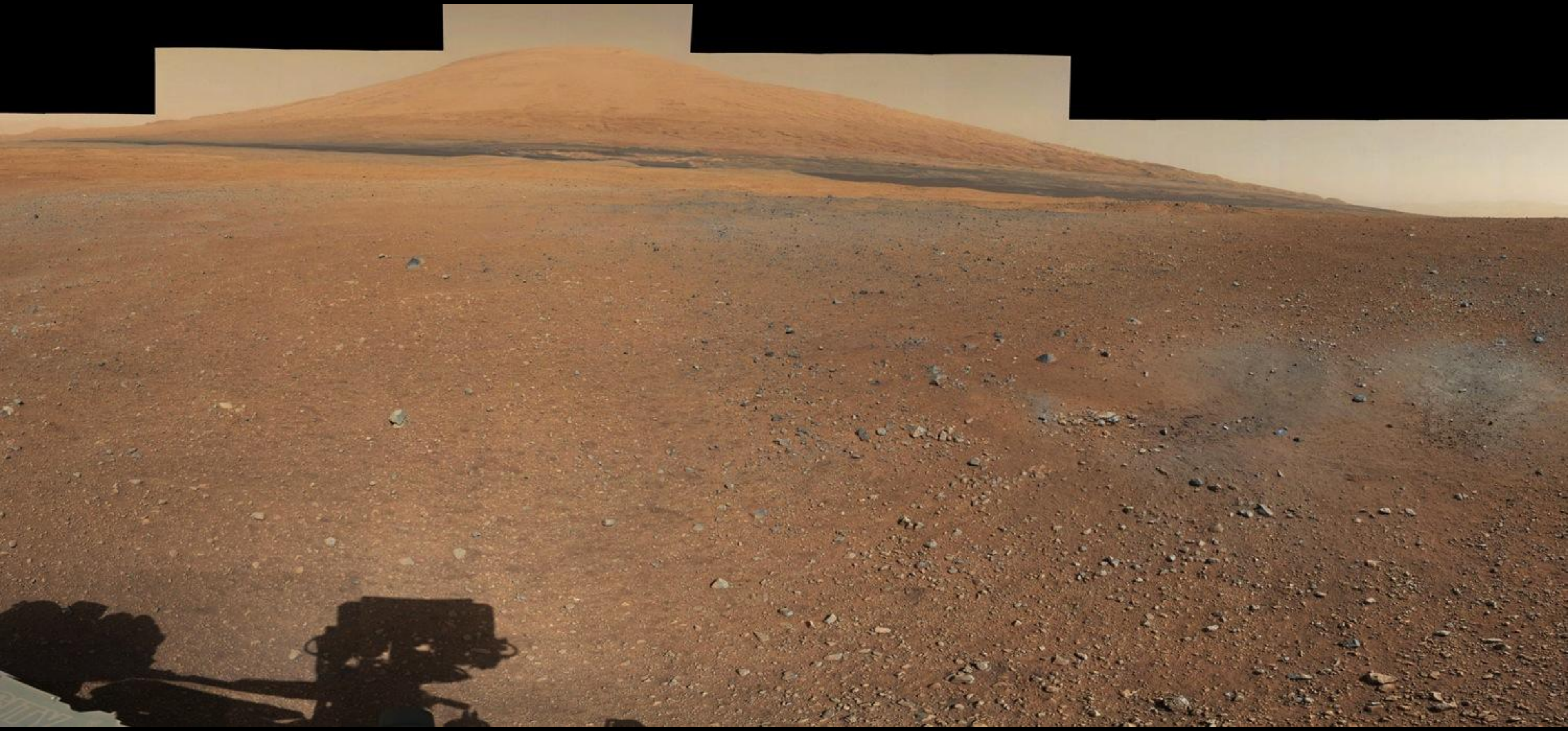
RAD observed galactic cosmic rays and five solar energetic particle events

RAD was shielded by the spacecraft structure, reducing the observed particle flux relative to NASA's ACE satellite

RAD is now collecting the first measurements of the radiation environment on the surface of another planet

