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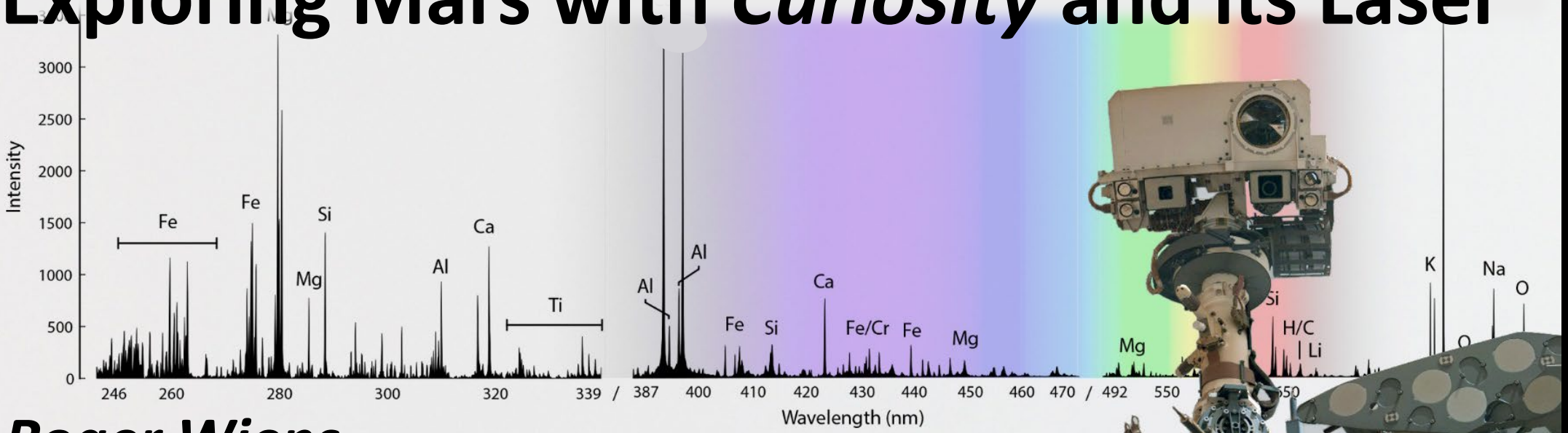
Title: Exploring Mars with Curiosity and its Laser

Author(s): Wiens, Roger Craig

Intended for: VIP presentation to Mars, Inc. Directors during visit to LANL

Issued: 2019-01-15

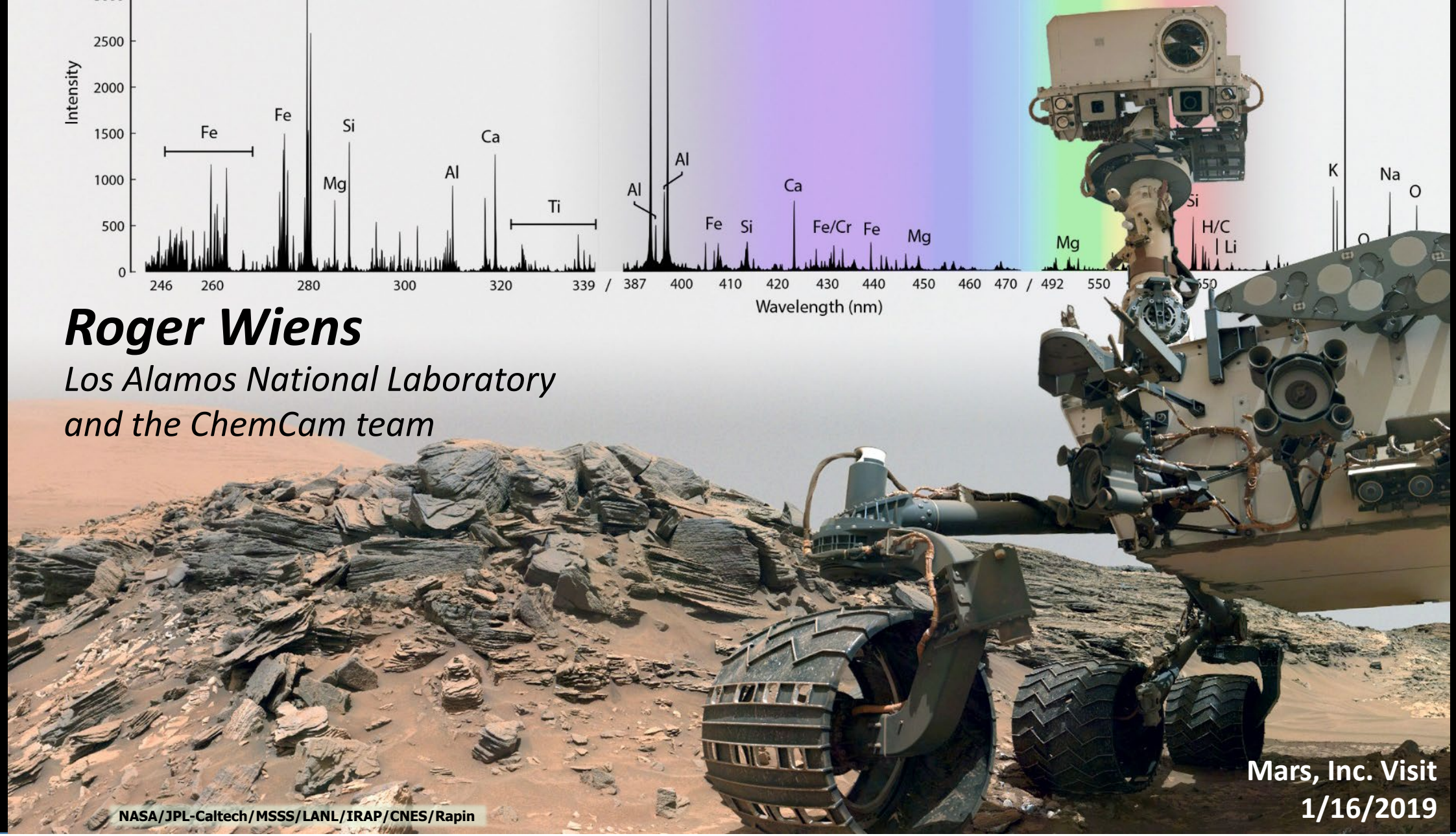
Exploring Mars with *Curiosity* and its Laser



Roger Wiens

Los Alamos National Laboratory

and the ChemCam team



NASA/JPL-Caltech/MSSS/LANL/IRAP/CNES/Rapin

Mars, Inc. Visit
1/16/2019

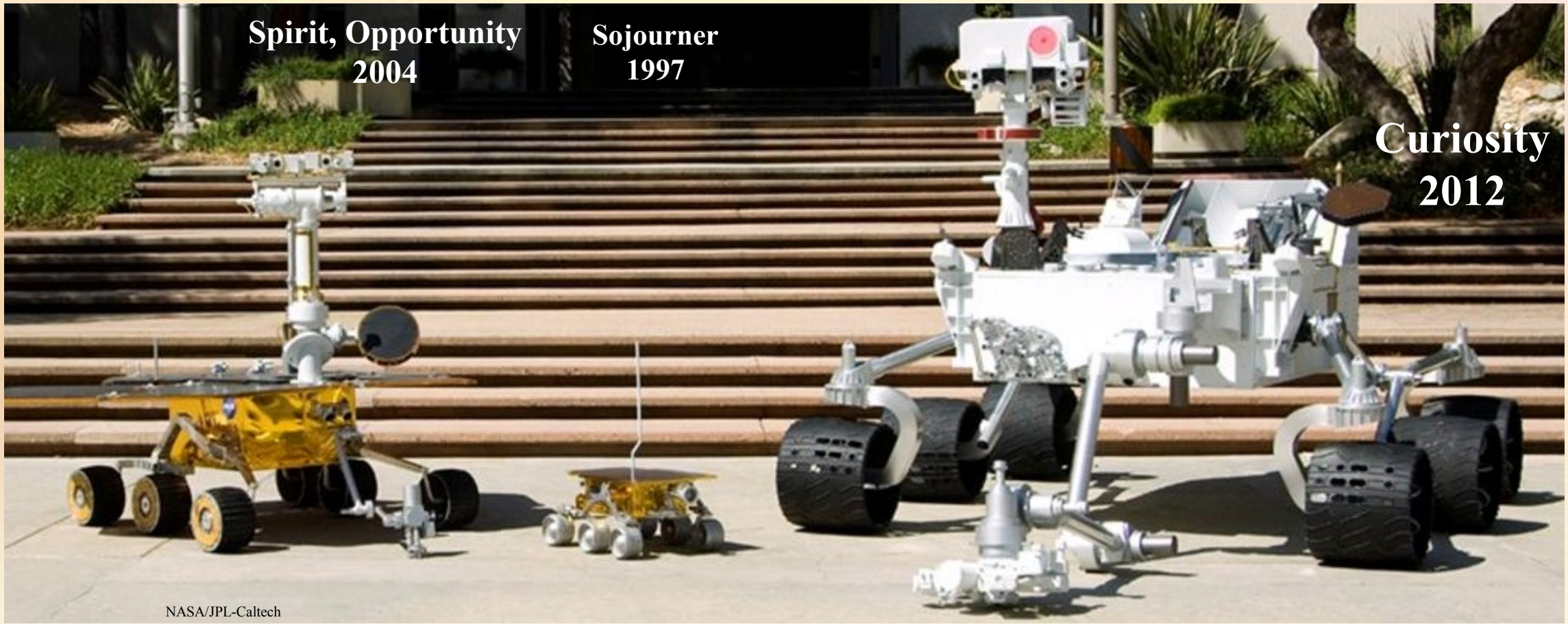
Abstract

The 1-ton Curiosity rover has been exploring Gale crater on Mars since 2012. Its payload includes the ChemCam laser instrument, led by LANL. ChemCam uses the laser-induced breakdown spectroscopy (LIBS) technique to obtain remote elemental compositions of Mars rocks and soils. In this presentation I explain how we operate this instrument on Mars and what we have discovered.

Note: slide 6 is a short video of ChemCam's operation. The video was sent through RASSTI separately in 2012.

Curiosity Rover *Goals*

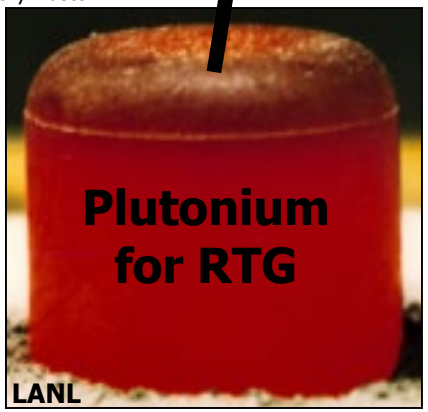
- Assess Mars' biological potential
- Characterize the geology of the landing region
- Study Mars' past habitability (the role of water)
- Characterize the human hazards on Mars