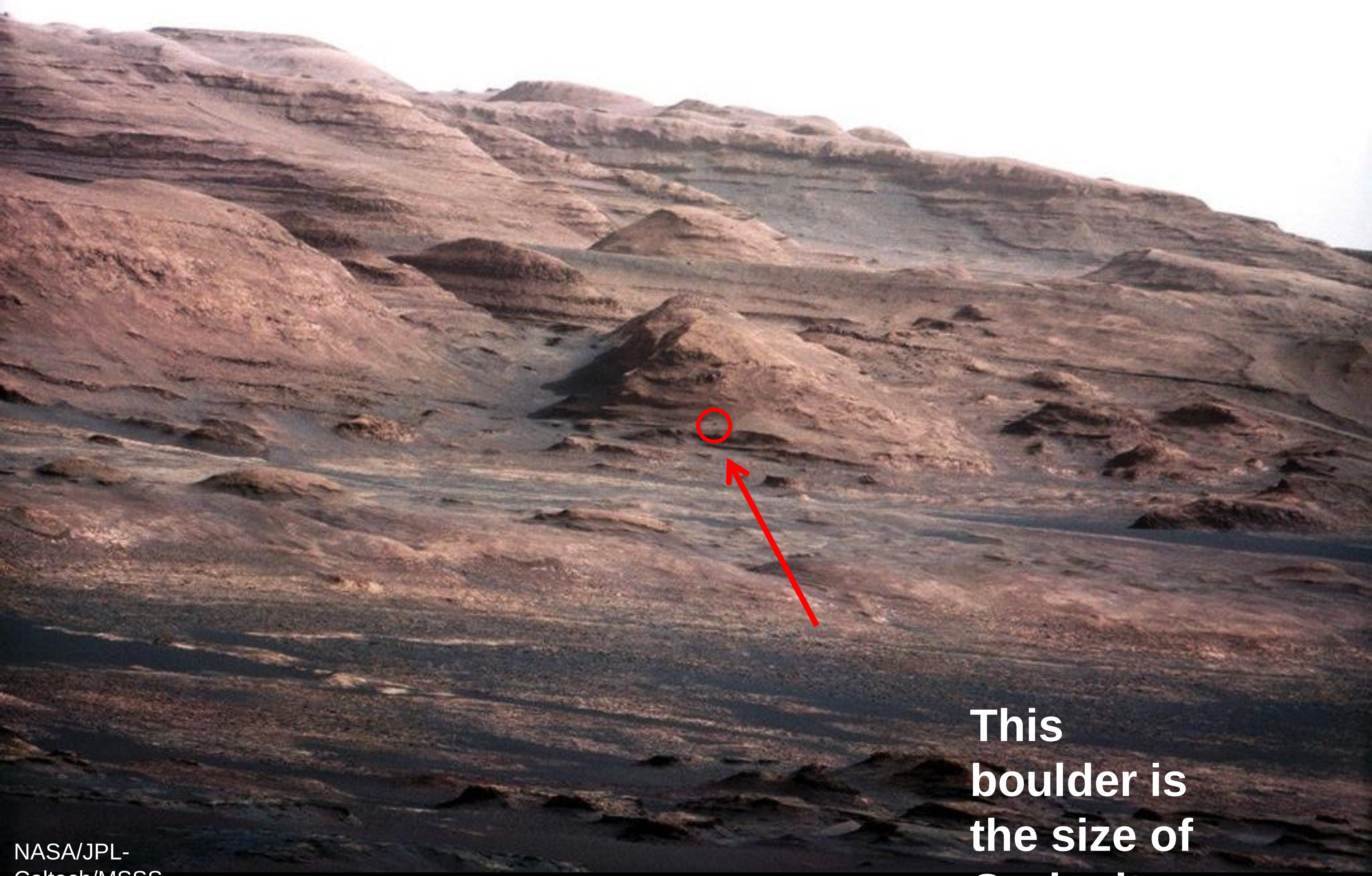
NASA/JPL-Caltech/SwRI

Curiosity's Radiation Assessment Detector operated throughout the cruise to Mars



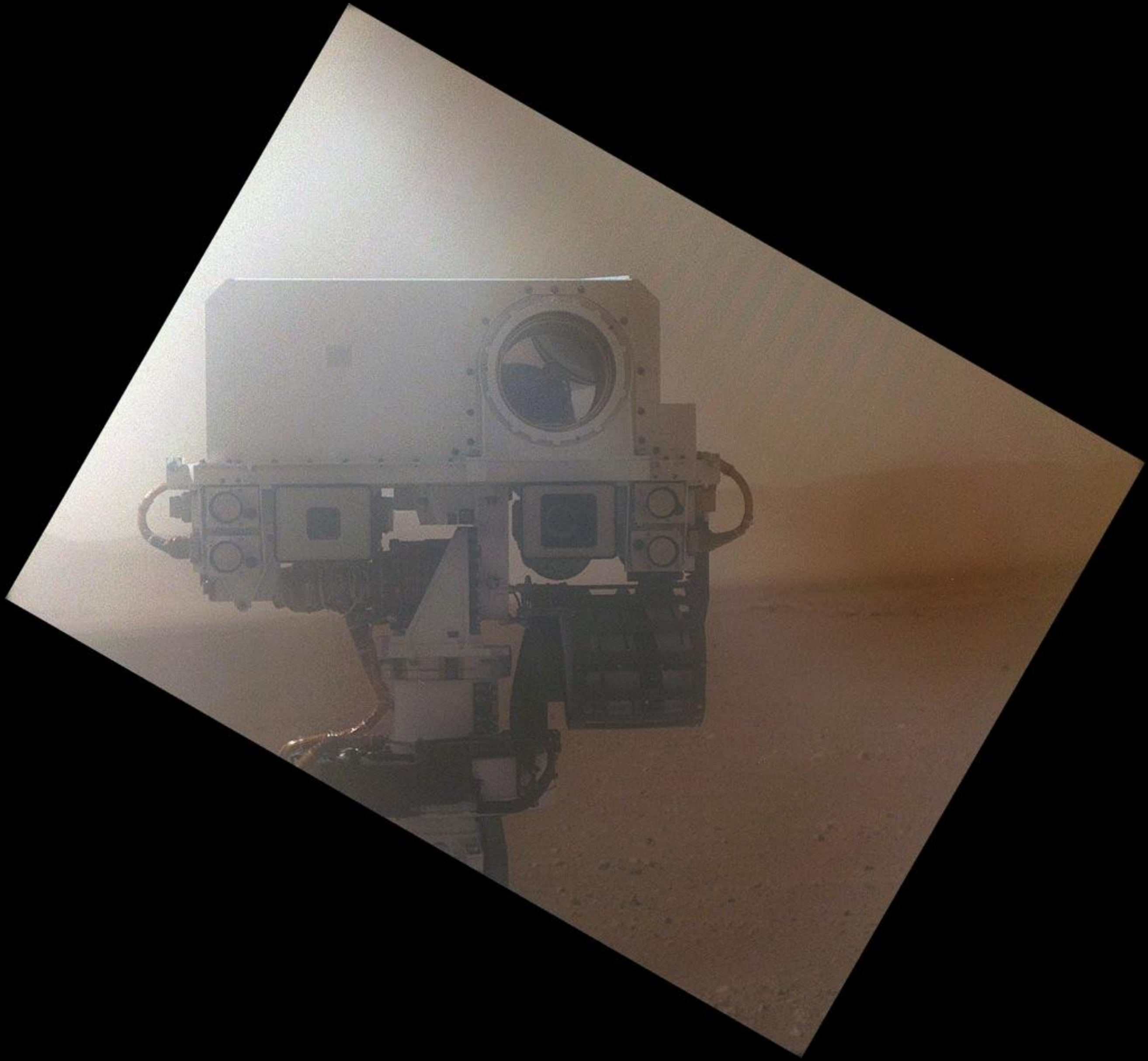
NASA/JPL-
Caltech/MSSS

Mastcam-34 mosaic of Mount Sharp, descent rocket scours, and rover shadow



CURIOSITY

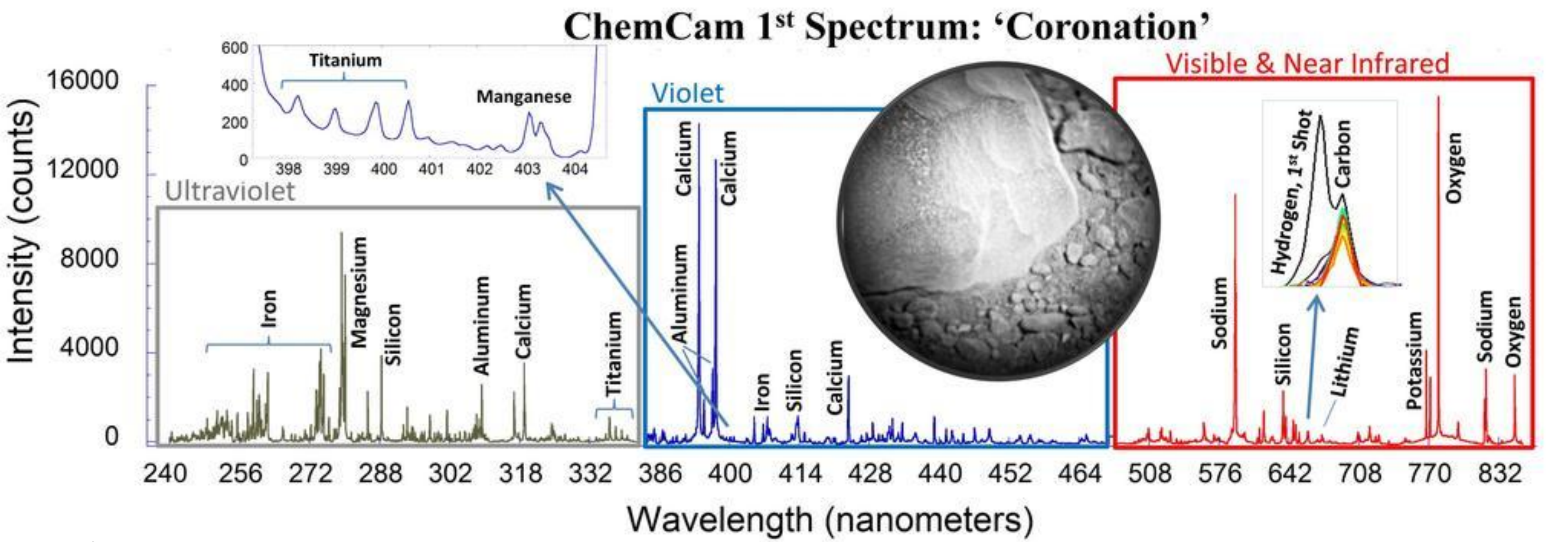
Mastcam-100 image of Mount Sharp's layers, canyons and buttes



NASA/JPL-
Caltech/MSSS

CURIOSITY

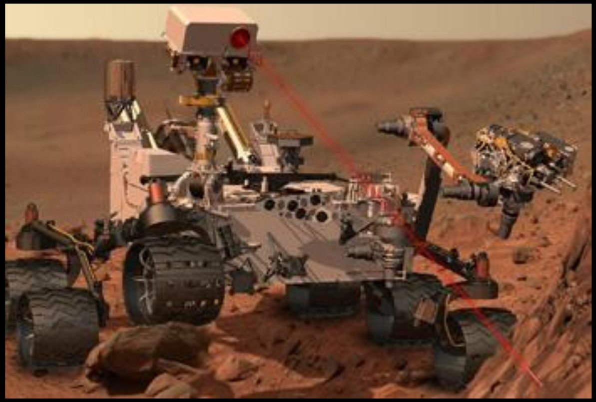
Curiosity self-portrait using the arm-mounted Mars Hand-Lens Imager, through dust cover

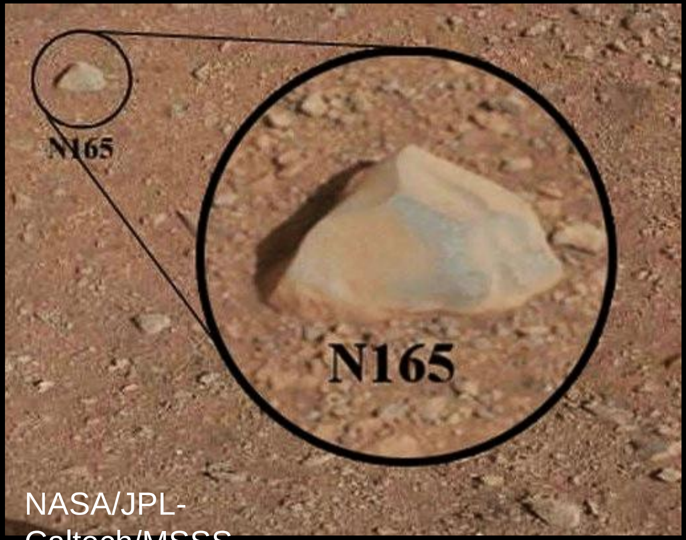


NASA/JPL-

ChemCam spectra of Coronation

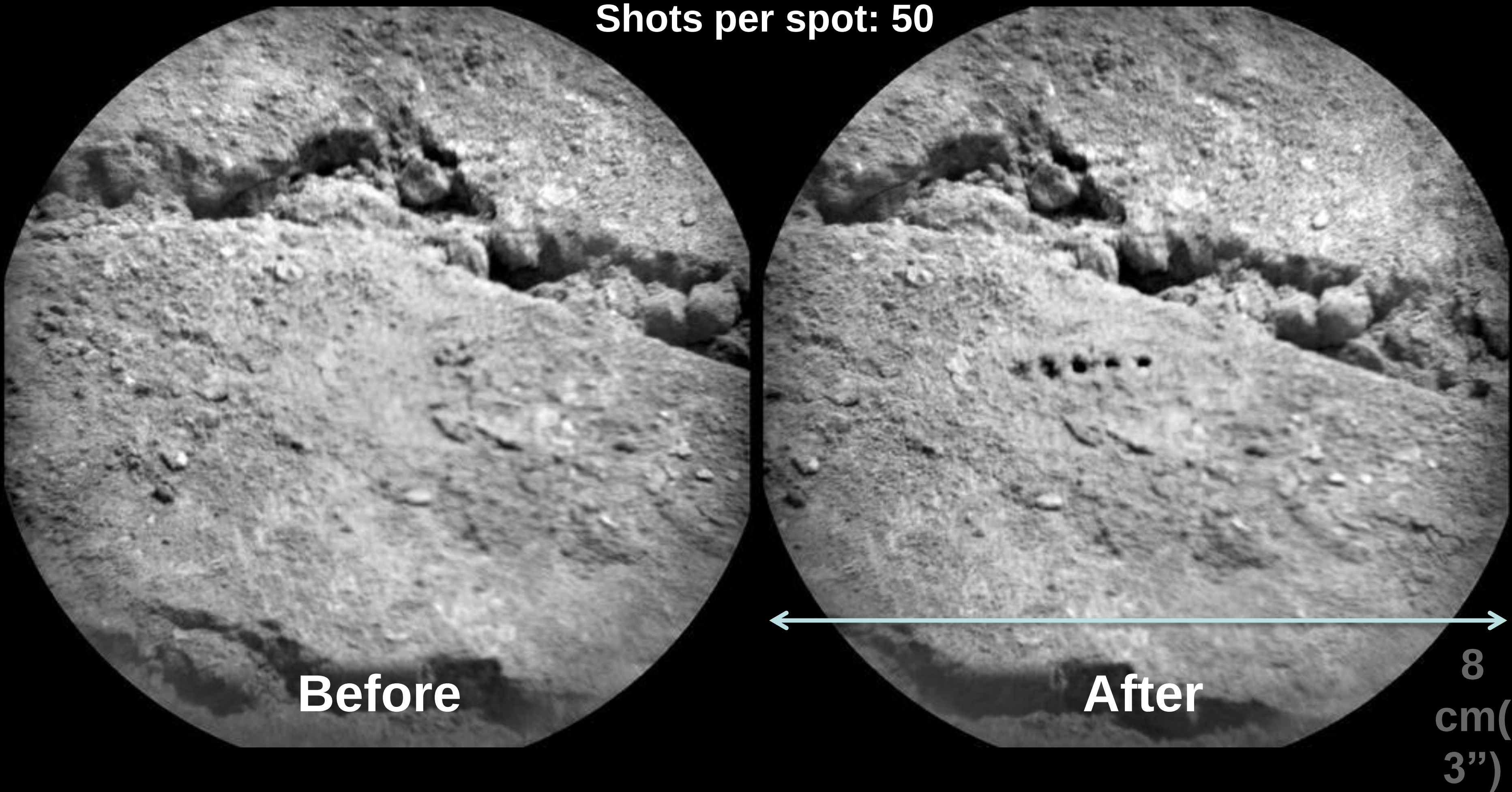
Target: Coronation (N16
Sol 13
Shots: 30





NASA/JPL-Caltech/MSSS

Target: Beechey (Sol 19)
Power: 1 Gigawatt
Shots per spot: 50



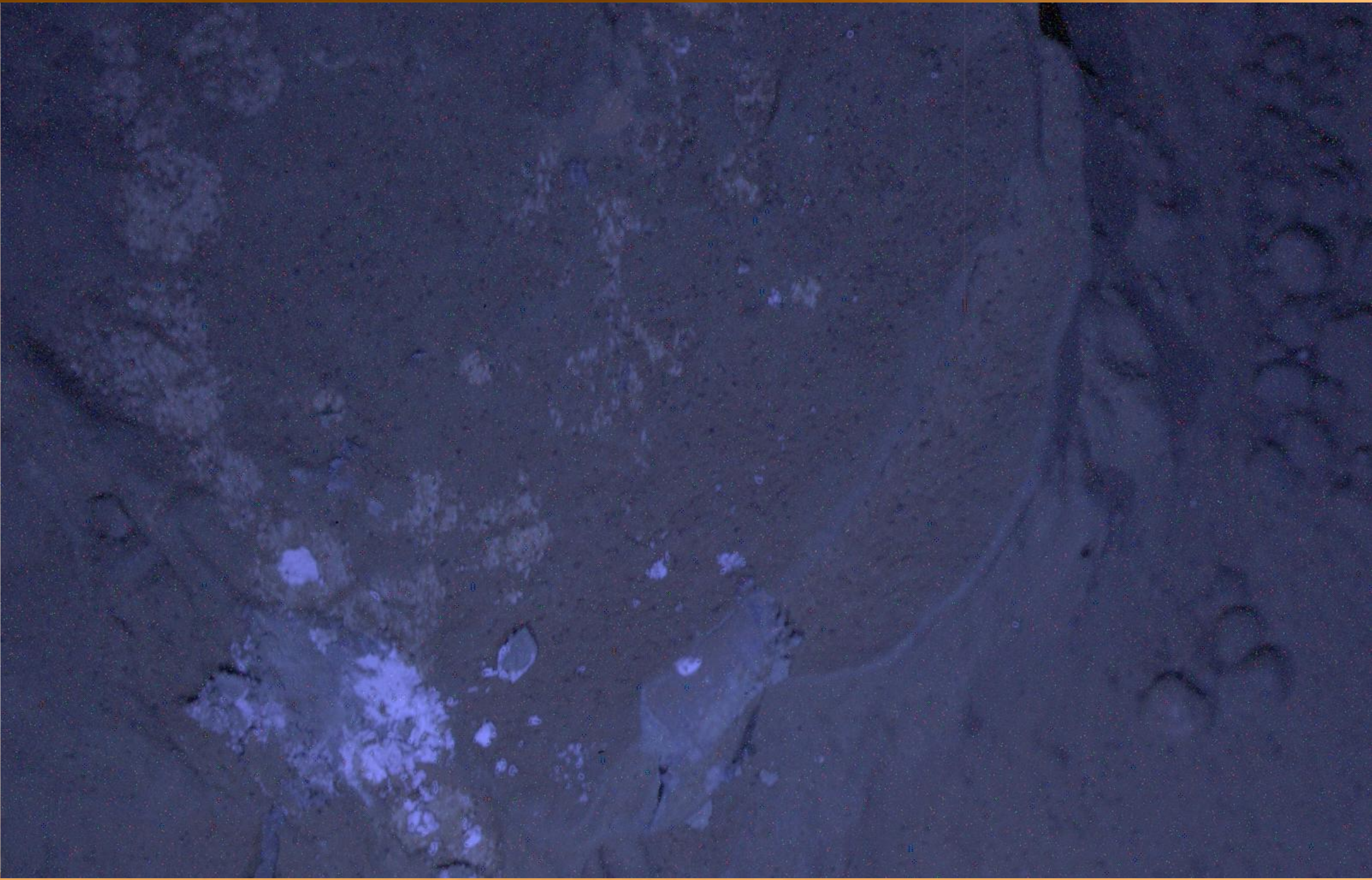
NASA/JPL-Caltech/LANL/CNES/IRAP/LPGN/CNRS

CURIOSITY

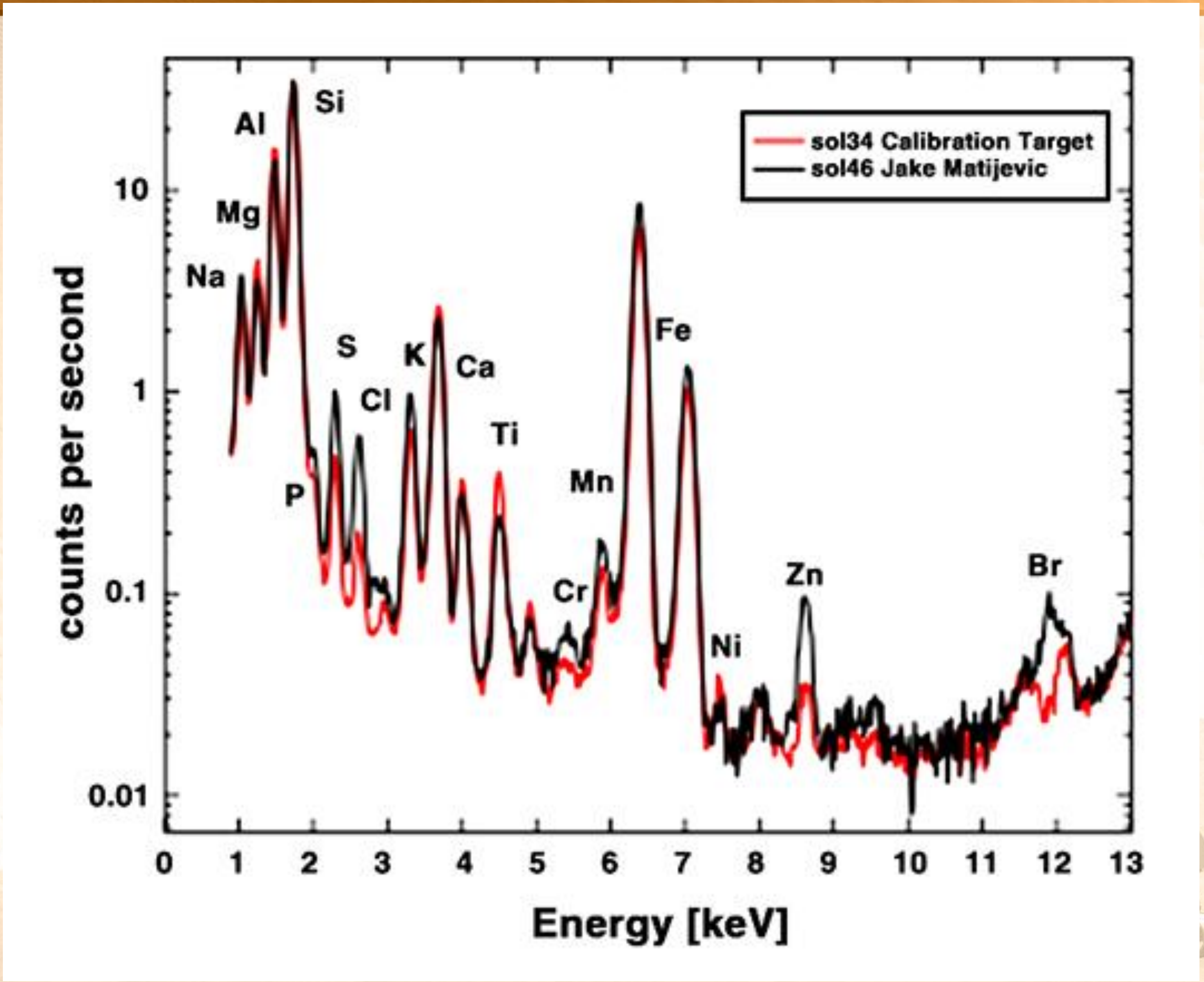
ChemCam’s laser induced breakdown spectrometer acquires a 5-spot raster

MAHLI – white LED

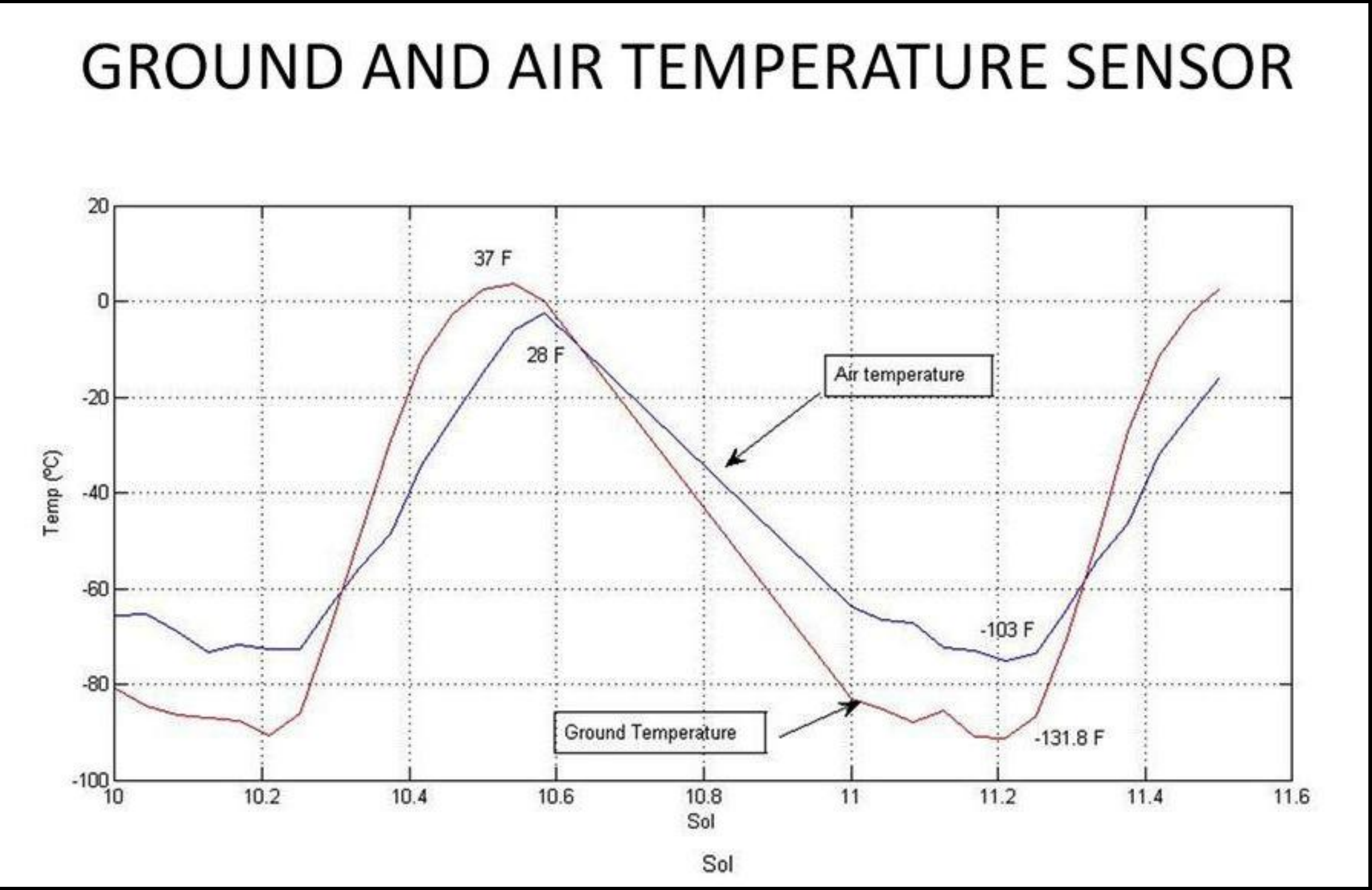
MAHLI – UV LED



APXS



sol34 Calibration Target
sol46 Jake Matijevic
counts per second
Energy [keV]
10
1
0.1
0.01
0
1
2
3
4
5
6
7
8
9
10
11
12
13
Na
Mg
Al
Si
P
S
Cl
K
Ca
Ti
Cr
Mn
Fe
Ni
Zn
Br



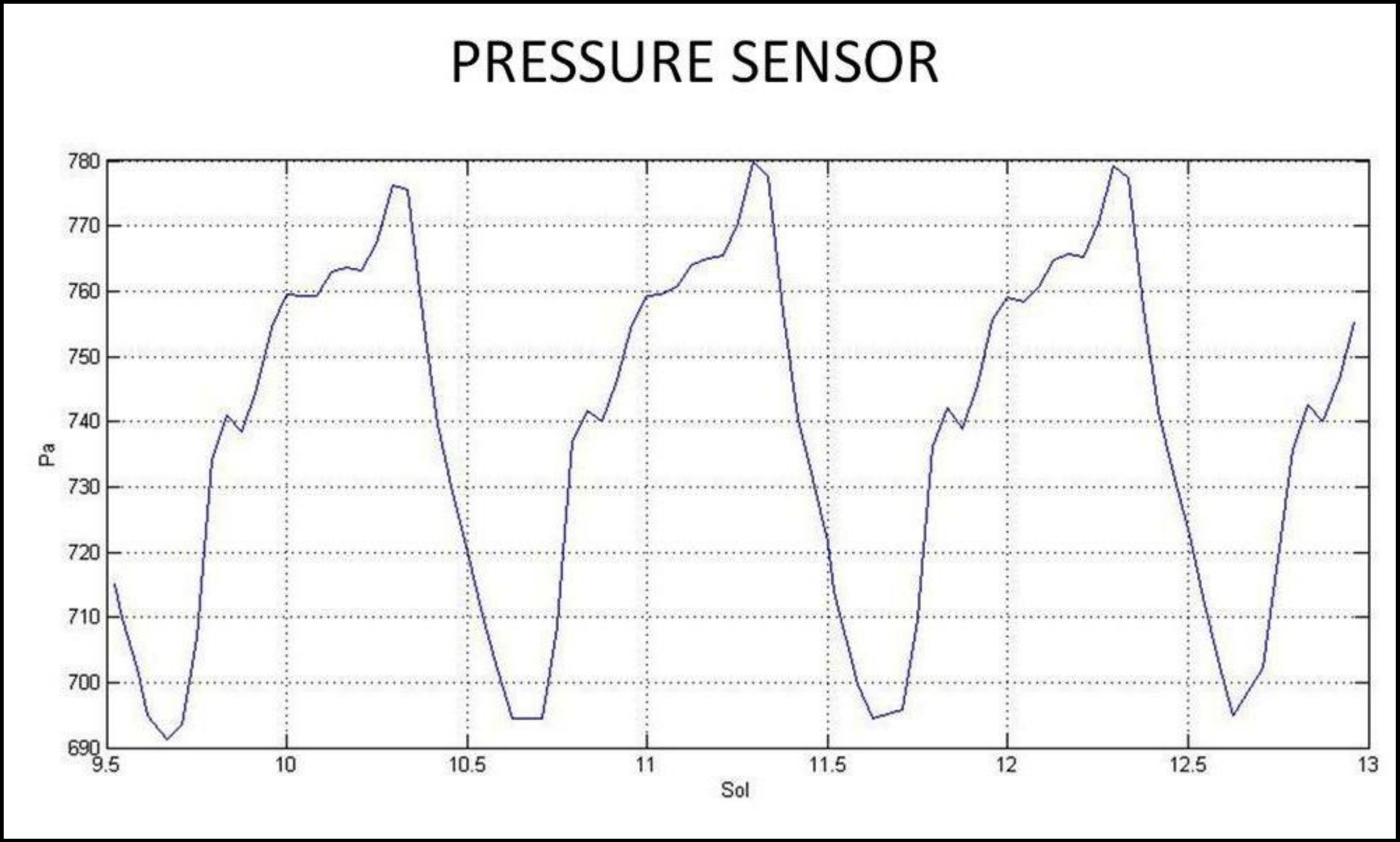
NASA/JPL-Caltech/CAB(CSIC-INTA)