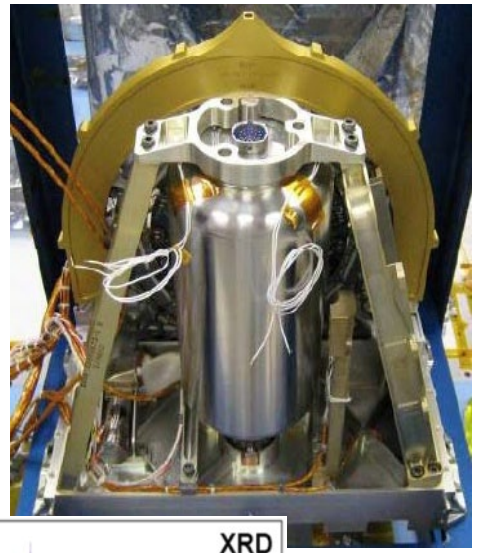


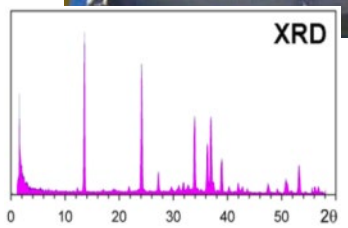
Los Alamos Involvement in Curiosity

NASA/JPL-Caltech /MSSS


NASA/Cory Huston




NASA/JPL-Caltech



CheMin
Science Co-lead is
from LANL

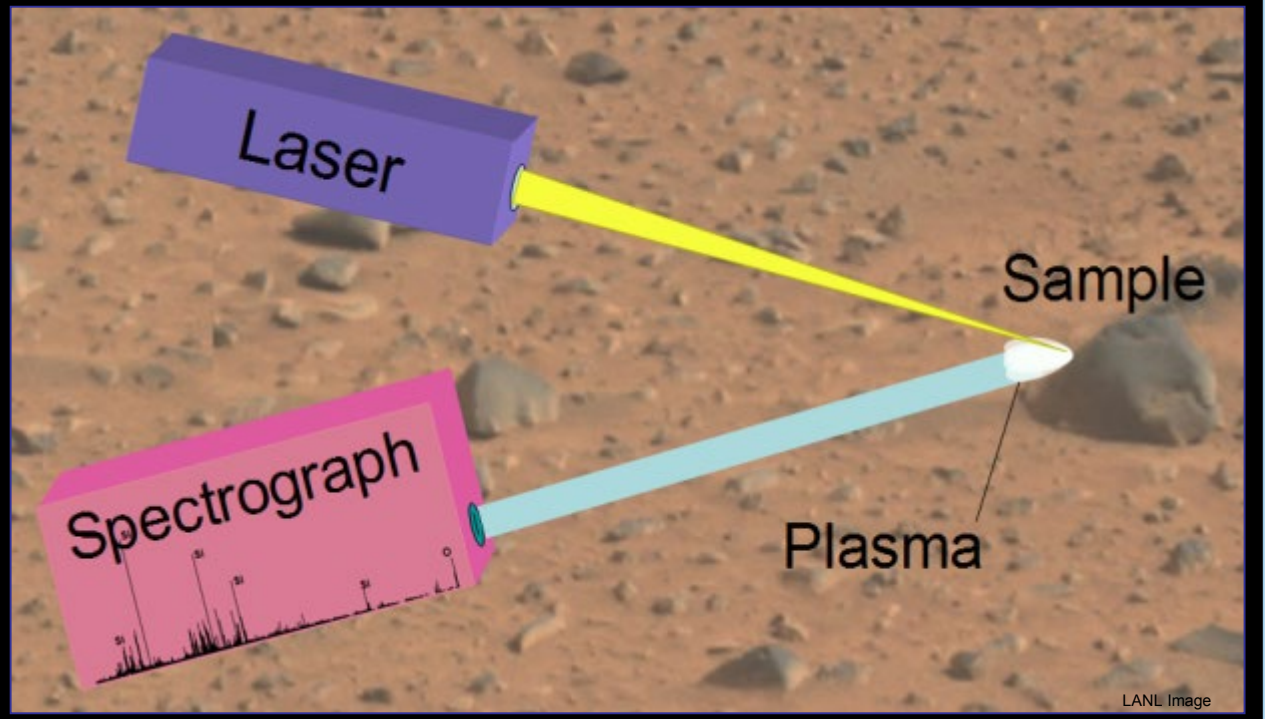
Los Alamos NATIONAL LABORATORY

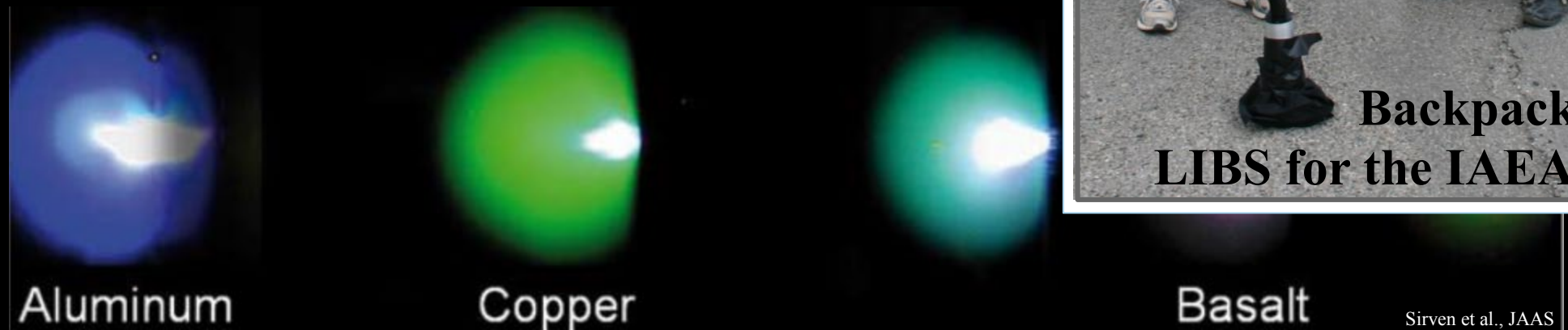
irap astrophysique & planétologie

cnes CENTRE NATIONAL D'ETUDES SPATIALES

NASA

Laser-Induced Breakdown Spectroscopy (LIBS)

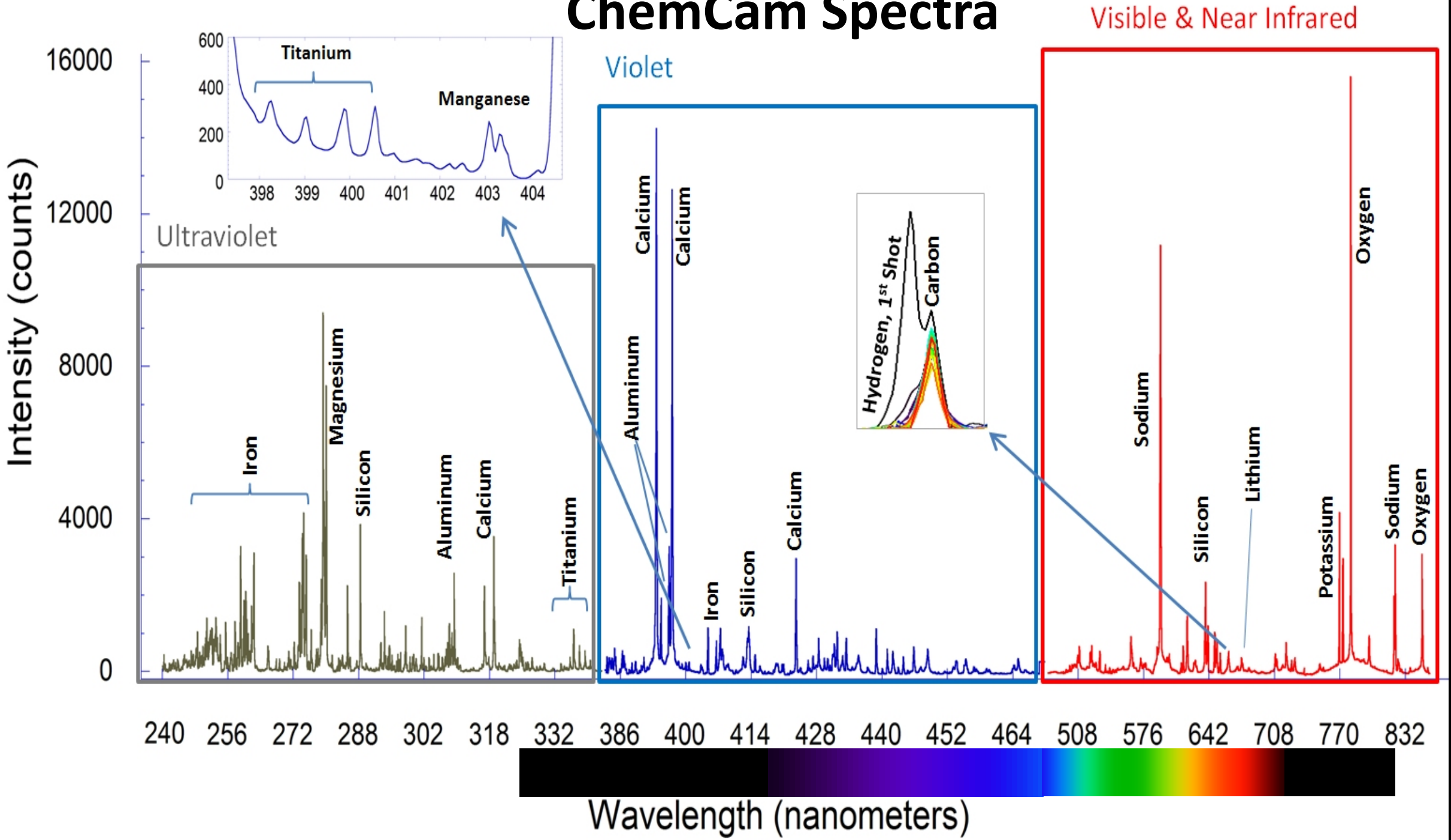




Sirven et al., JAAS

What Really Happens?