REMS' ground and air temperature sensors are located on small booms on the rover's mast

The ground temperature changes by 90° C (170 degrees Fahrenheit) between day and night

The air is warmer than the ground at night, and cooler during the morning, before it is heated by the ground

Curiosity's Rover Environmental Monitoring Station is taking weather readings 24 × 7



NASA/JPL-Caltech/CAB(CSIC-INTA)

REMS' pressure sensor is located inside the rover's body

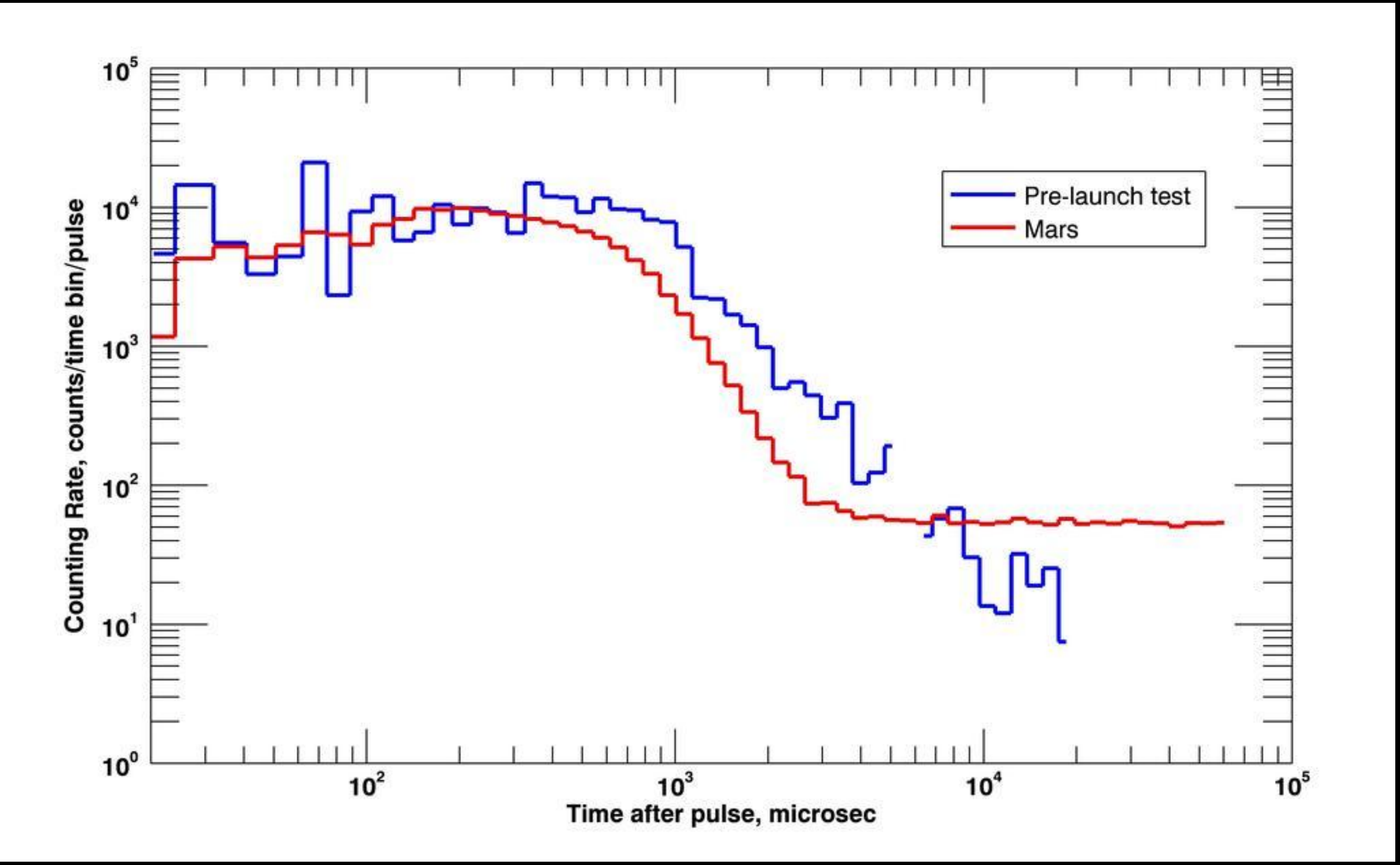
Each day the pressure varies by over 10%, similar to the change in pressure between Los Angeles and Denver

Solar heating of the ground drives an atmospheric "tidal wave" that sweeps across the planet each day

Earth's atmosphere = 101,325 Pascals, or about 140 times the pressure at Gale Crater

CURIOSITY

Curiosity's Rover Environmental Monitoring Station is taking weather readings 24 × 7



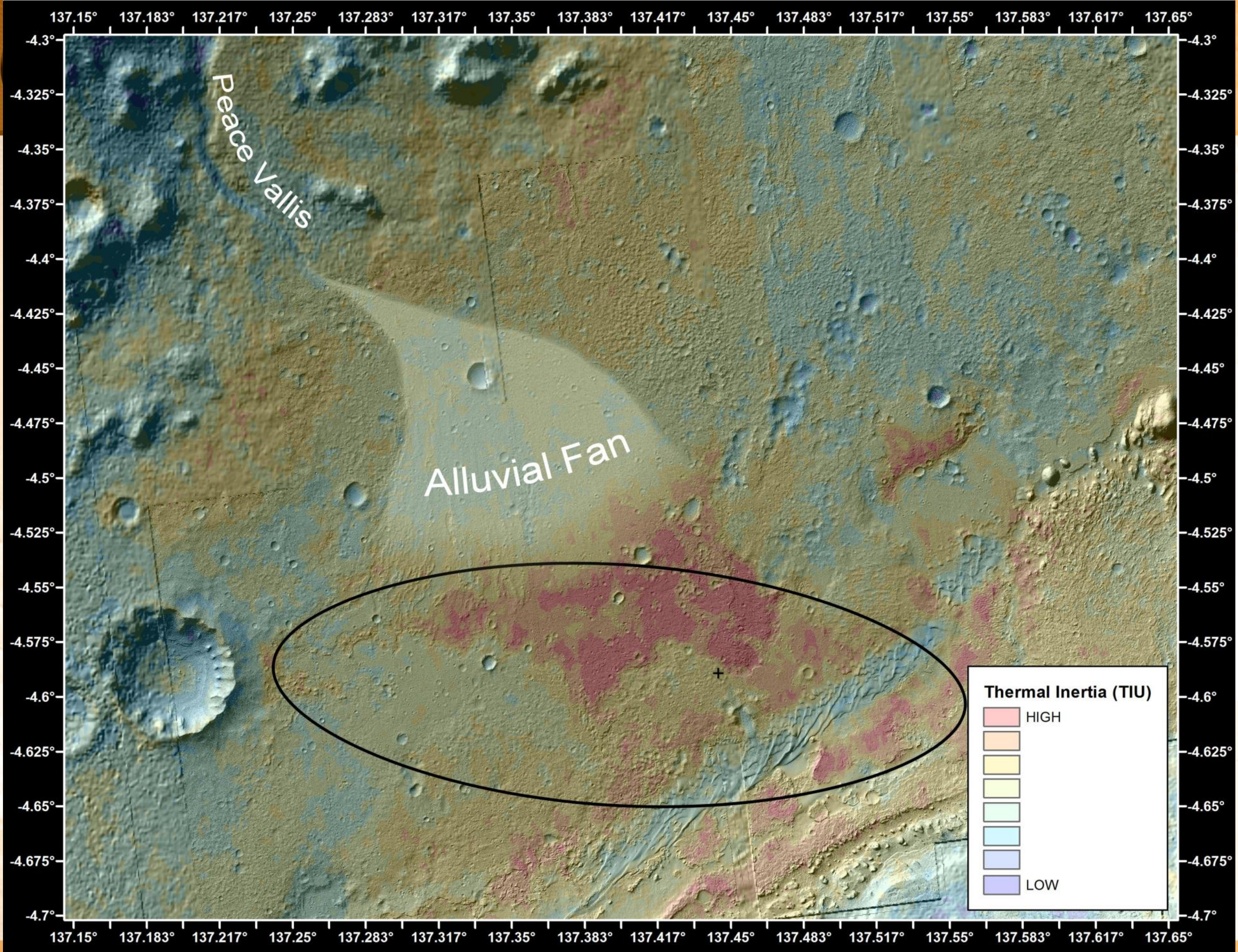
NASA/JPL-Caltech/Russian Space Research Institute

DAN sends ten million neutrons into the ground, ten times a second

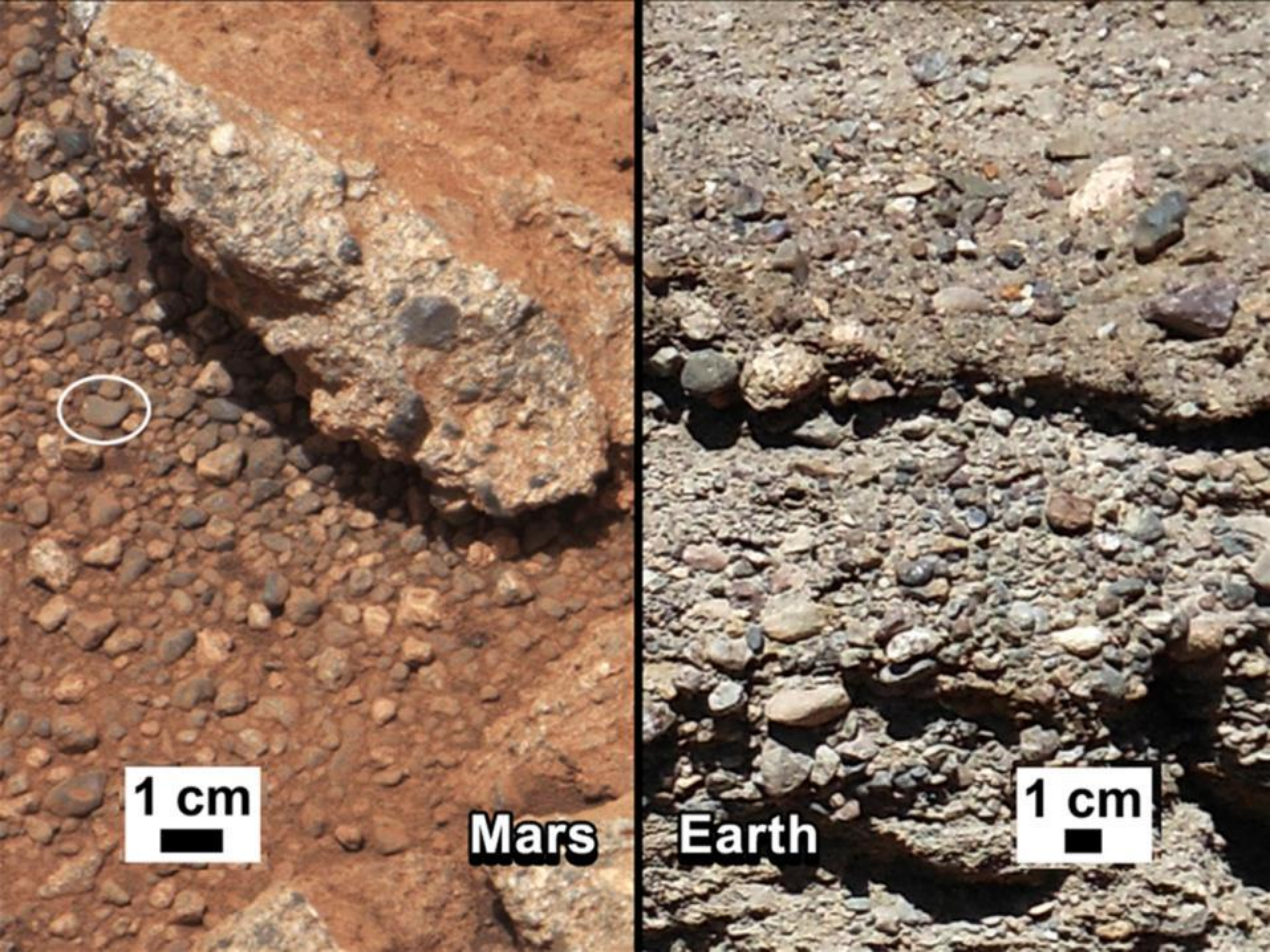
The "echo" back is recorded. If hydrogen is present in the ground, perhaps in aqueous minerals, some neutrons will collide and lose energy

DAN is used to survey the upper one meter of the ground below the rover as it drives along

Curiosity's Dynamic Albedo of Neutrons experiment sounds the ground for hydrogen



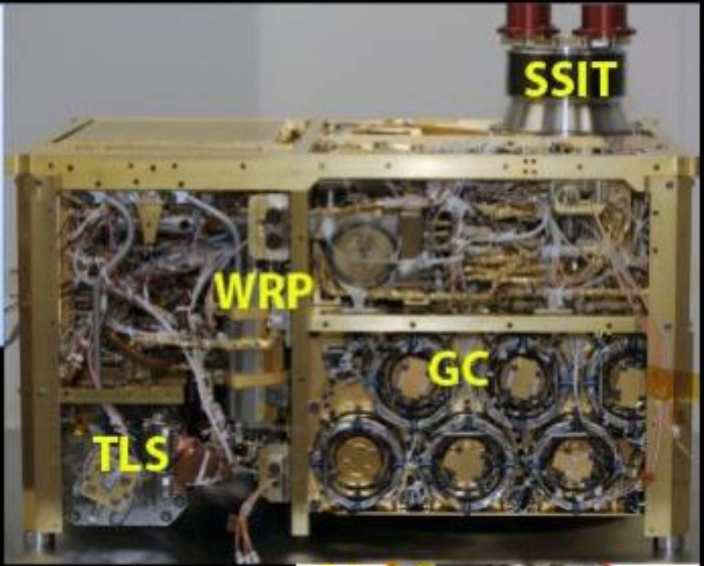
Peace Vallis
Alluvial Fan
Thermal Inertia (TIU)
HIGH
LOW
137.15°
137.183°
137.217°
137.25°
137.283°
137.317°
137.35°
137.383°
137.417°
137.45°
137.483°
137.517°
137.55°
137.583°
137.617°
137.65°
-4.3°
-4.325°
-4.35°
-4.375°
-4.4°
-4.425°
-4.45°
-4.475°
-4.5°
-4.525°
-4.55°
-4.575°
-4.6°
-4.625°
-4.65°
-4.675°
-4.7°

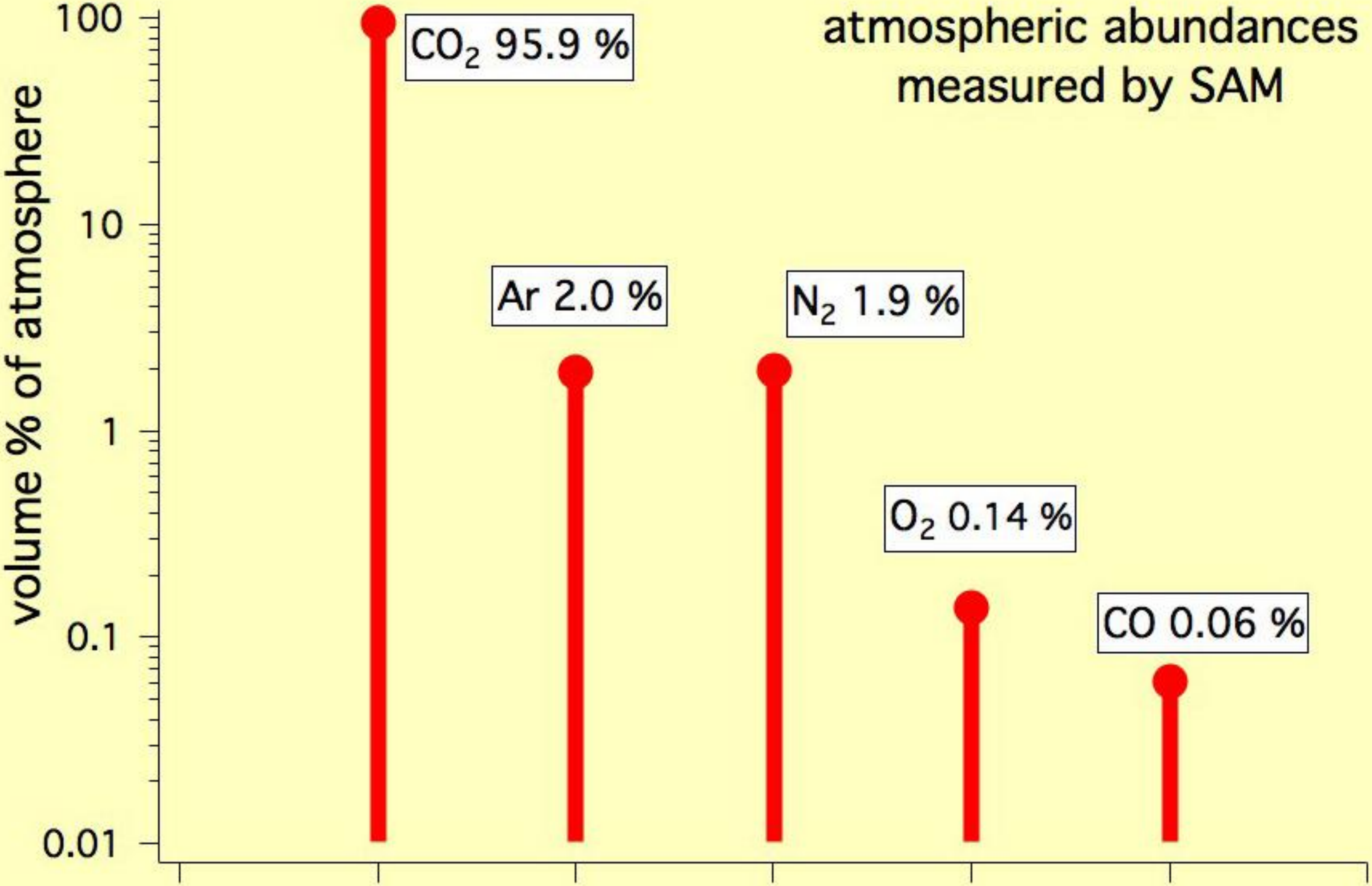

1 cm
Mars
Earth
1 cm

The SAM suite

SAM suite instruments and major subsystems

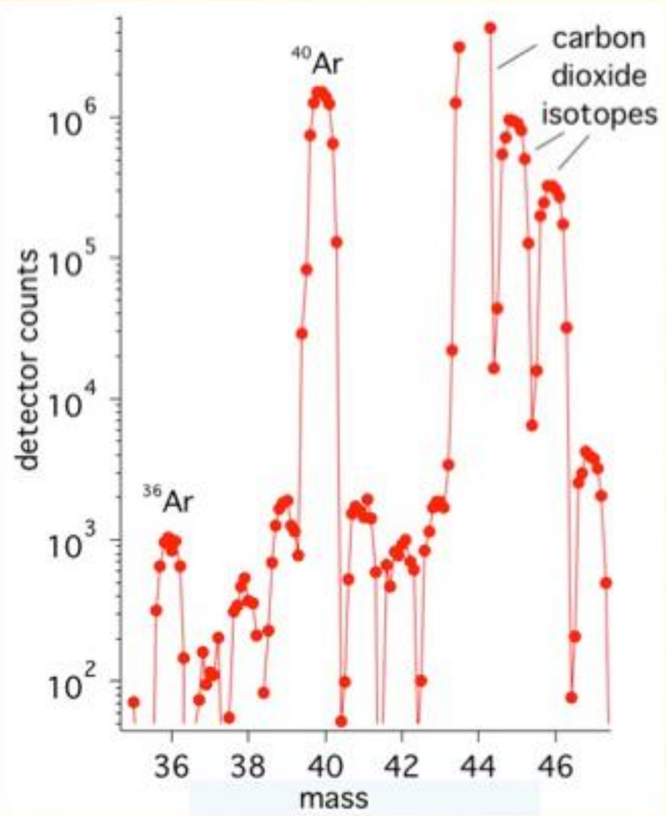
- Quadrupole Mass Spectrometer
- 6-column Gas Chromatograph
- 2-channel Tunable Laser Spectrometer
- Gas Processing System
- Sample Manipulation System



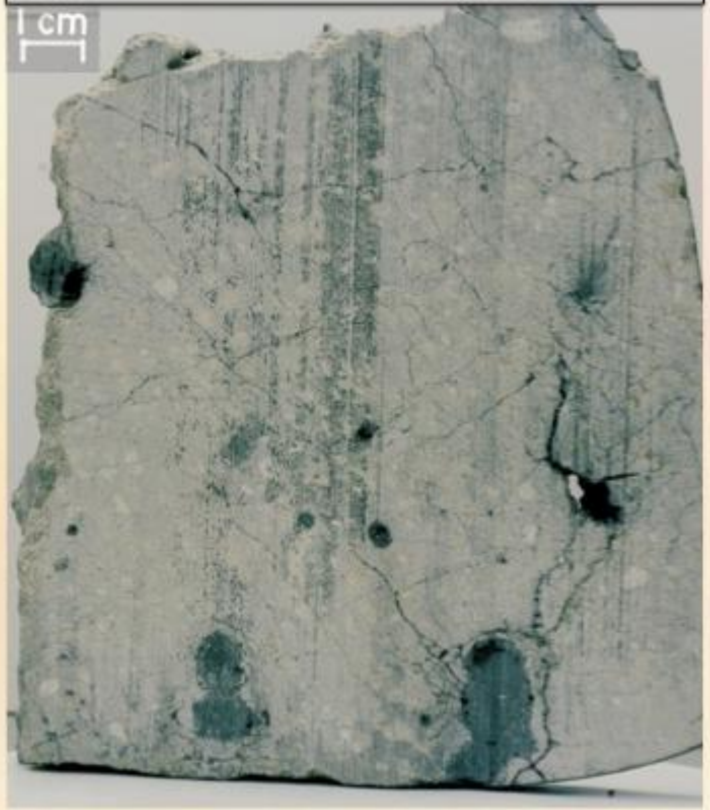

atmospheric abundances
measured by SAM
volume % of atmosphere
100
10
1
0.1
0.01
CO2 95.9 %
Ar 2.0 %
N2 1.9 %
O2 0.14 %
CO 0.06 %