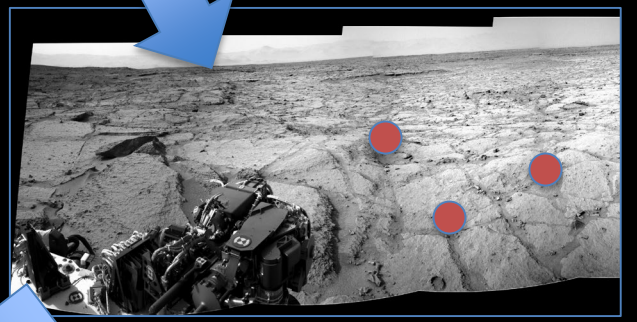
ChemCam Spectra



Operating on Mars

Drive

Downlink New Mosaic



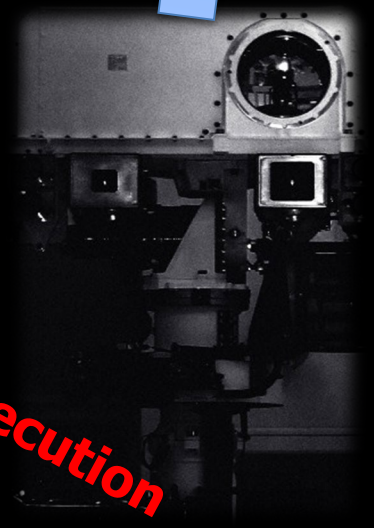
Science Theme Group Selects Targets

Long-Term Guidance

Lien List

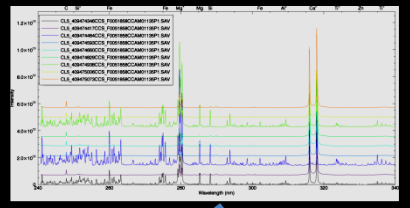
Engineers Build Command Sequences

Uplink



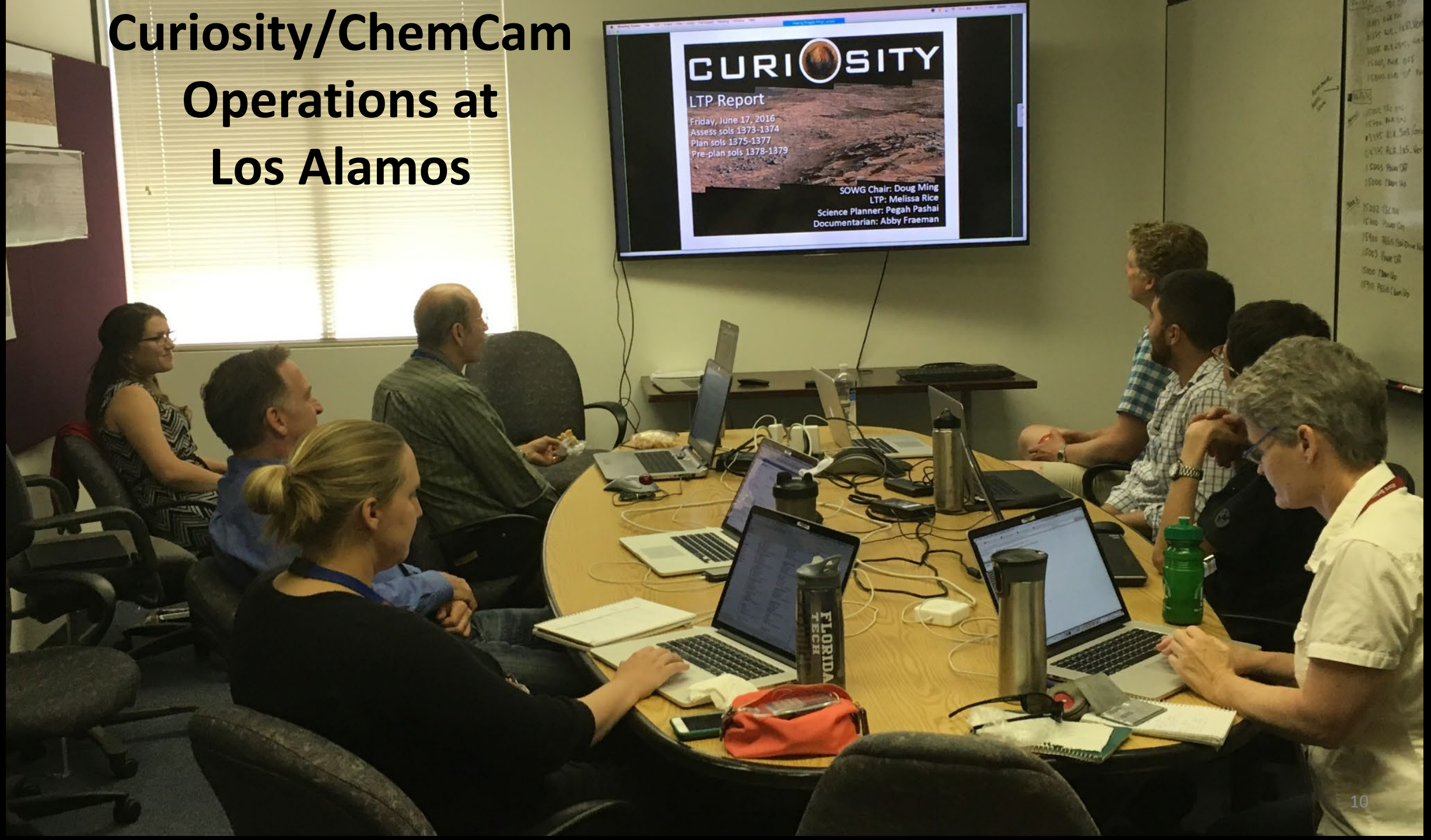
Execution

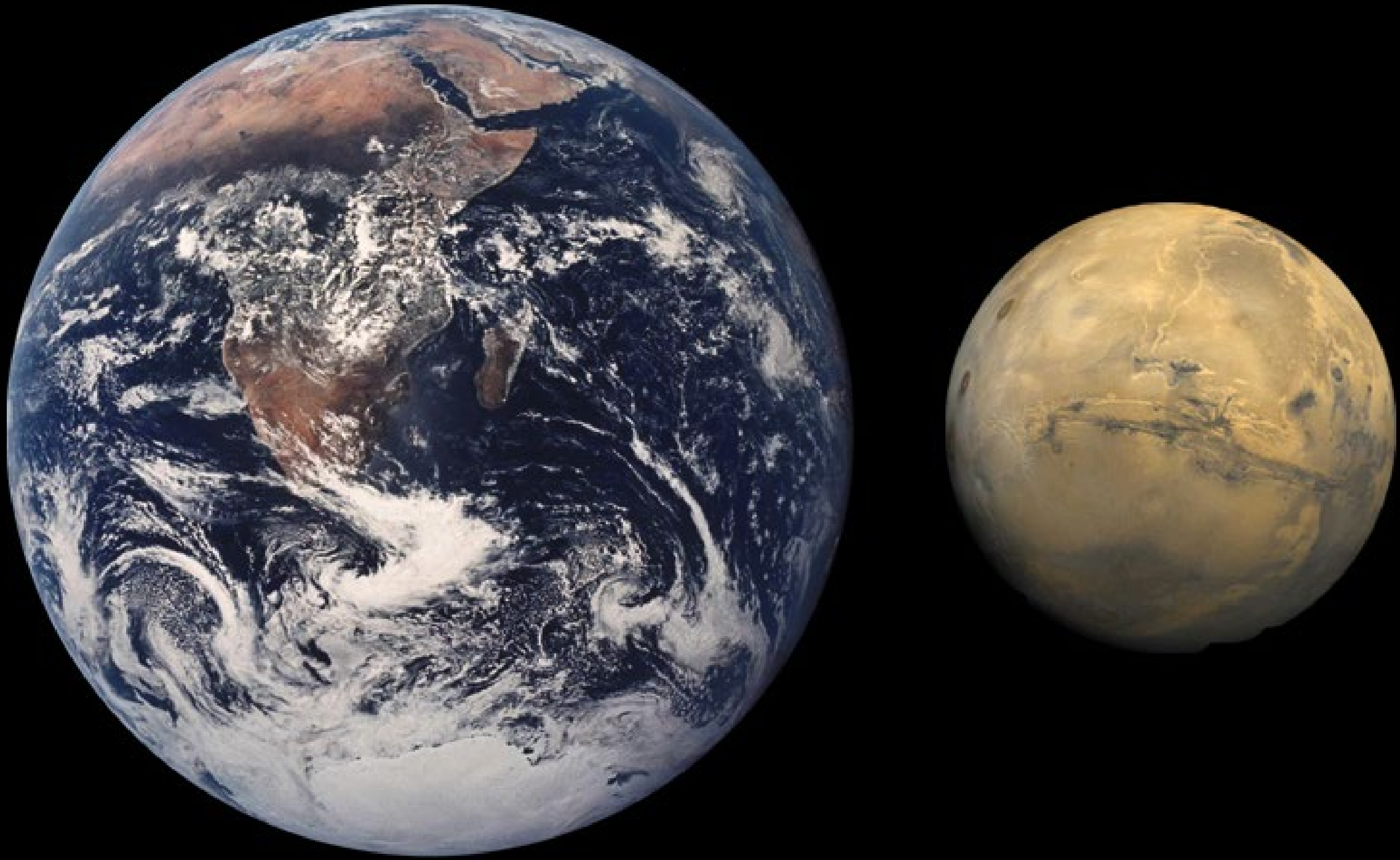
Downlink



Investigate Eng. & Sci. Data

Curiosity/ChemCam Operations at Los Alamos

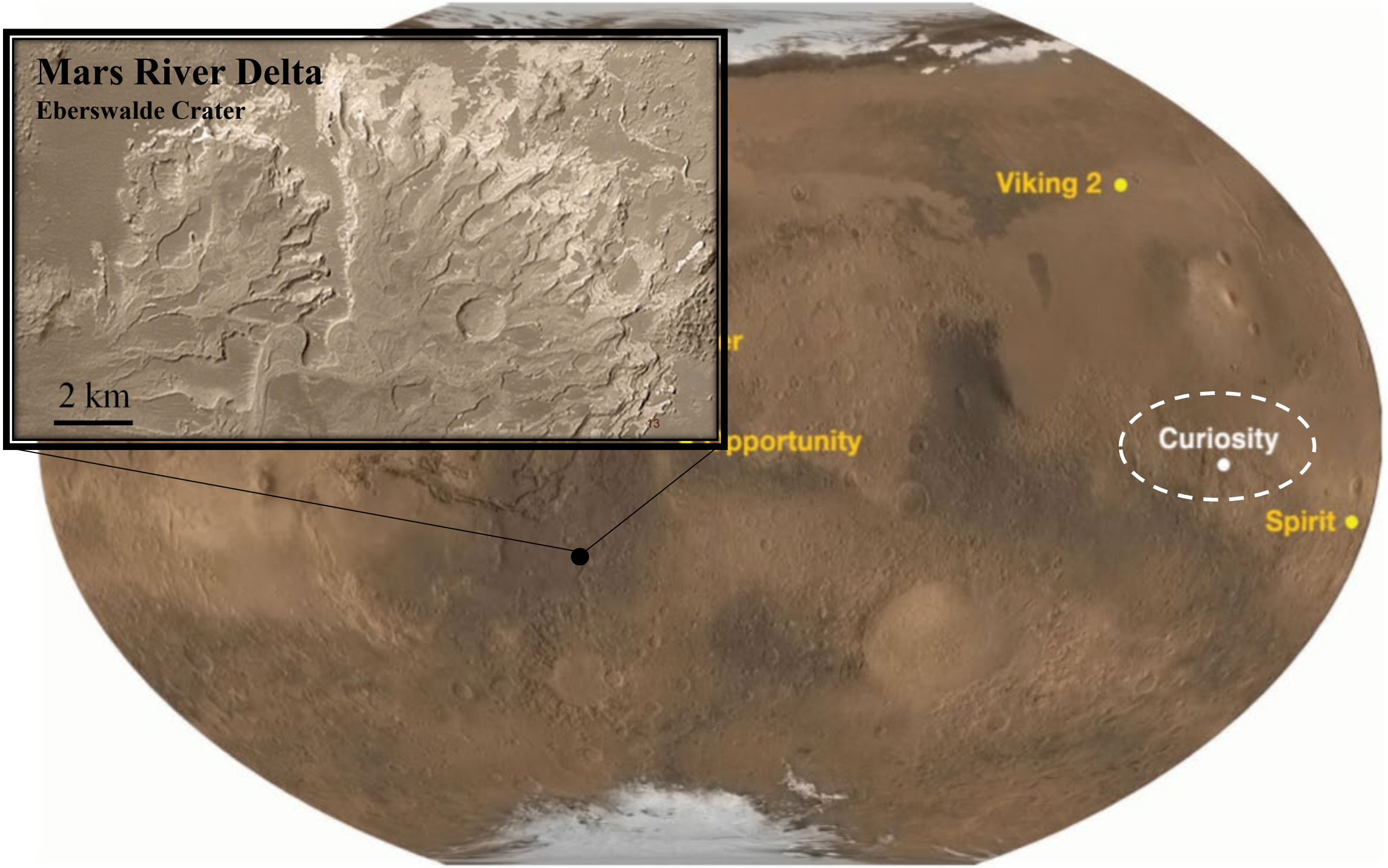




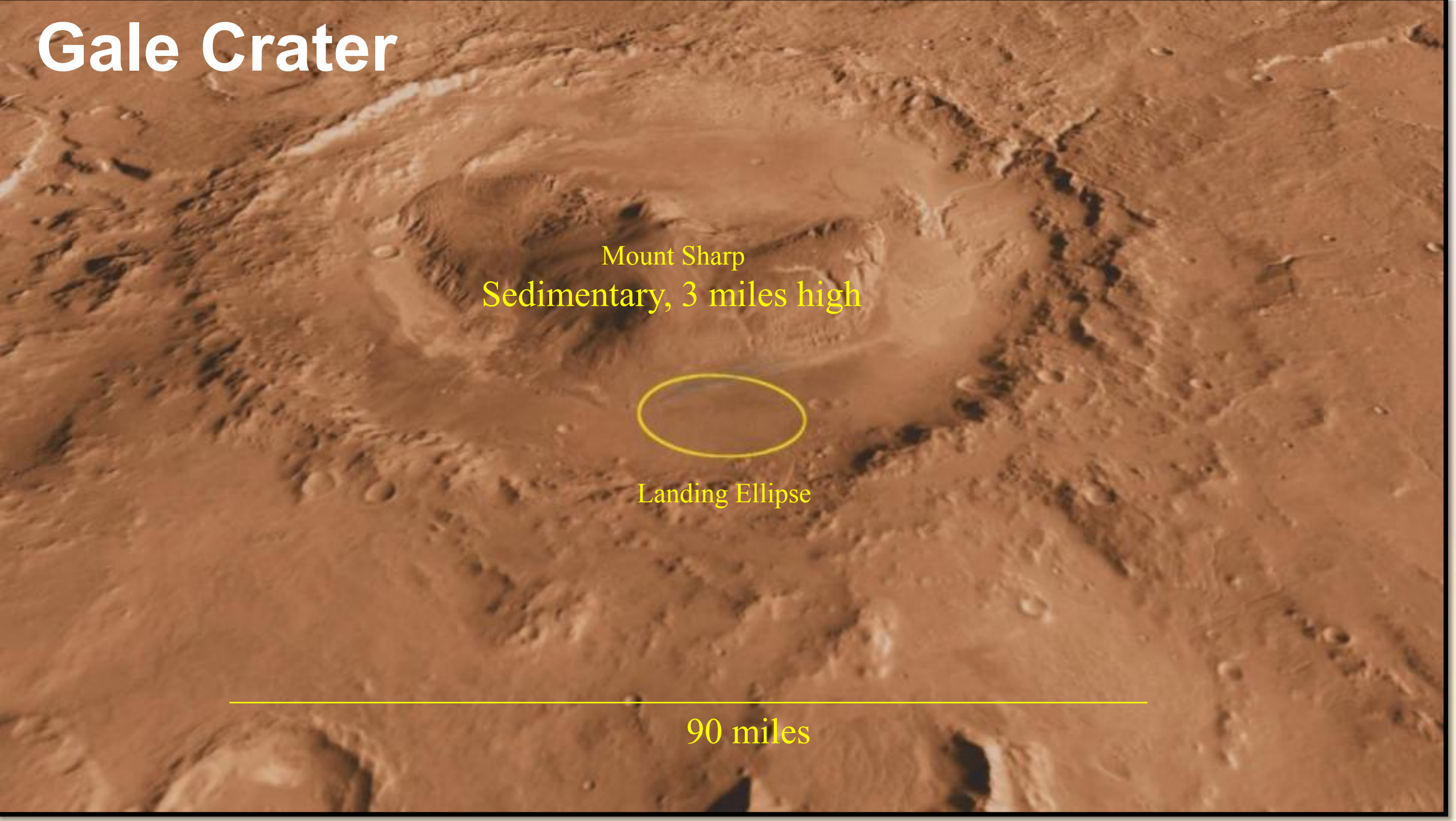
Was Mars Ever Like This?