Weighing Molecules on Mars

SAM atmospheric measurements

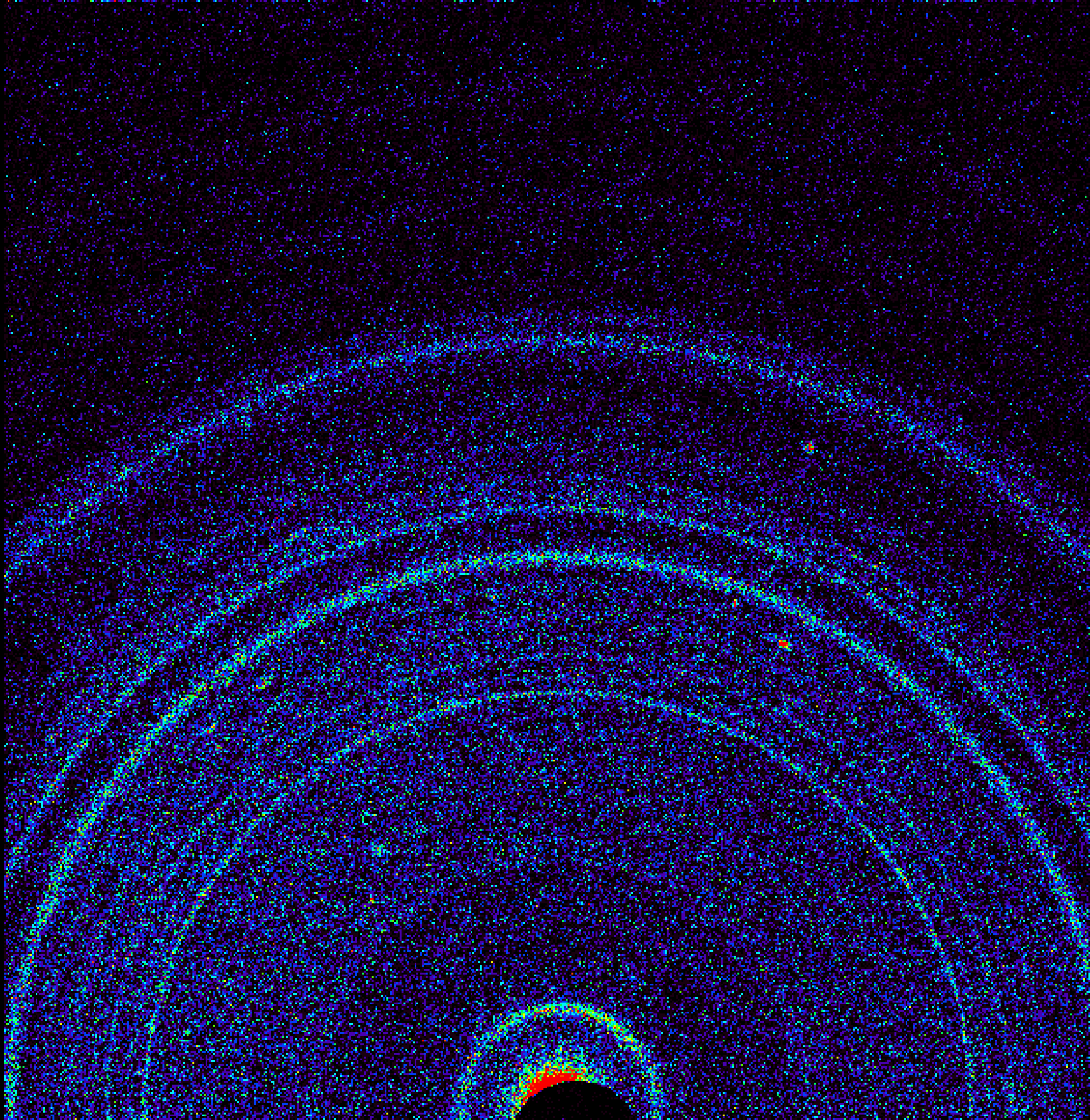


Martian meteorite EETA79001
image credit NASA JSC Astromaterials Curation



Rocknest

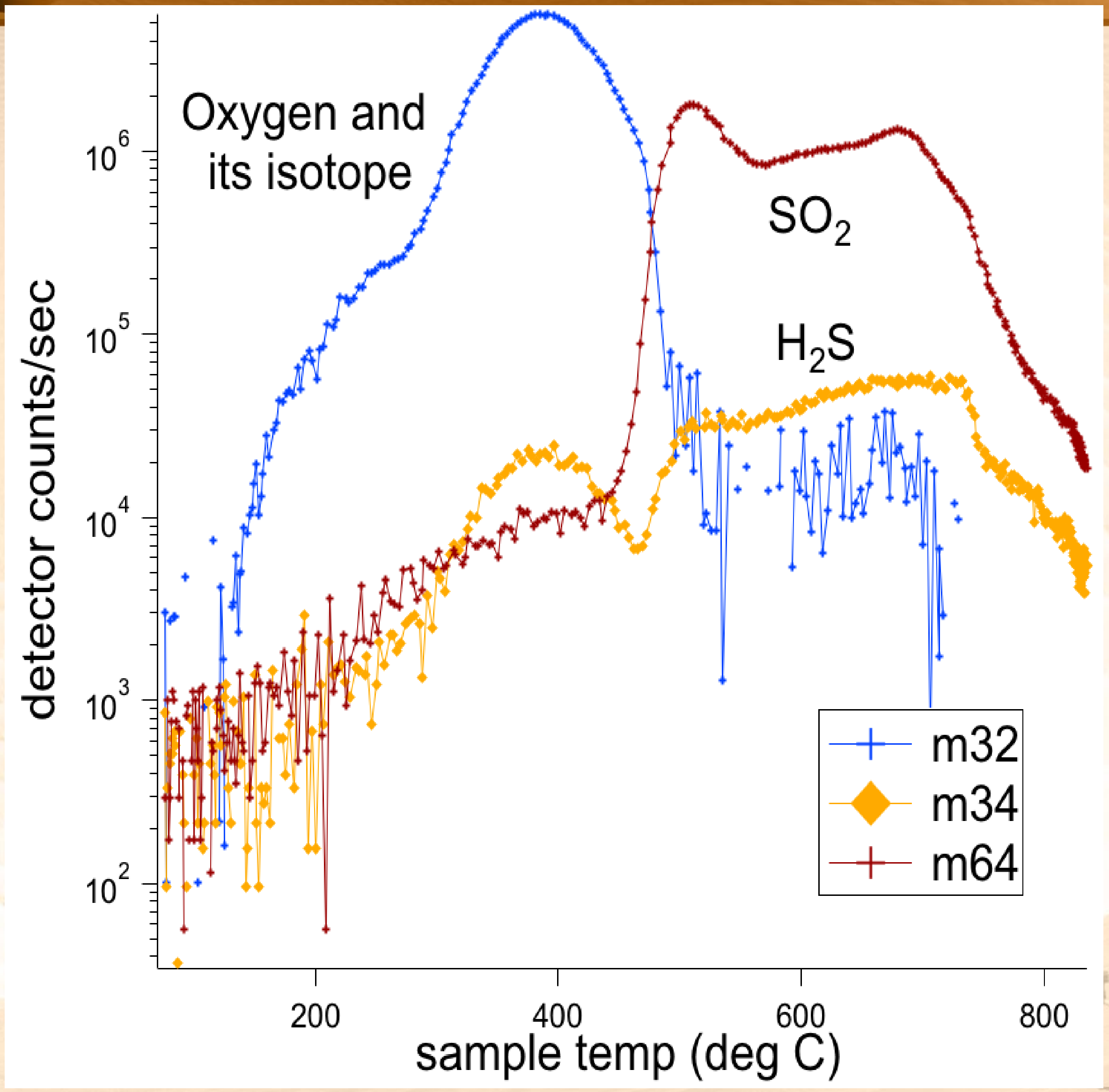
CheMin
2D X-Ray
Diffraction
Pattern of
Rocknest Soil



CheMin: X-ray Diffraction, from Big to Small

Physics meets Art: NASA Helps Check out King Tut's Tomb

O, S, and N compounds from Rocknest samples



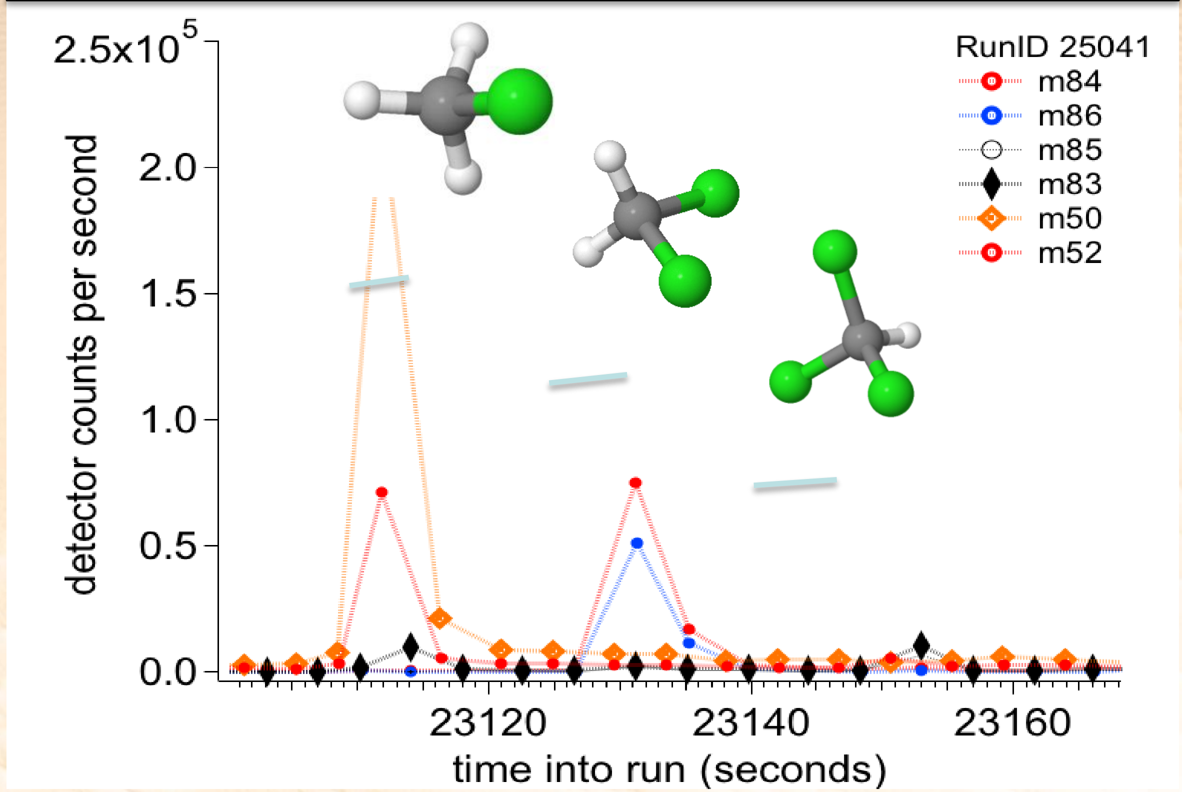
Evolved oxygen could be from decomposition of a perchlorate such as $Ca(ClO_4)_2$. Since it is hydroscopic some of the released water may be from its tetrahydrate.

Higher temperature S containing compounds indicate the presence of sulfates or sulfides.

Trace levels of N containing compounds are present as both HCN and NO.