Abe et al., 2011

Kees Veenenbos

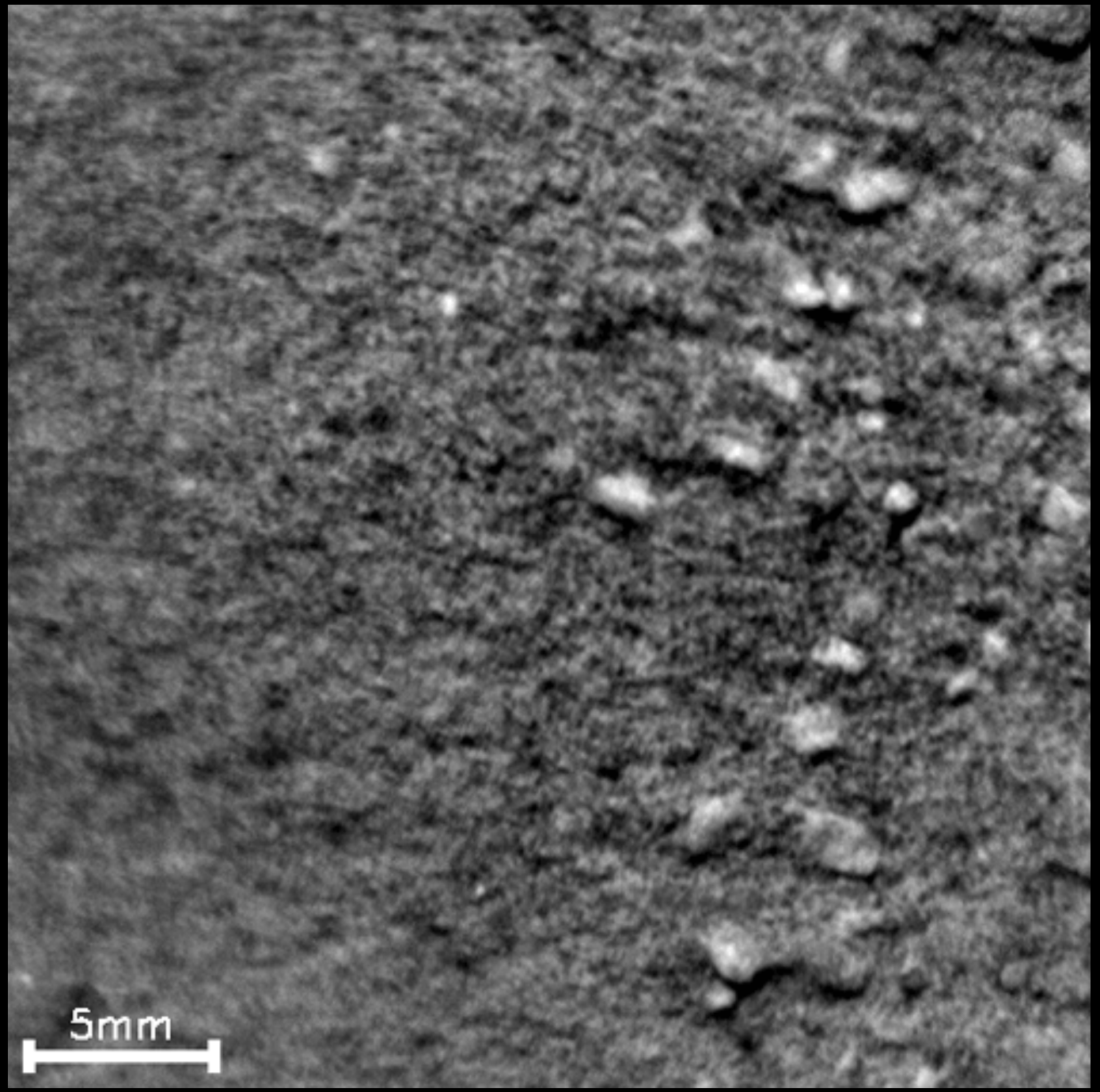

Mars River Delta
Eberswalde Crater
2 km
Viking 2
pportunity
Curiosity
Spirit

Gale Crater


Mount Sharp
Sedimentary, 3 miles high
Landing Ellipse
90 miles

NASA/JPL-Caltech/MSSS

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



NASA/JPL-Caltech/LANL/IRAP/IAS

Alluvial Debris from Crater Rim

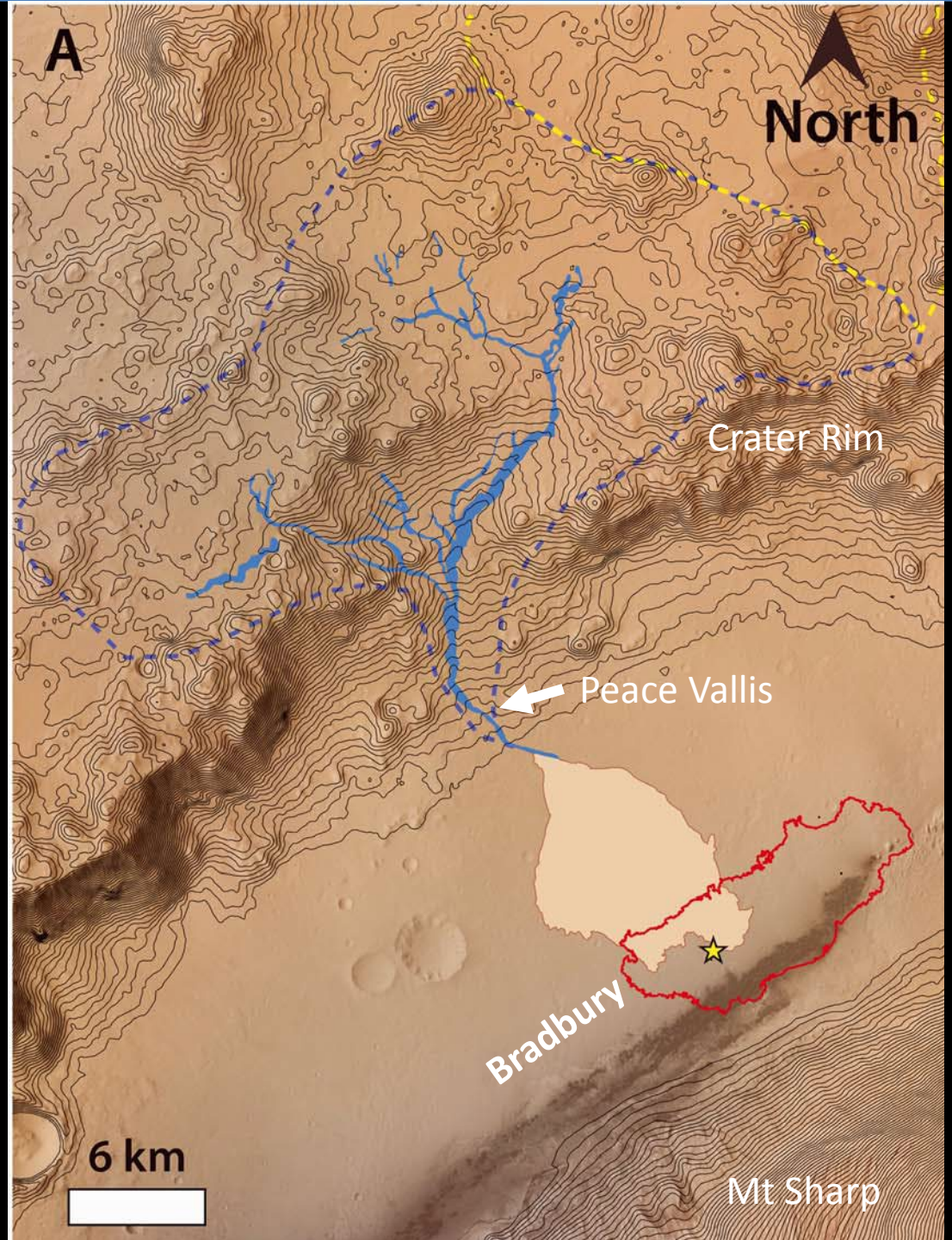


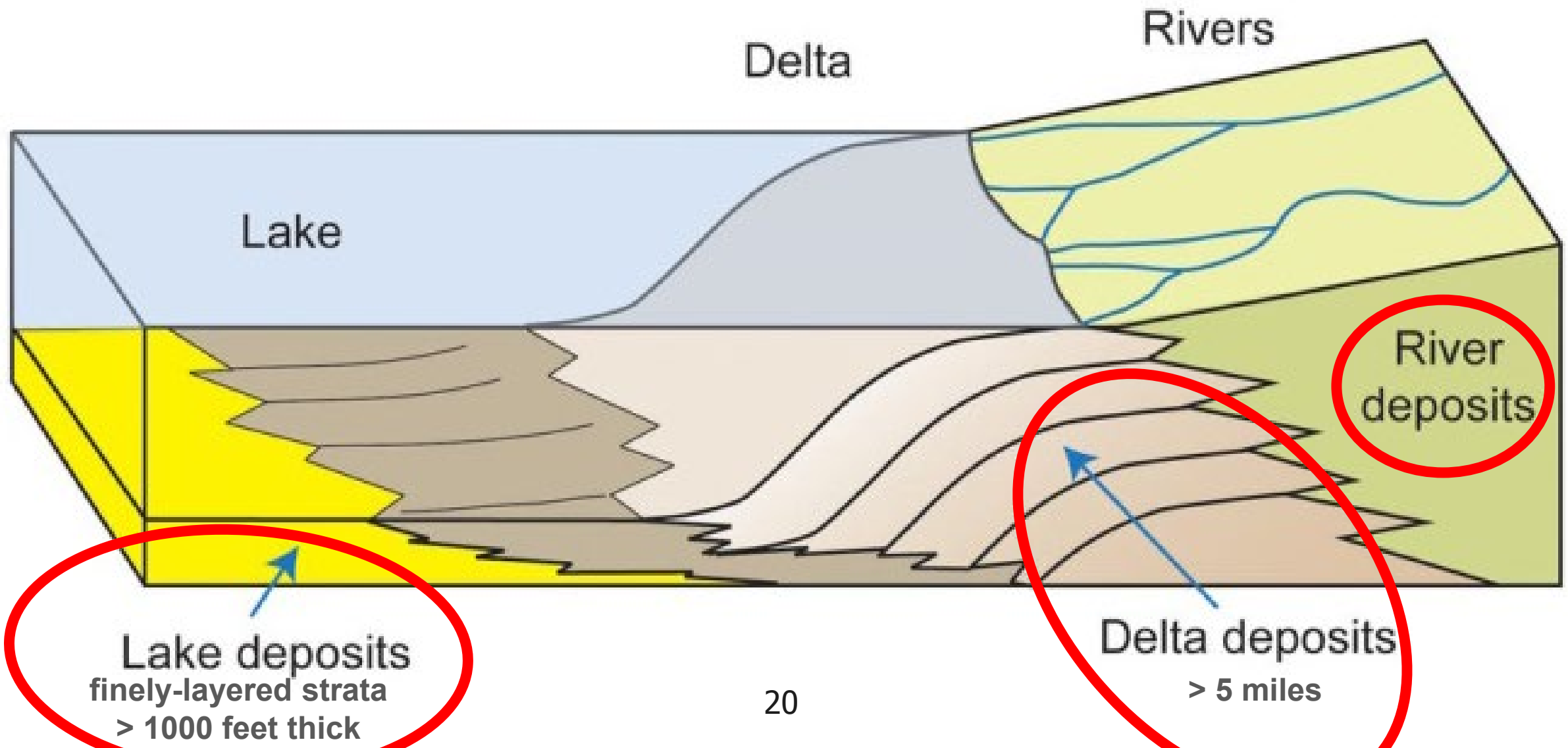
Image credit: Palucis et al., 2014

Conglomerate Outcrops Show Evidence of Ancient Rivers on Mars

Center-Dipping Beds Deposited as Gale Lake Filled with Sediment

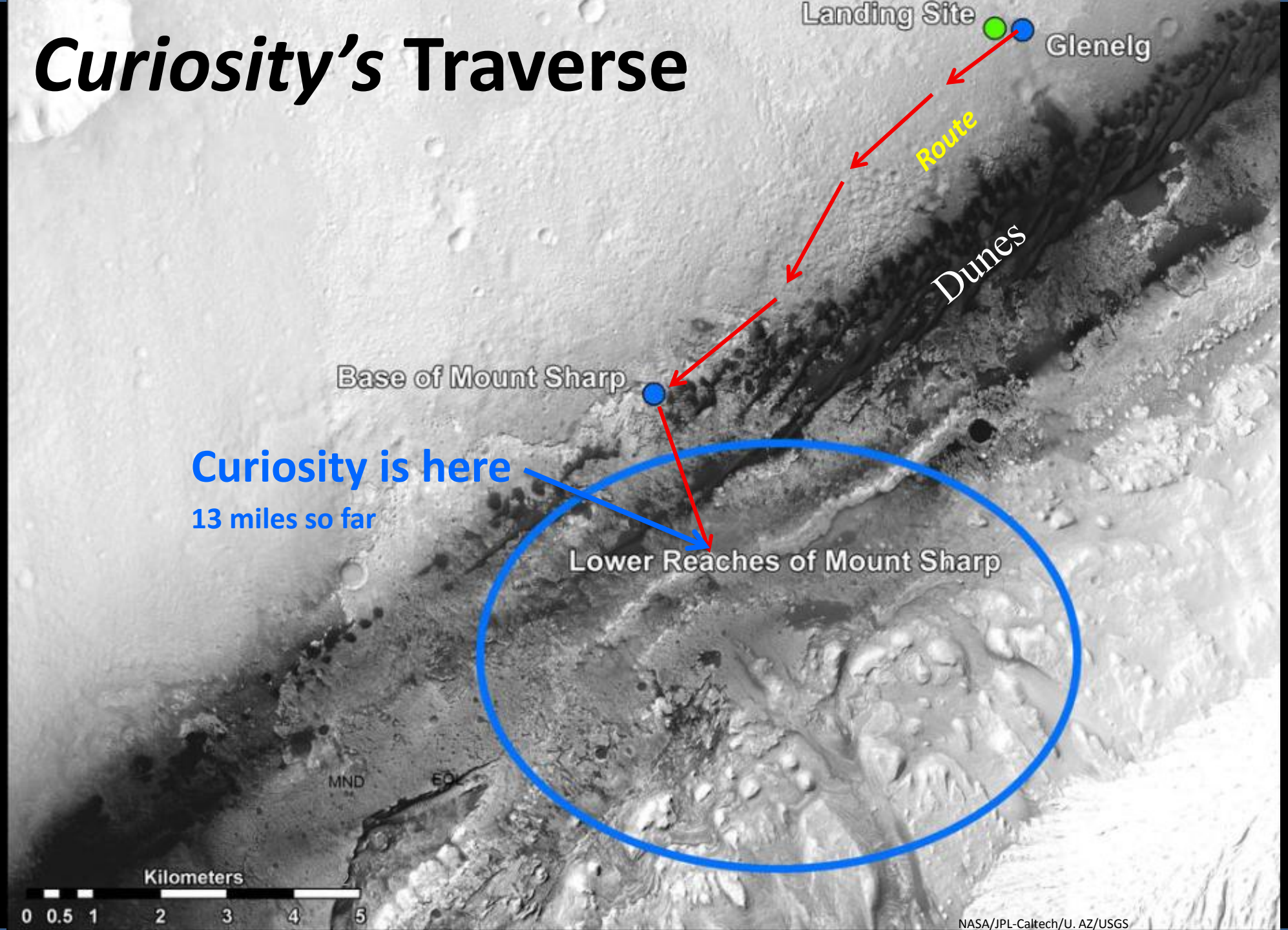
NASA/JPL-Caltech/MSSS

Massive Evidence for a Large, Long-Lived Lake



The Sediment Load Found in Gale Crater Must Have Taken a Long Time to be Deposited

Curiosity's Traverse



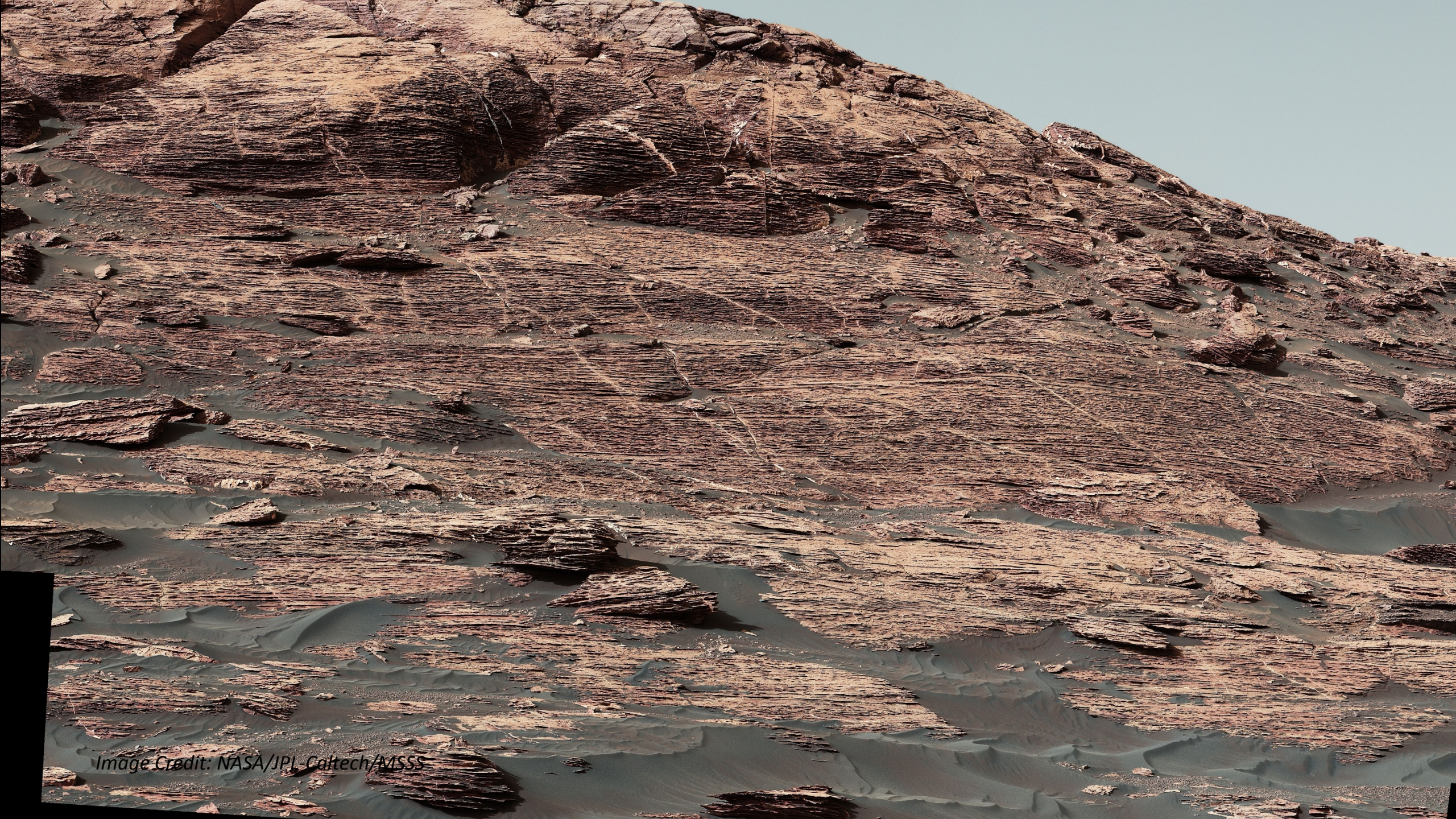
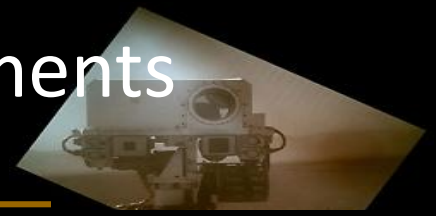
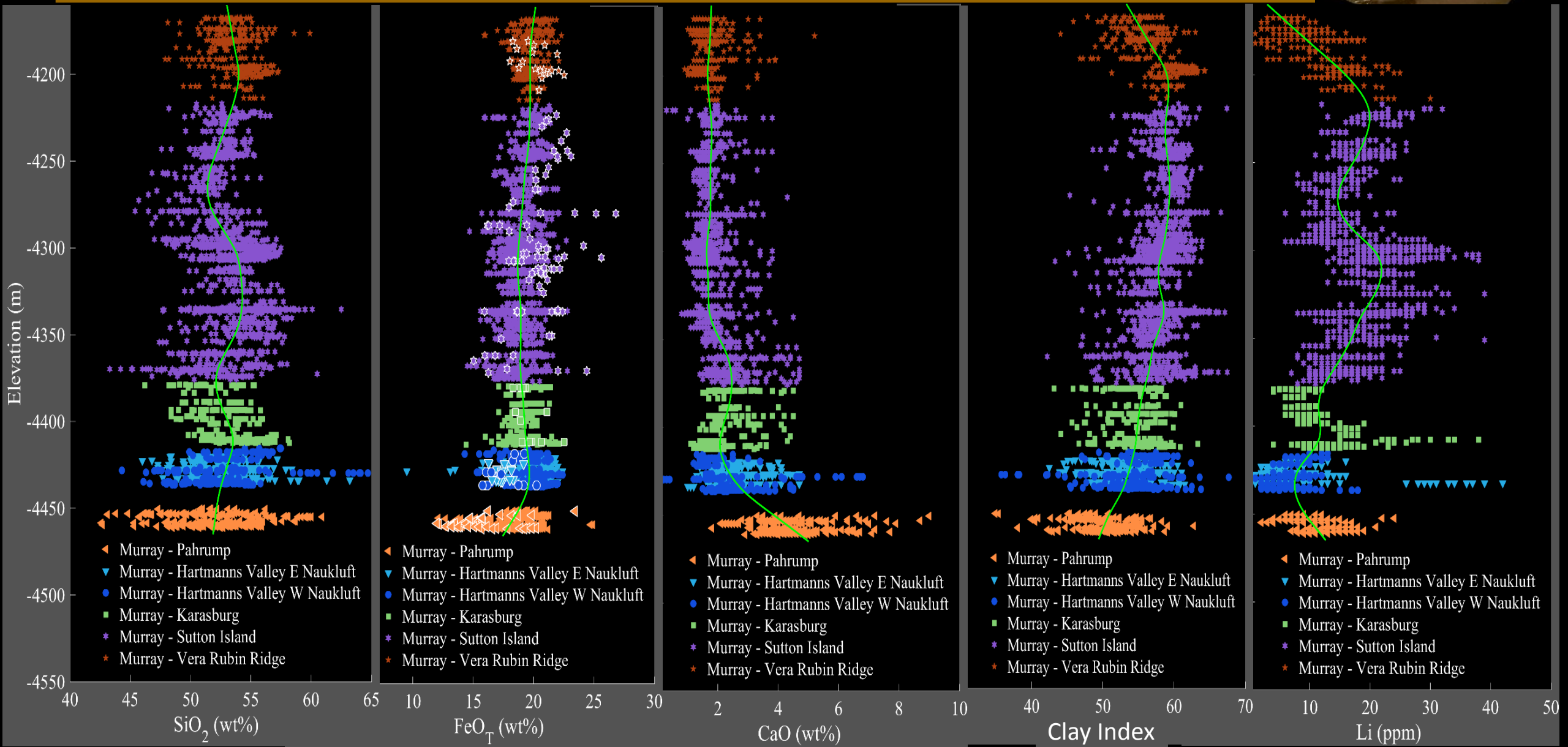


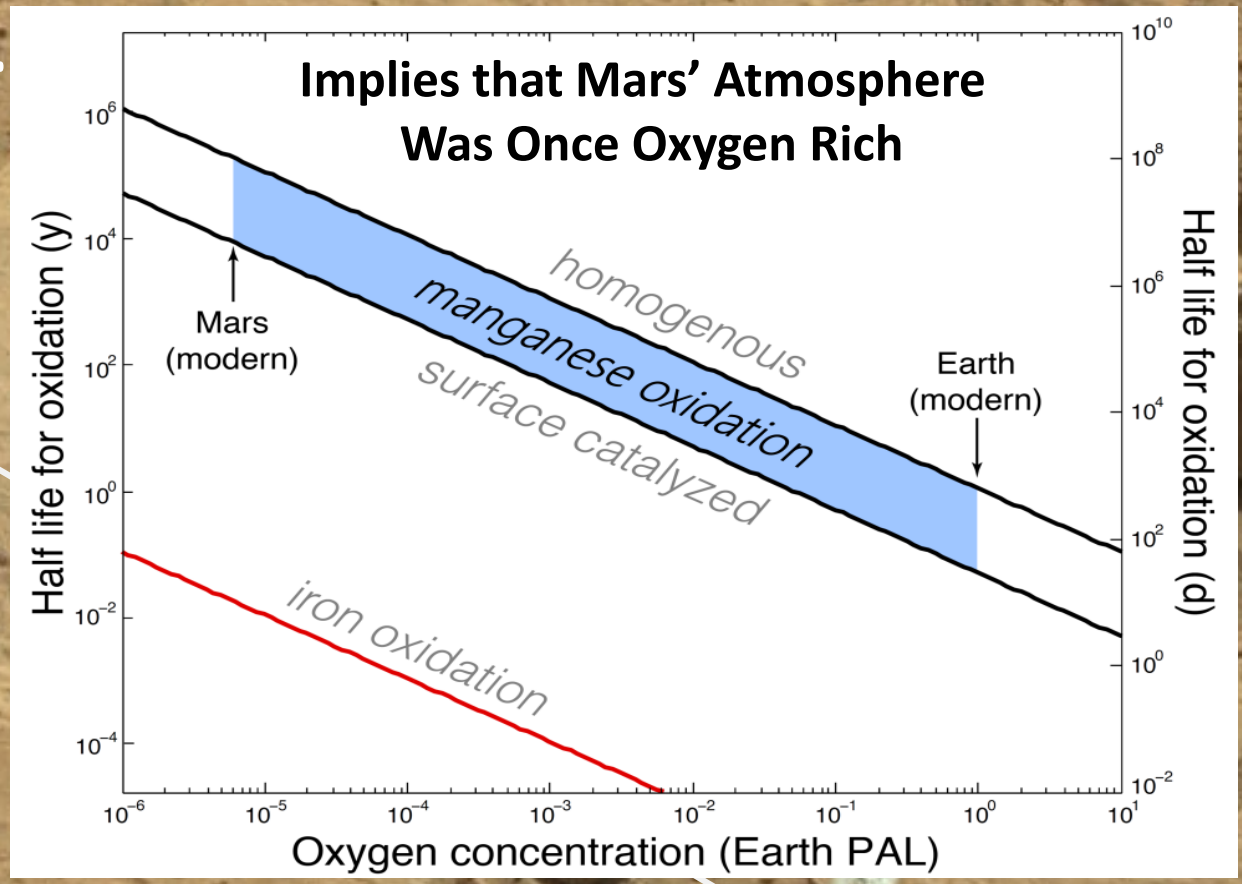
Image Credit: NASA/JPL-Caltech/MSSS

ChemCam Studies the Composition of Lakebed Sediments





Discovery of Manganese Oxide Coatings…

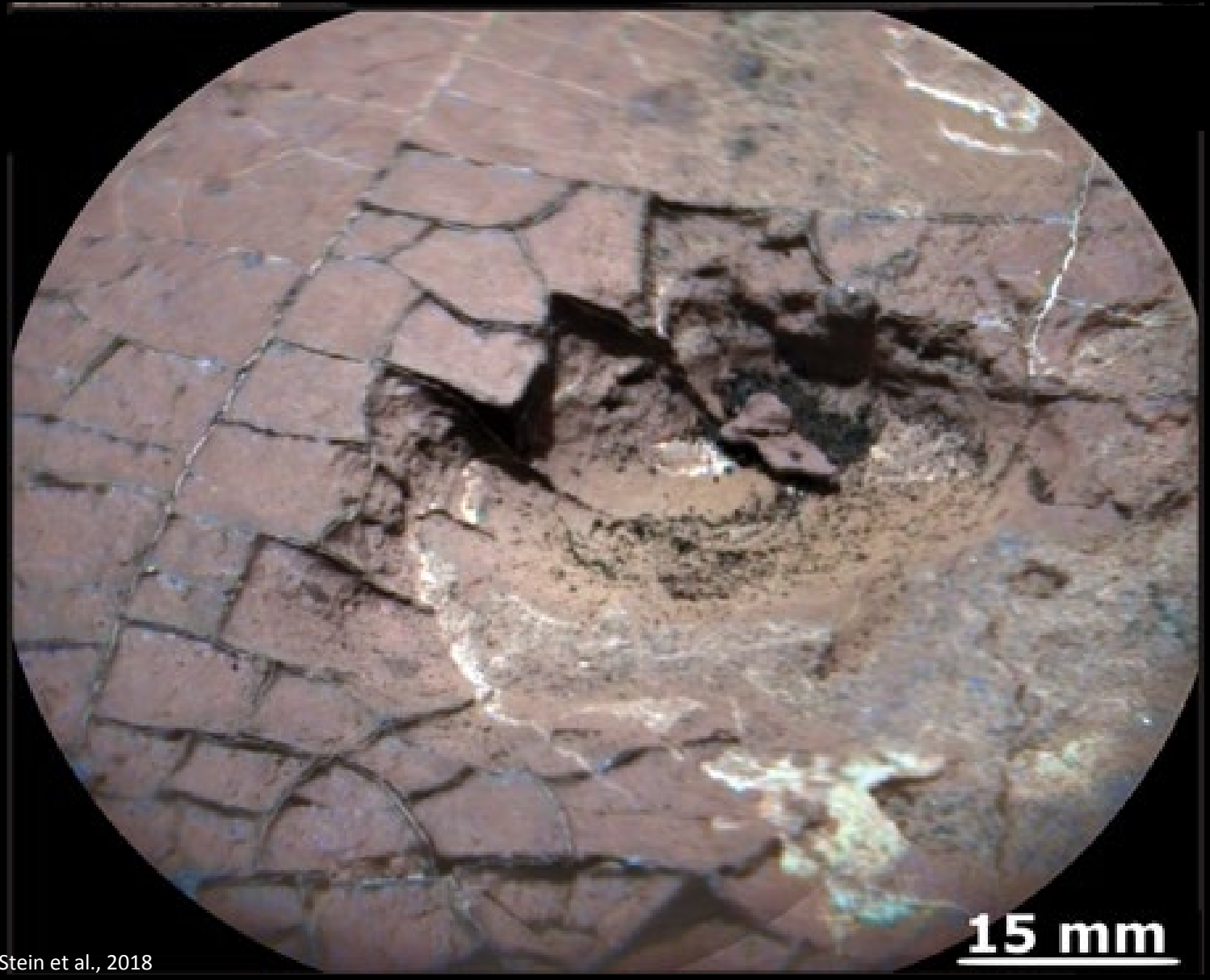


Nina Lanza, LANL

Is it Mars or New Mexico?

Murray Buttes

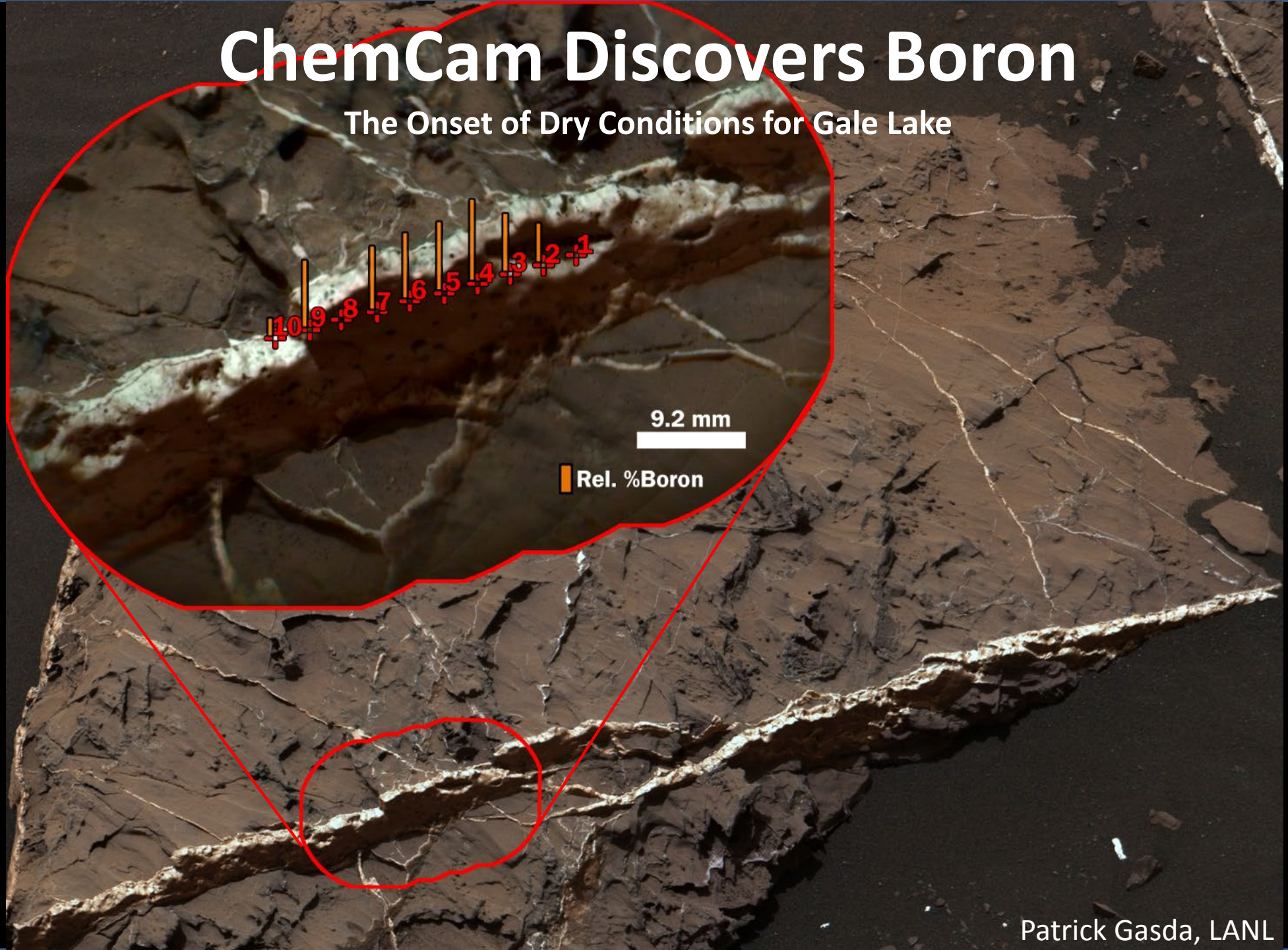
Mud Cracks in 3 Billion Year Old Sediments