Just a few chlorinated organic compounds are found in Rocknest

Chlorine compounds found in Rocknest



Rocknest compounds

- **Chloromethane** CH_3Cl
- **Dichloromethane** CH_2Cl_2
- **Trichloromethane** $CHCl_3$
- **A 4-carbon Cl containing compound**

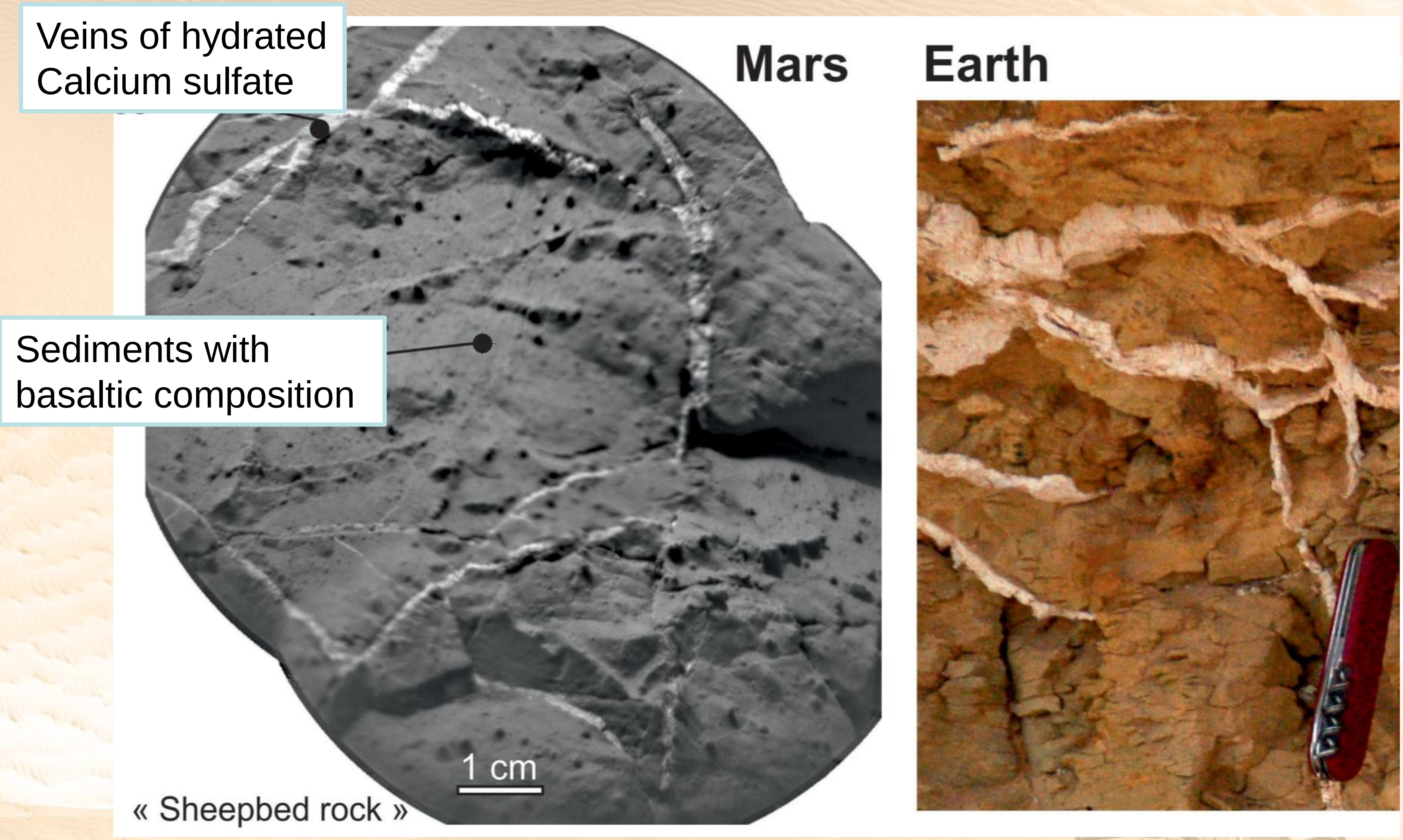
- **Abundance is parts per million by weight**
- **Detected in the GCMS runs & in the direct QMS sampling**

Although the Cl in these compounds is Martian, the source of the carbon in these compounds as Martian or terrestrial remains to be established with future laboratory work and experiments on Mars

Yellowknife Bay

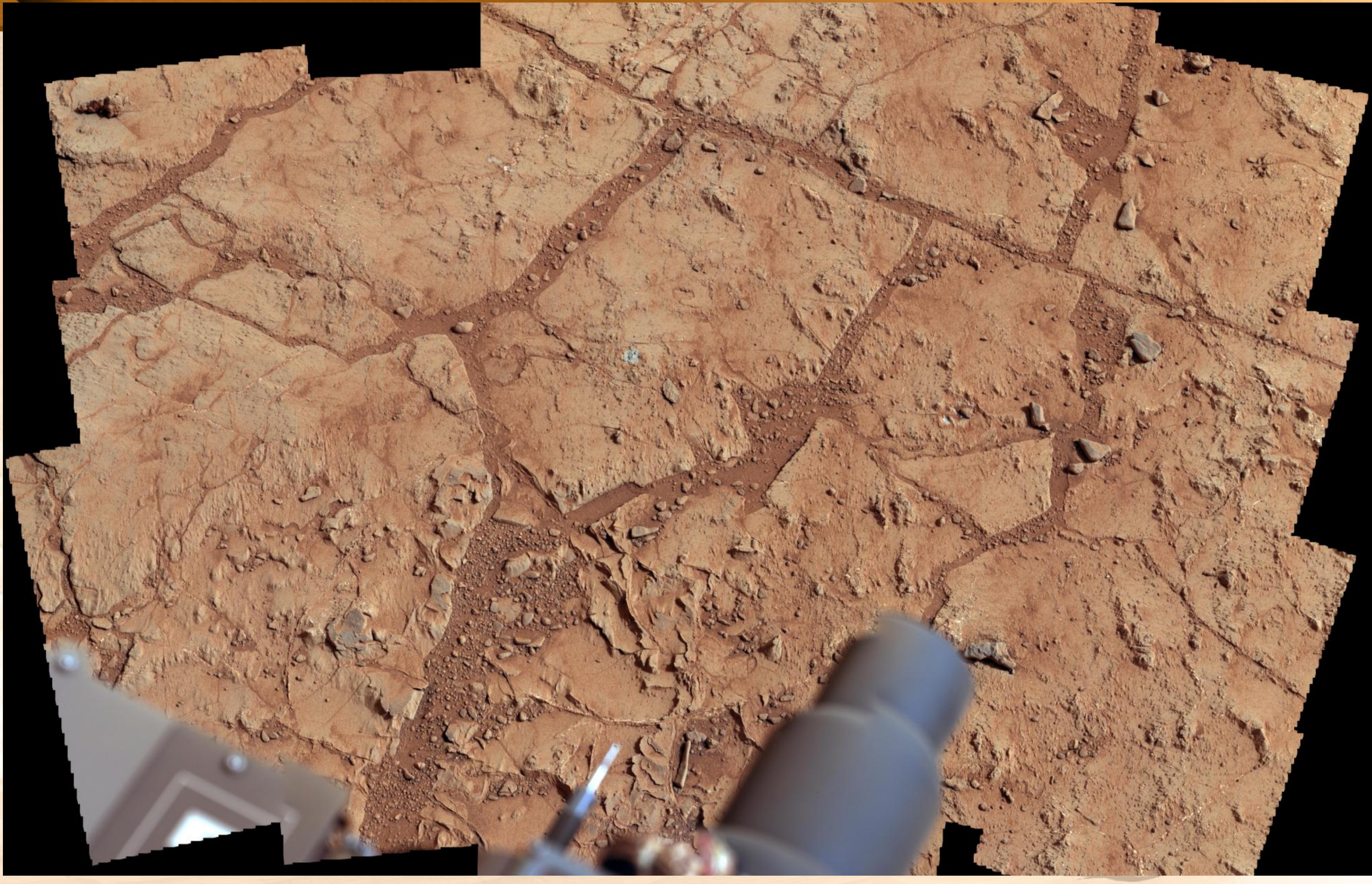
Yellowknife Bay

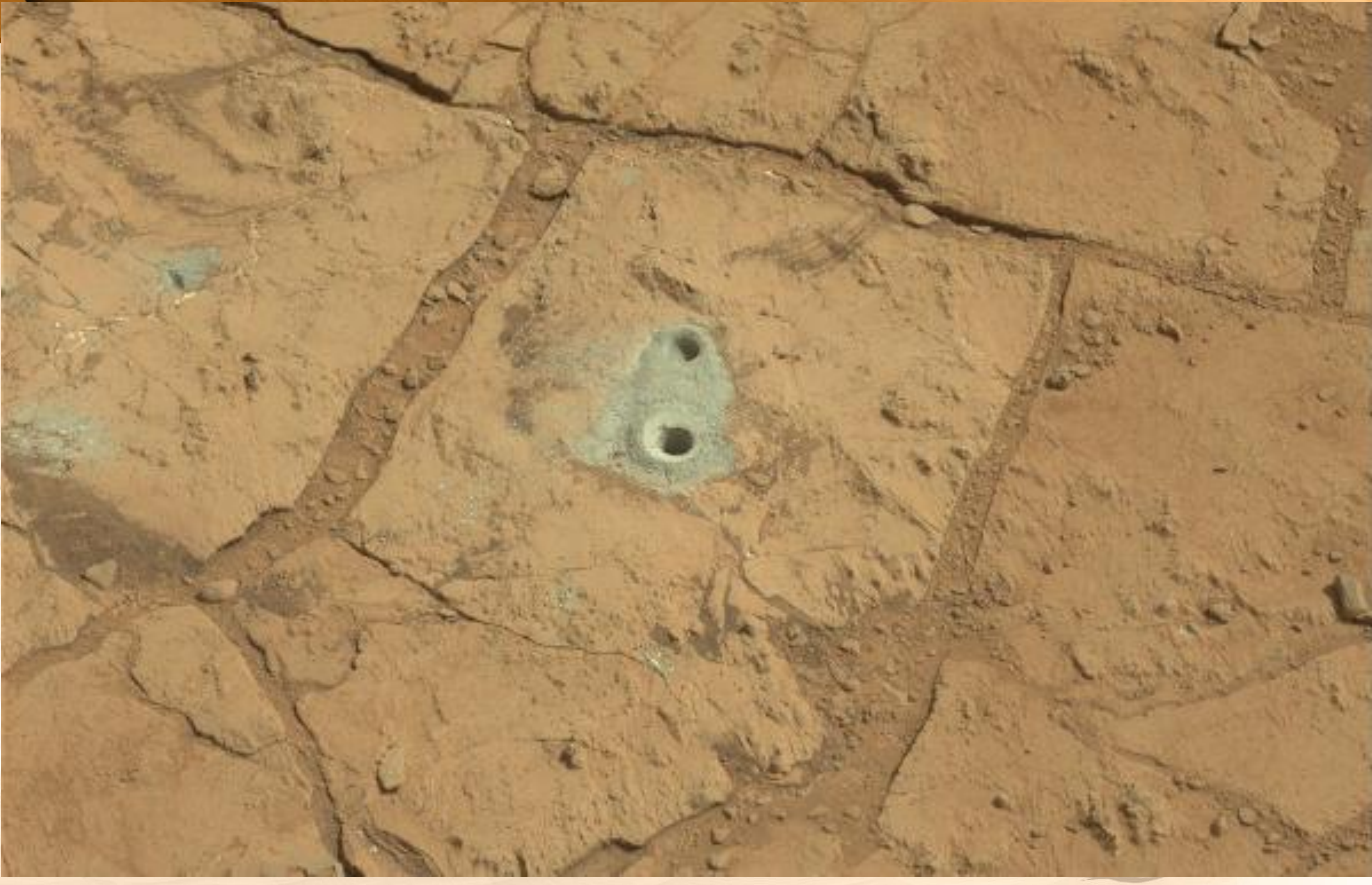
Sheepbed


Veins of hydrated
Calcium sulfate
Sediments with
basaltic composition
Mars
Earth
1 cm
« Sheepbed rock »

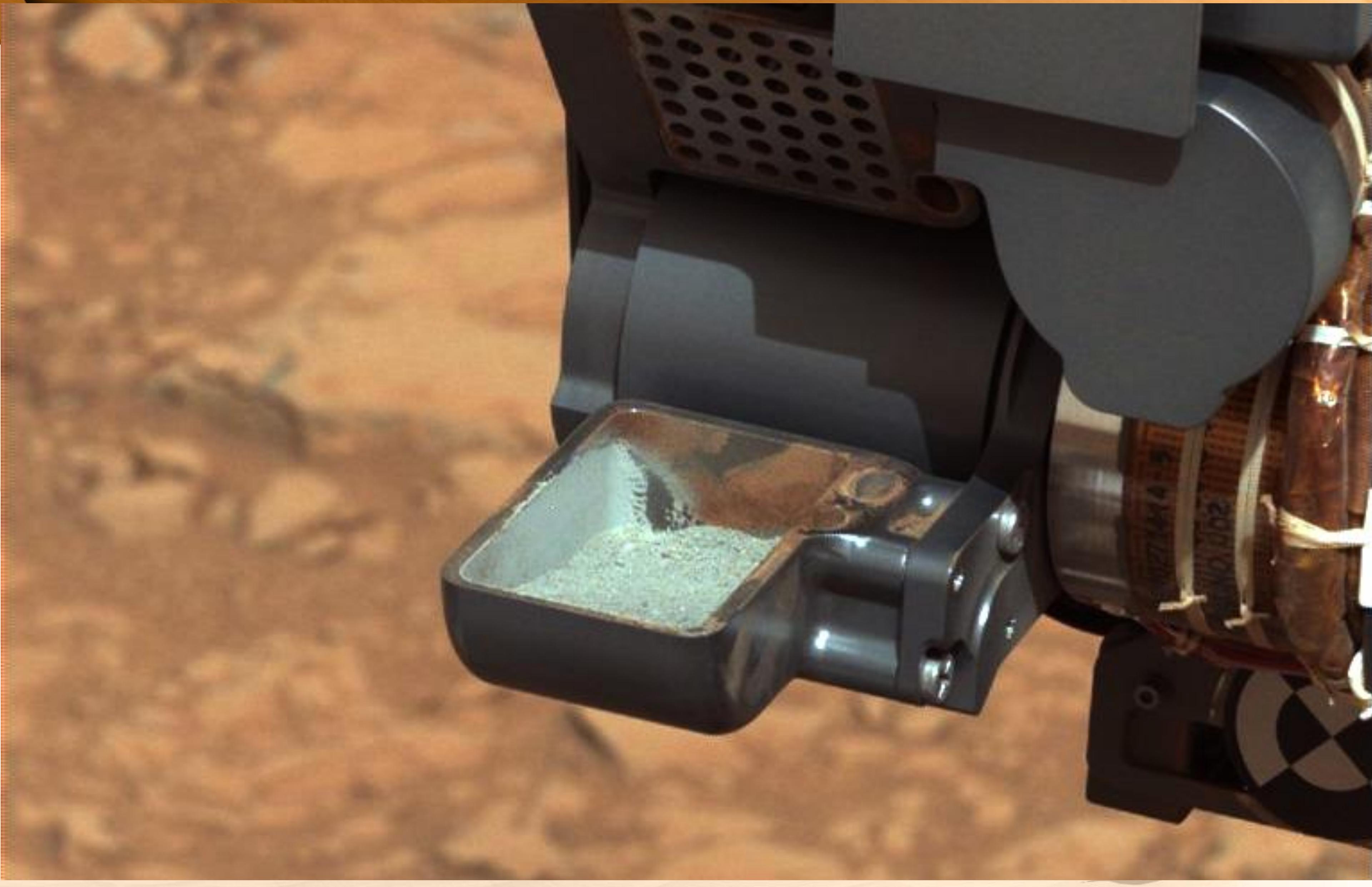
Drill Loading Test

Drill Area

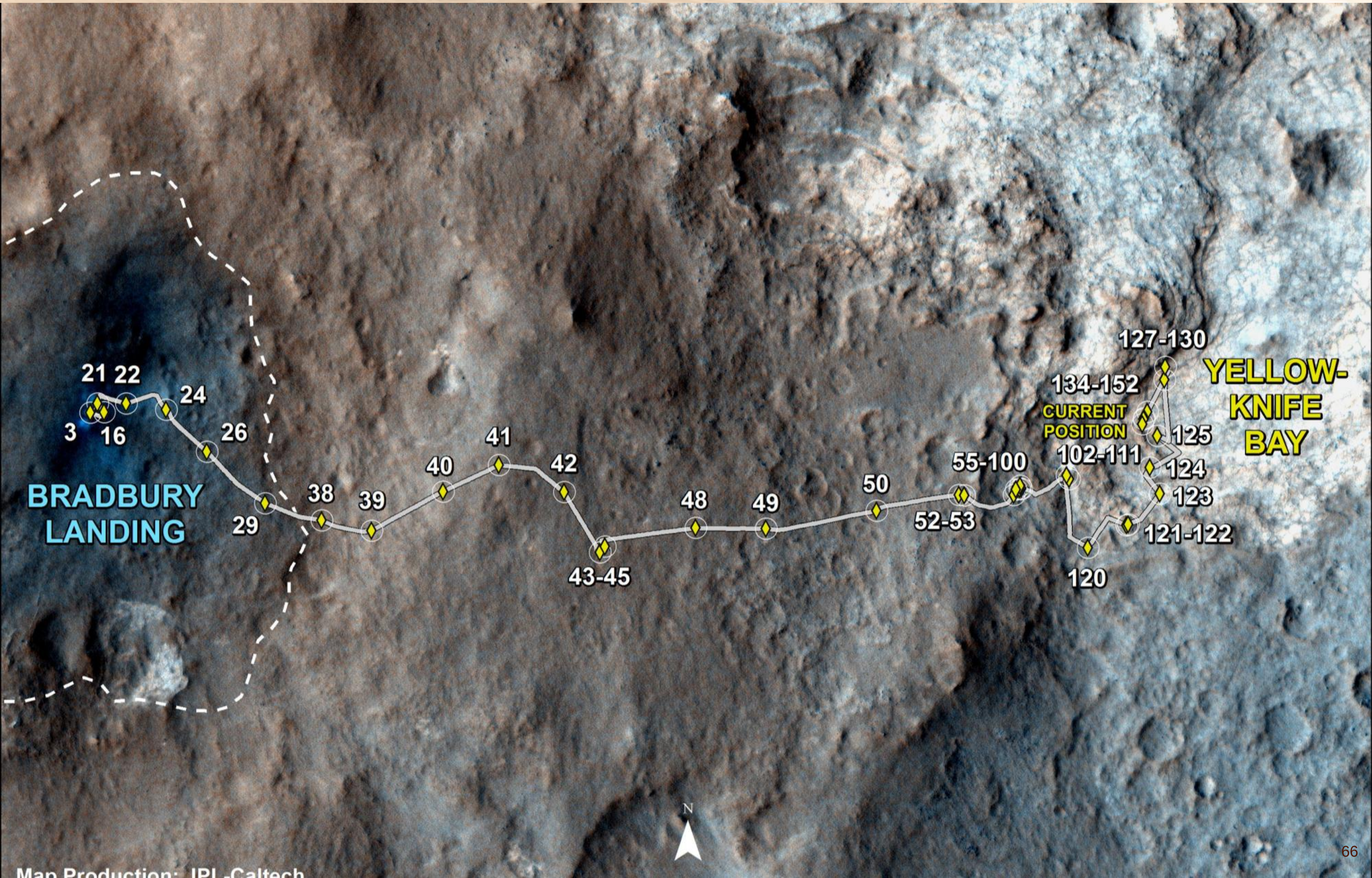




Drill Sample



Traverse Map Sol 152+

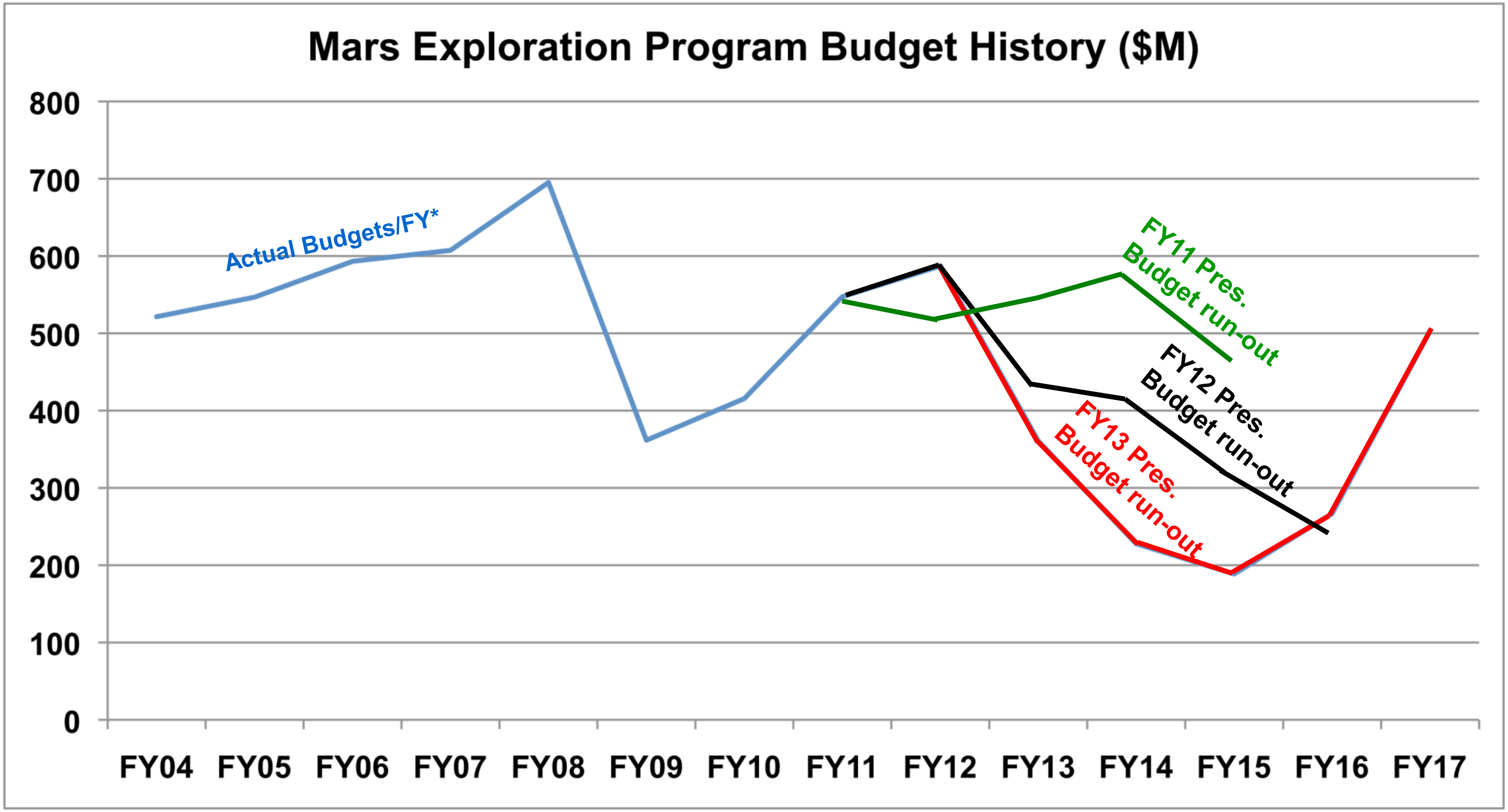


Map Production: JPL-Caltech


NASA/JPL-Caltech/MSSS

Backup

MEP Budget History
Including President's FY13 Request



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