Stein et al., 2018

ChemCam Discovers Boron

The Onset of Dry Conditions for Gale Lake



Patrick Gasda, LANL

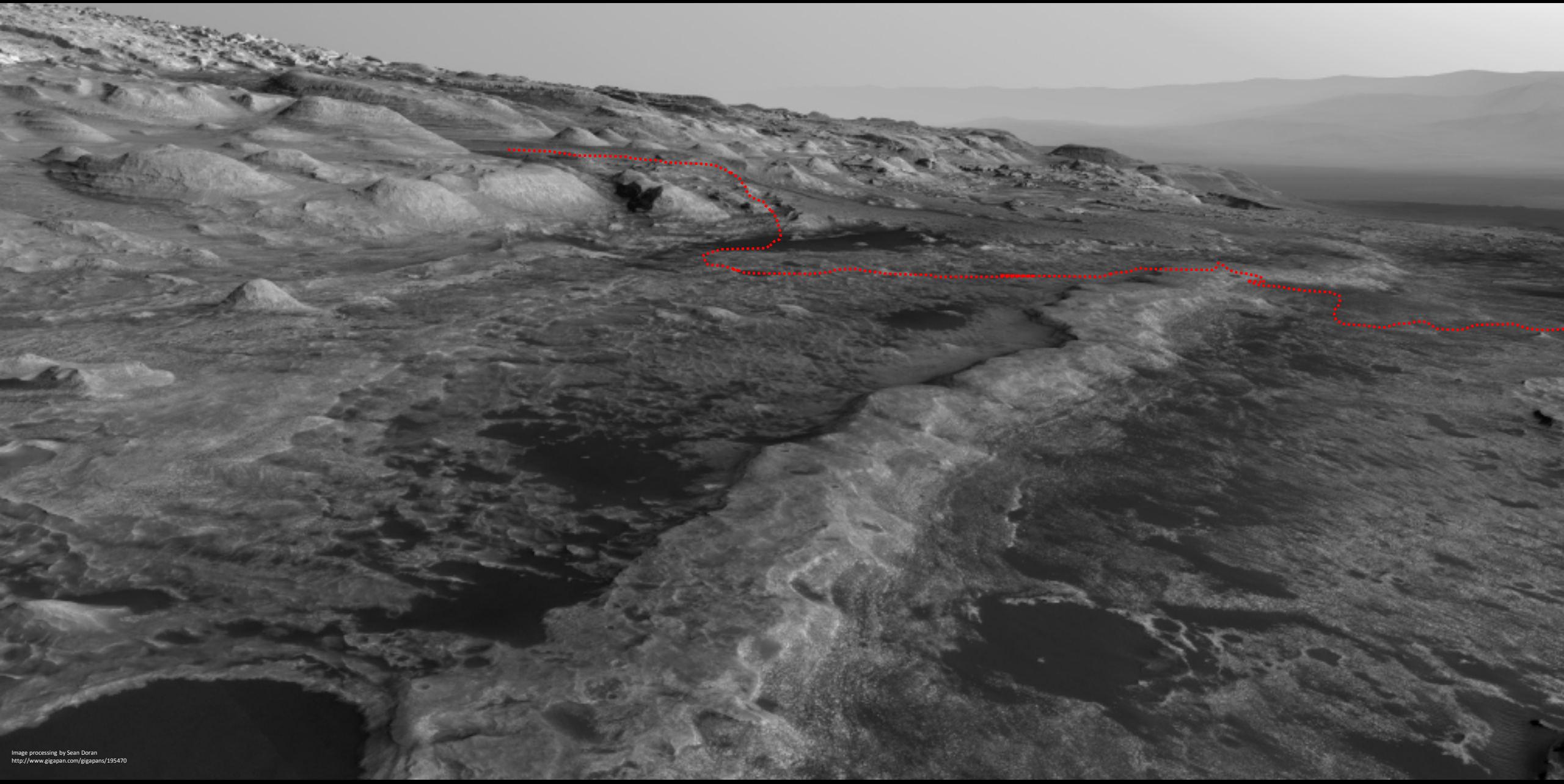


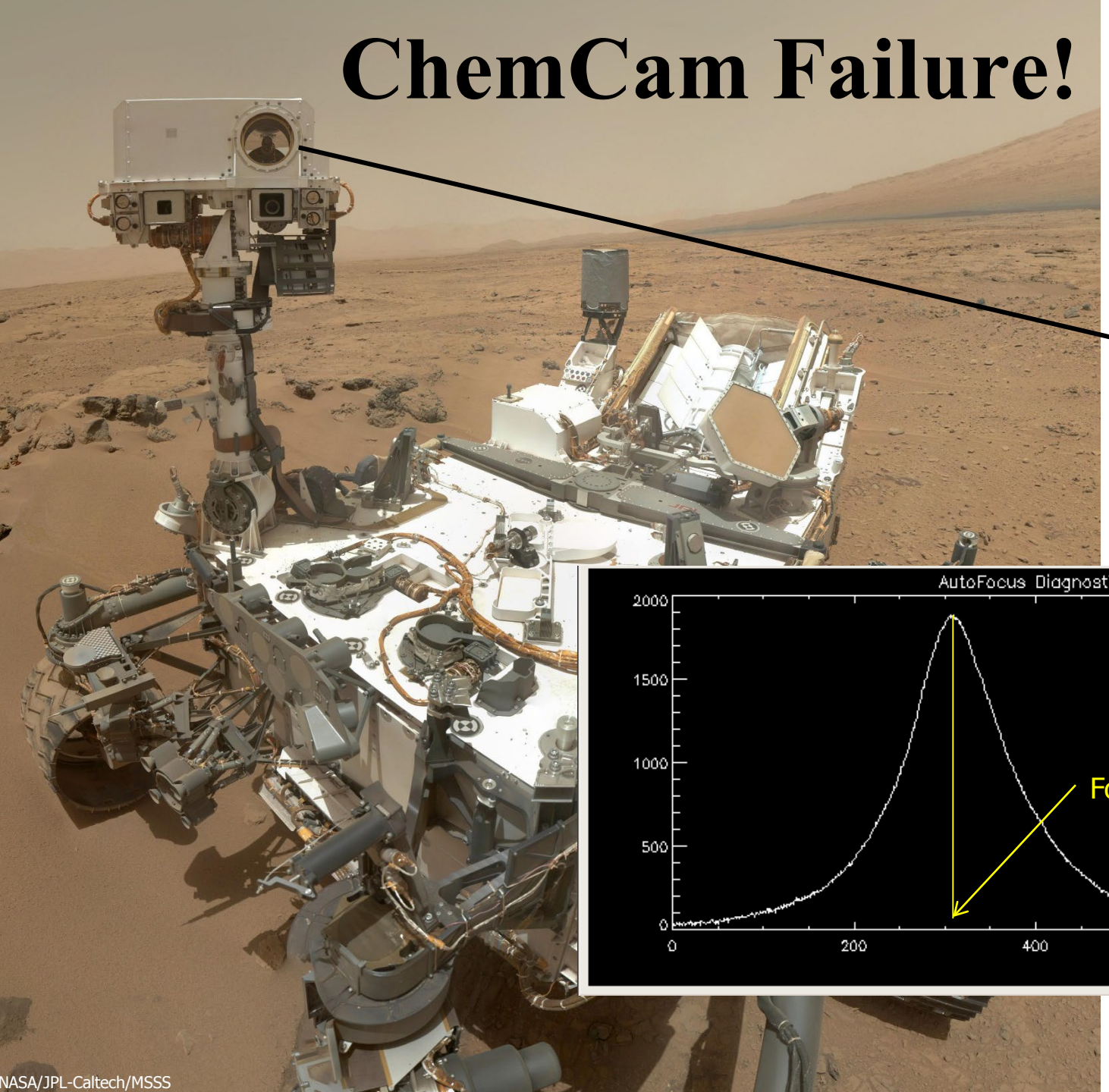
Image processing by Sean Doran
http://www.gigapan.com/gigapans/195470

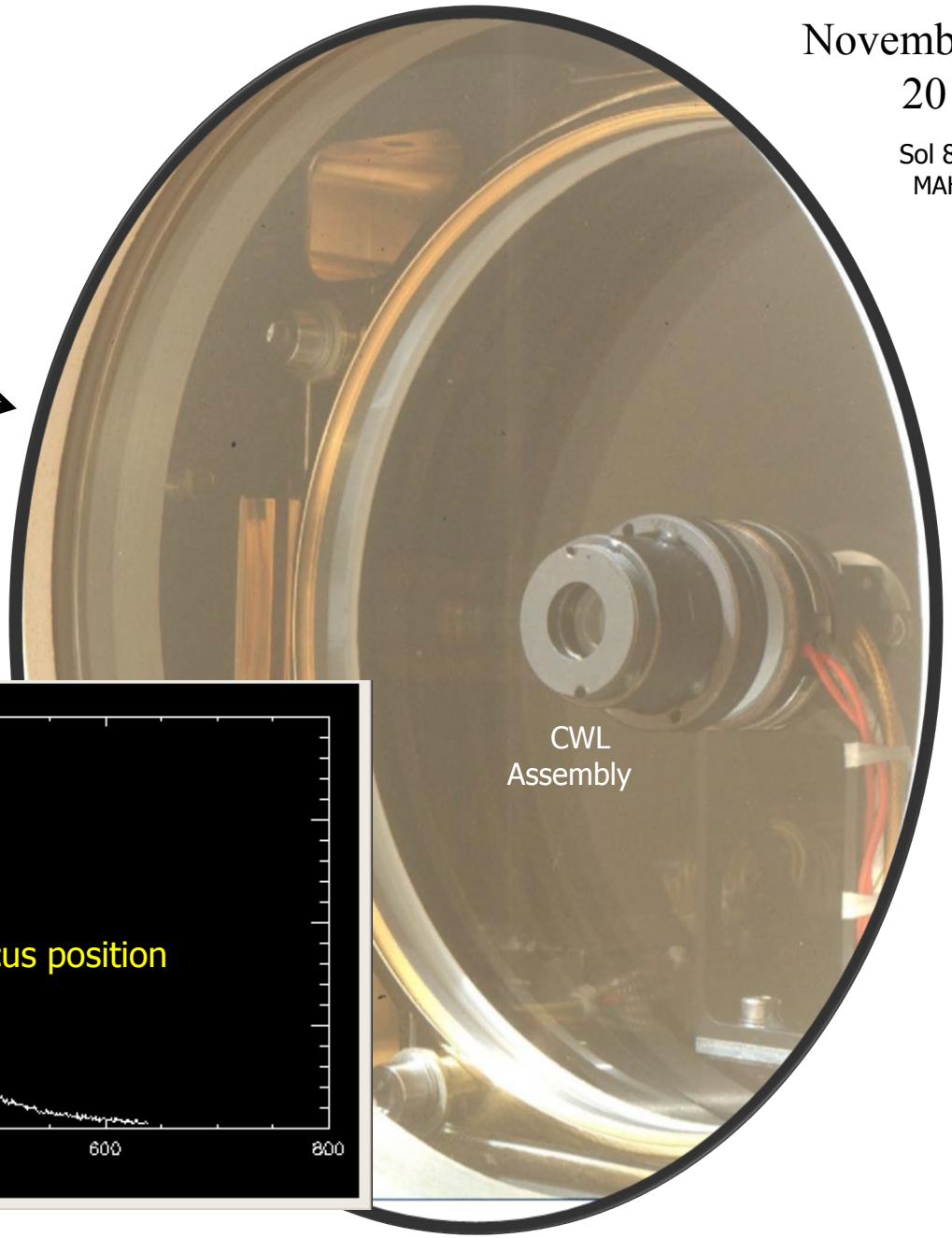

THE
MARTIAN
02:38

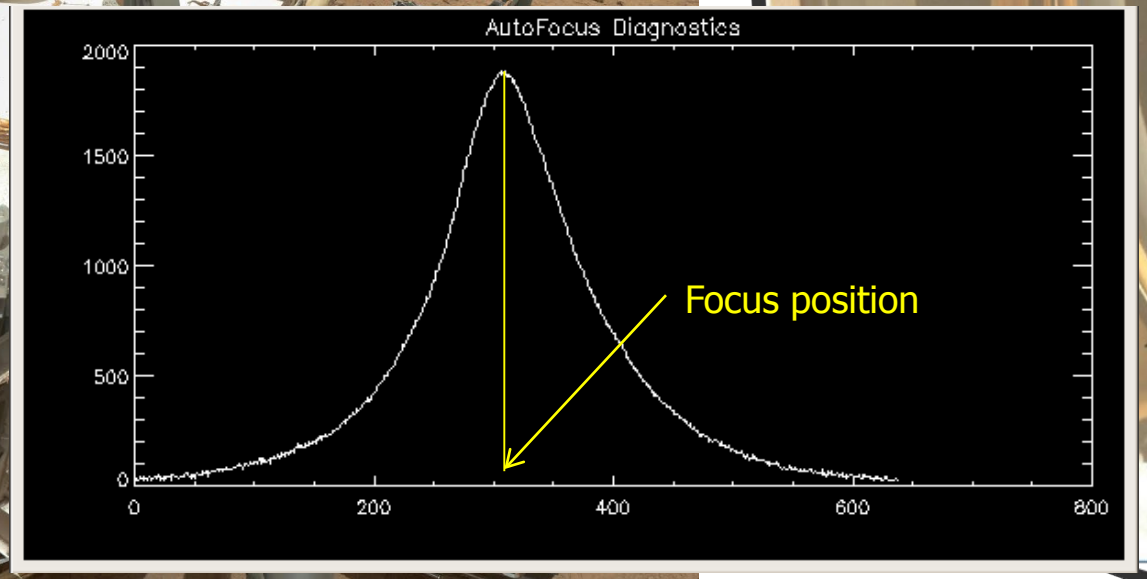
ChemCam Failure!

November 2014

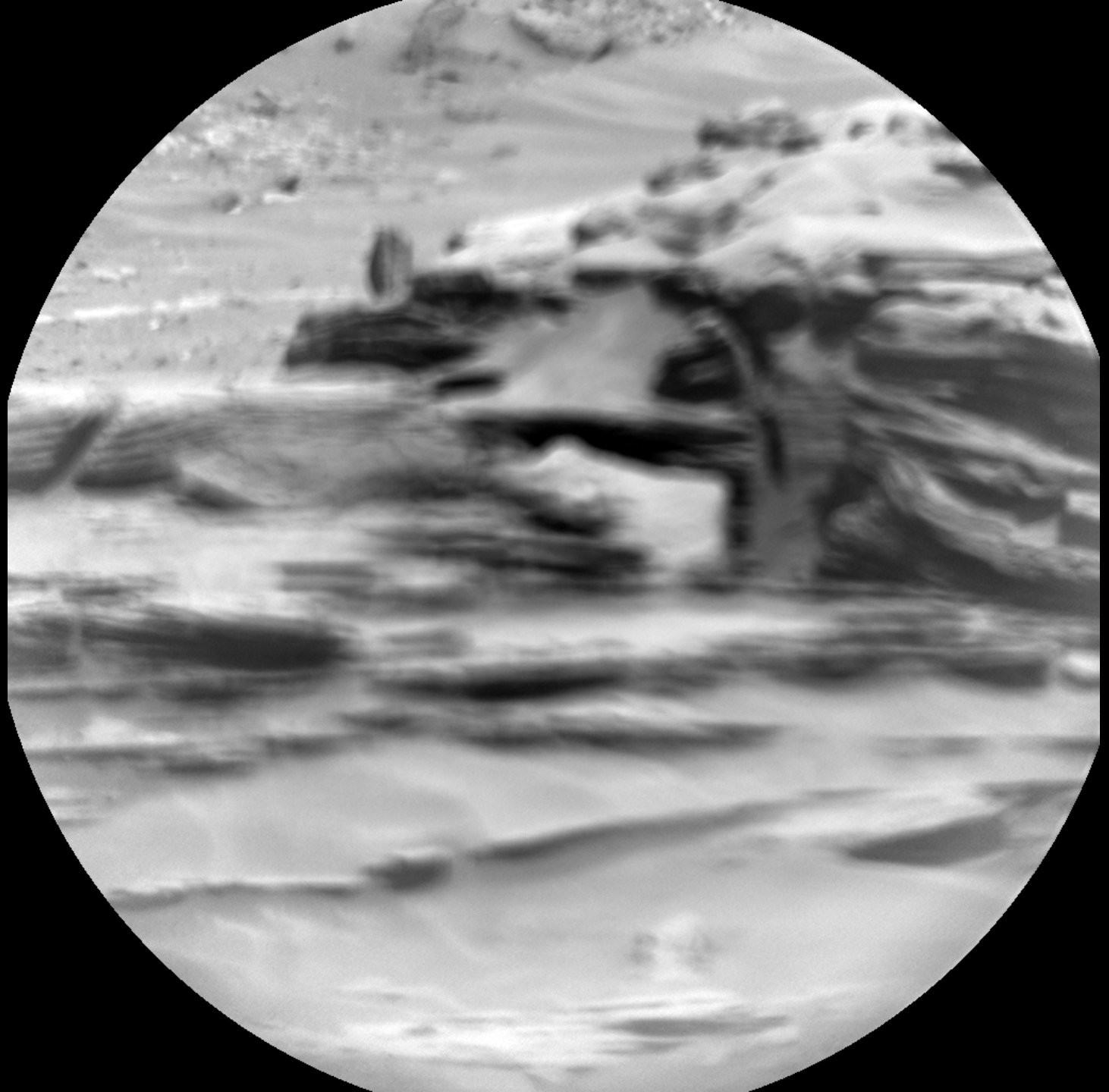
Sol 808
MAHLI

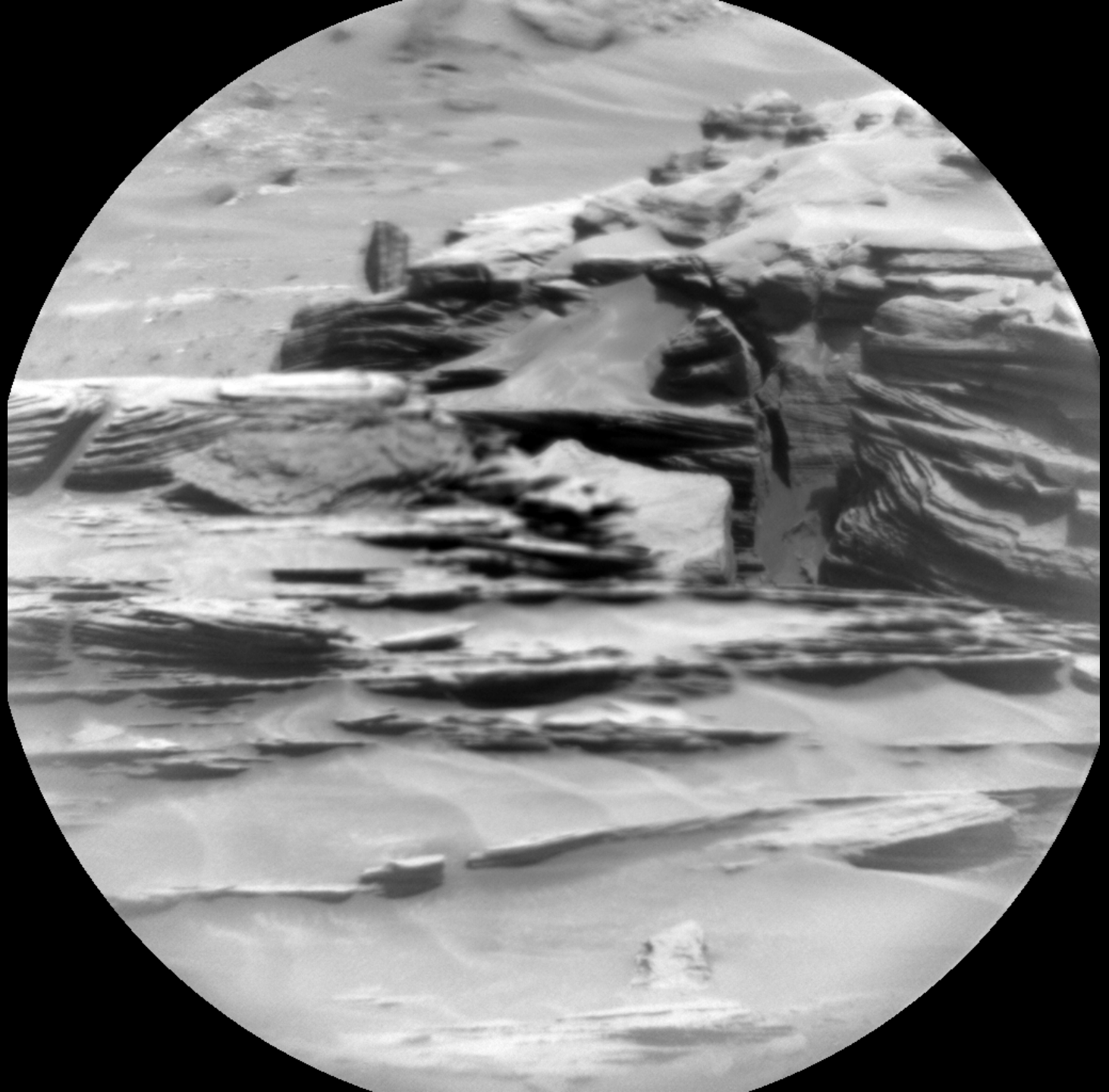


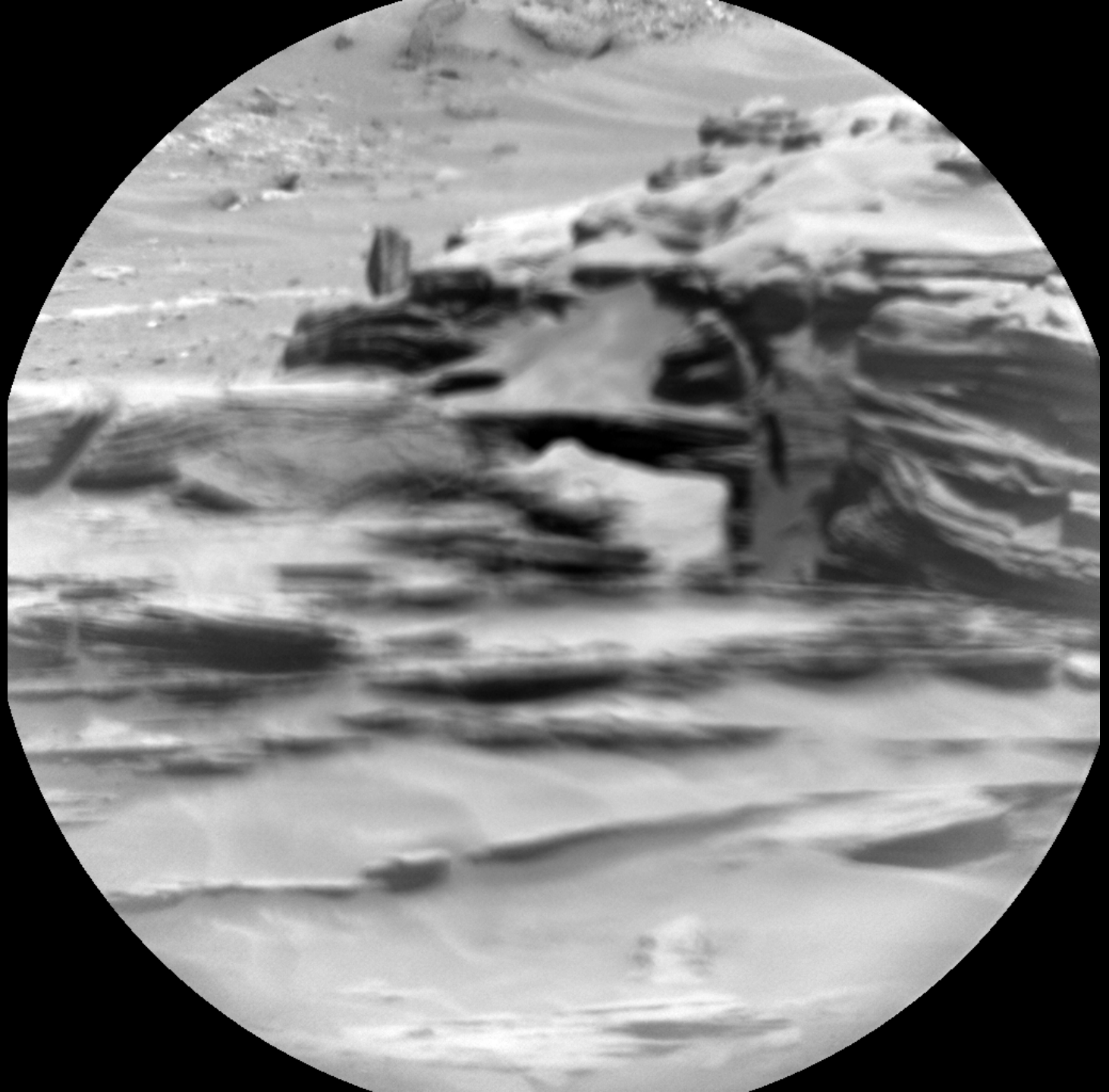




NASA/JPL-Caltech/MSSS





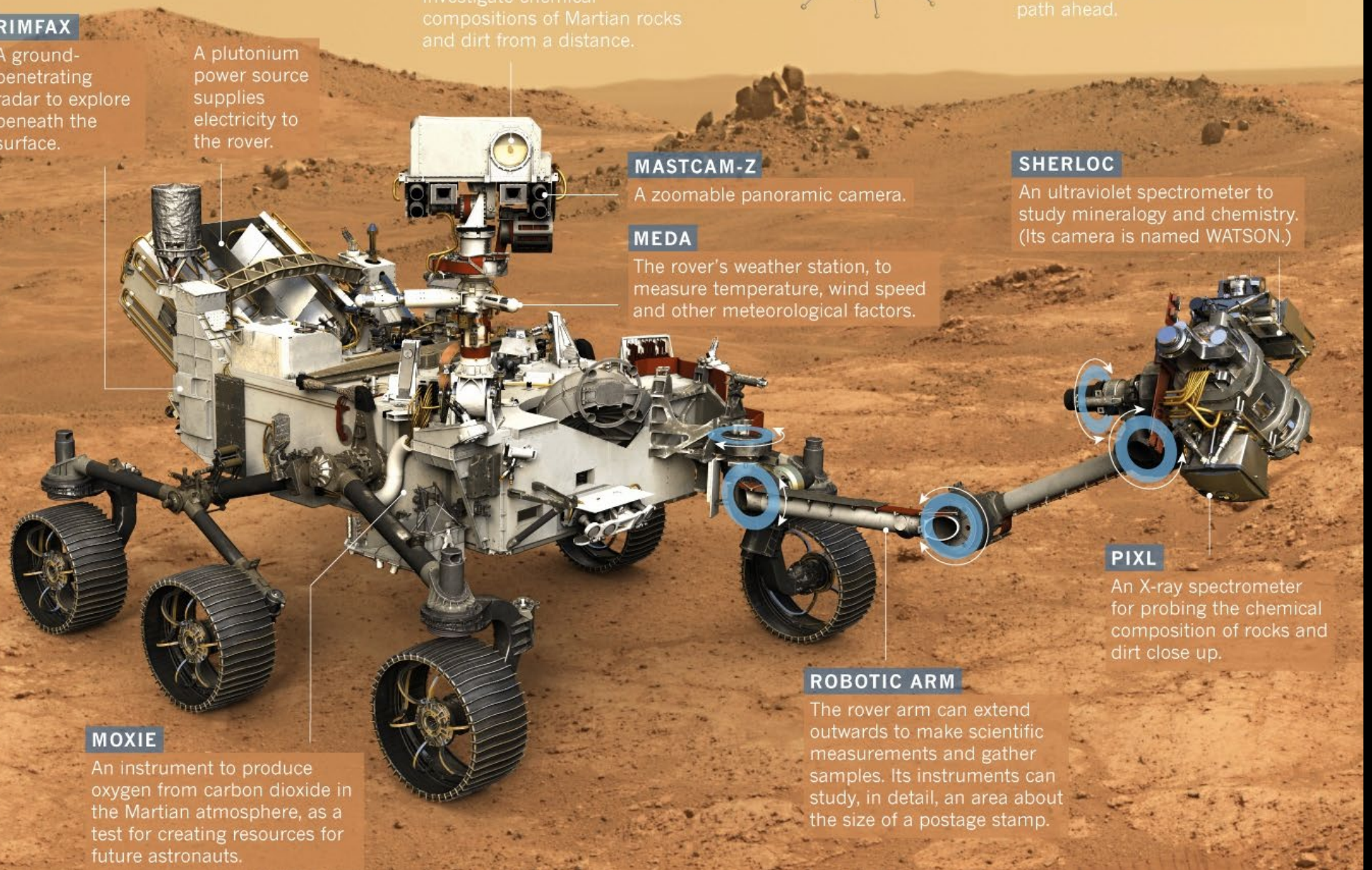


NASA's Next Rover: 2020

To Collect Samples for Return to Earth

SAMPLING MARS

In 2020, NASA plans to send a rover to Mars to collect and store tubes of rock and dirt. The plutonium-powered vehicle will have seven instruments and may also carry a helicopter.



RIMFAX
A ground-penetrating radar to explore beneath the surface.

A plutonium power source supplies electricity to the rover.

SUPERCAM
A laser blaster that can investigate chemical compositions of Martian rocks and dirt from a distance.

HELICOPTER
The rover may carry a helicopter that would fly through the thin atmosphere and scout out the path ahead.

MASTCAM-Z
A zoomable panoramic camera.

MEDA
The rover's weather station, to measure temperature, wind speed and other meteorological factors.

SHERLOC
An ultraviolet spectrometer to study mineralogy and chemistry. (Its camera is named WATSON.)

PIXL
An X-ray spectrometer for probing the chemical composition of rocks and dirt close up.

ROBOTIC ARM
The rover arm can extend outwards to make scientific measurements and gather samples. Its instruments can study, in detail, an area about the size of a postage stamp.

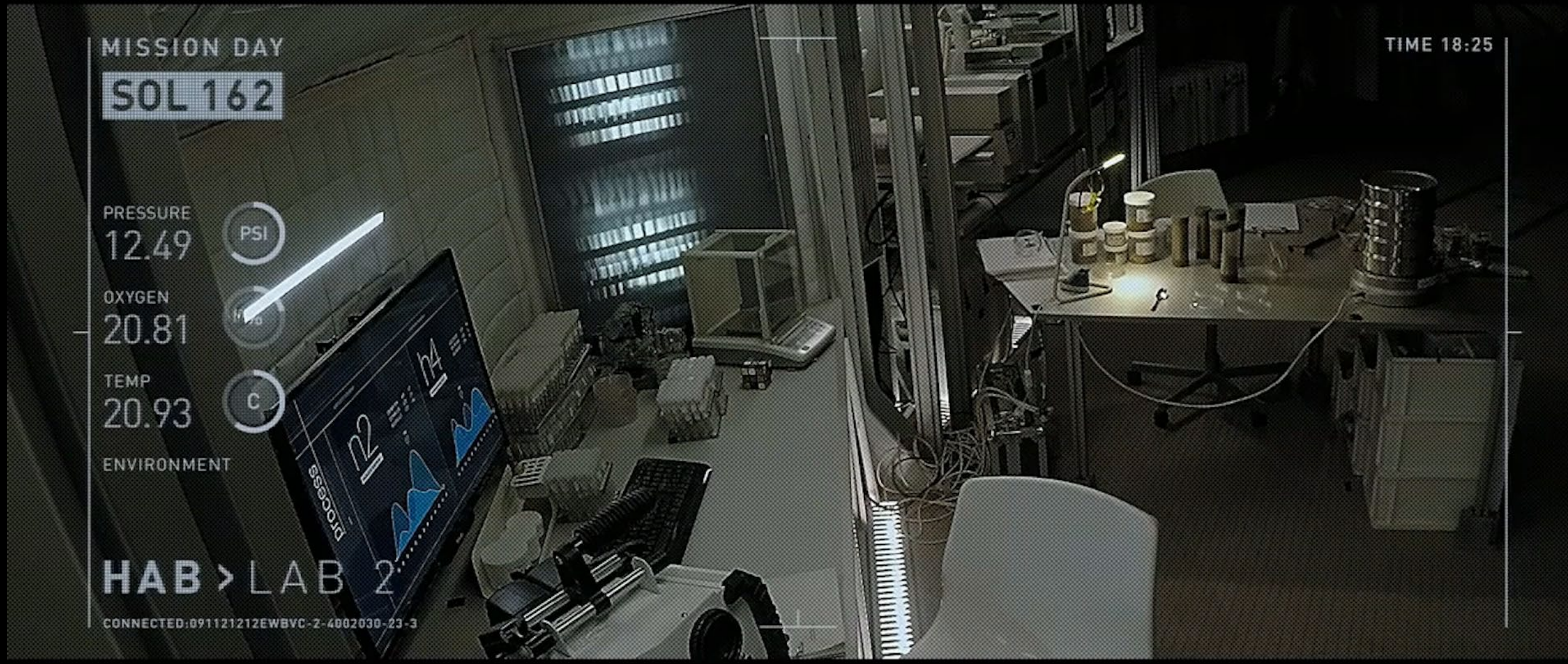
MOXIE
An instrument to produce oxygen from carbon dioxide in the Martian atmosphere, as a test for creating resources for future astronauts.

Mars Sample Return

Mid to late 2020s?

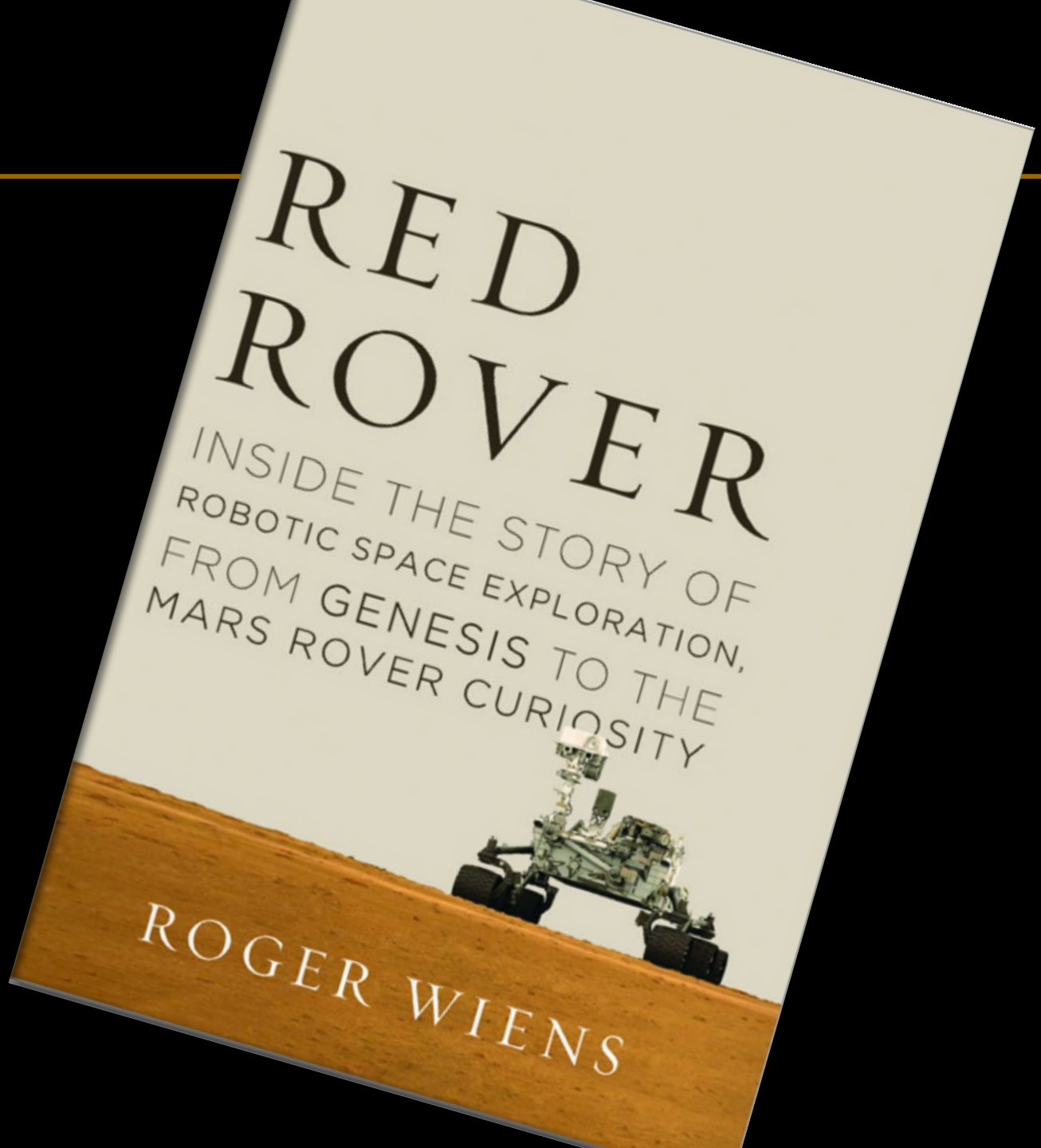
And Someday...


A RIDLEY SCOTT FILM
MATT DAMON
THE MARTIAN
BRING HIM HOME
SIMON KINBERG RIDLEY SCOTT MICHAEL SCHAEFER ADITYA SOOD MARK HUFFAM
REALD 3D
DIGITAL 3D
ANDY WEIR
DREW GODDARD
RIDLEY SCOTT
#TheMartian
TheMartianMovie.com
NOVEMBER


MISSION DAY
SOL 162
TIME 18:25
PRESSURE
12.49
PSI
OXYGEN
20.81
TEMP
20.93
C
ENVIRONMENT
HAB > LAB 2
CONNECTED:091121212EWBVC-2-4002030-23-3

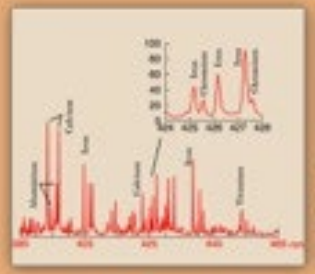
http://www.msl-chemcam.com

NASA/JPL-Caltech/MSSS

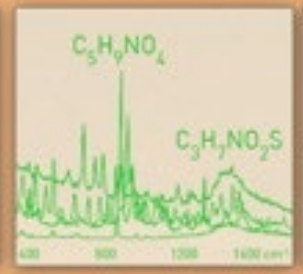

RED ROVER
INSIDE THE STORY OF ROBOTIC SPACE EXPLORATION, FROM GENESIS TO THE MARS ROVER CURIOSITY
ROGER WIENS

SUPERCAM

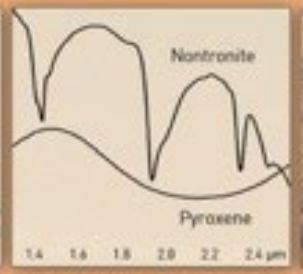
AN INSTRUMENT SUITE FOR THE MARS 2020 ROVER



LIBS Capability

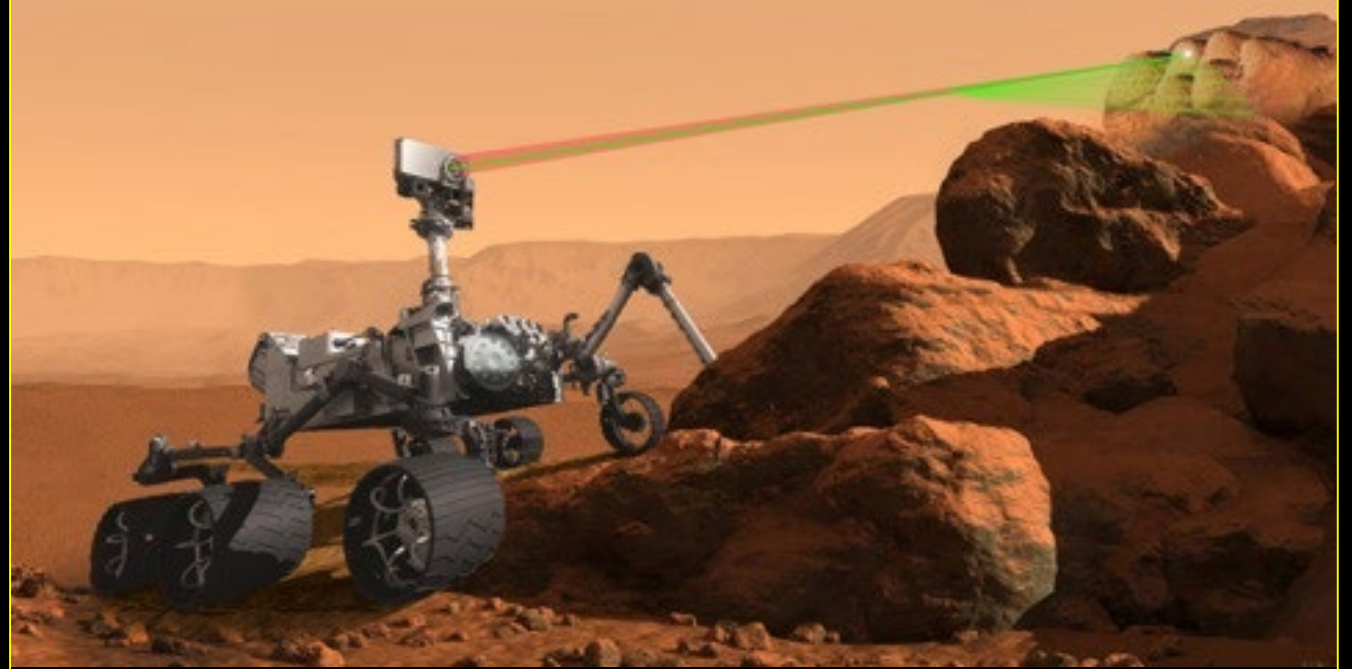


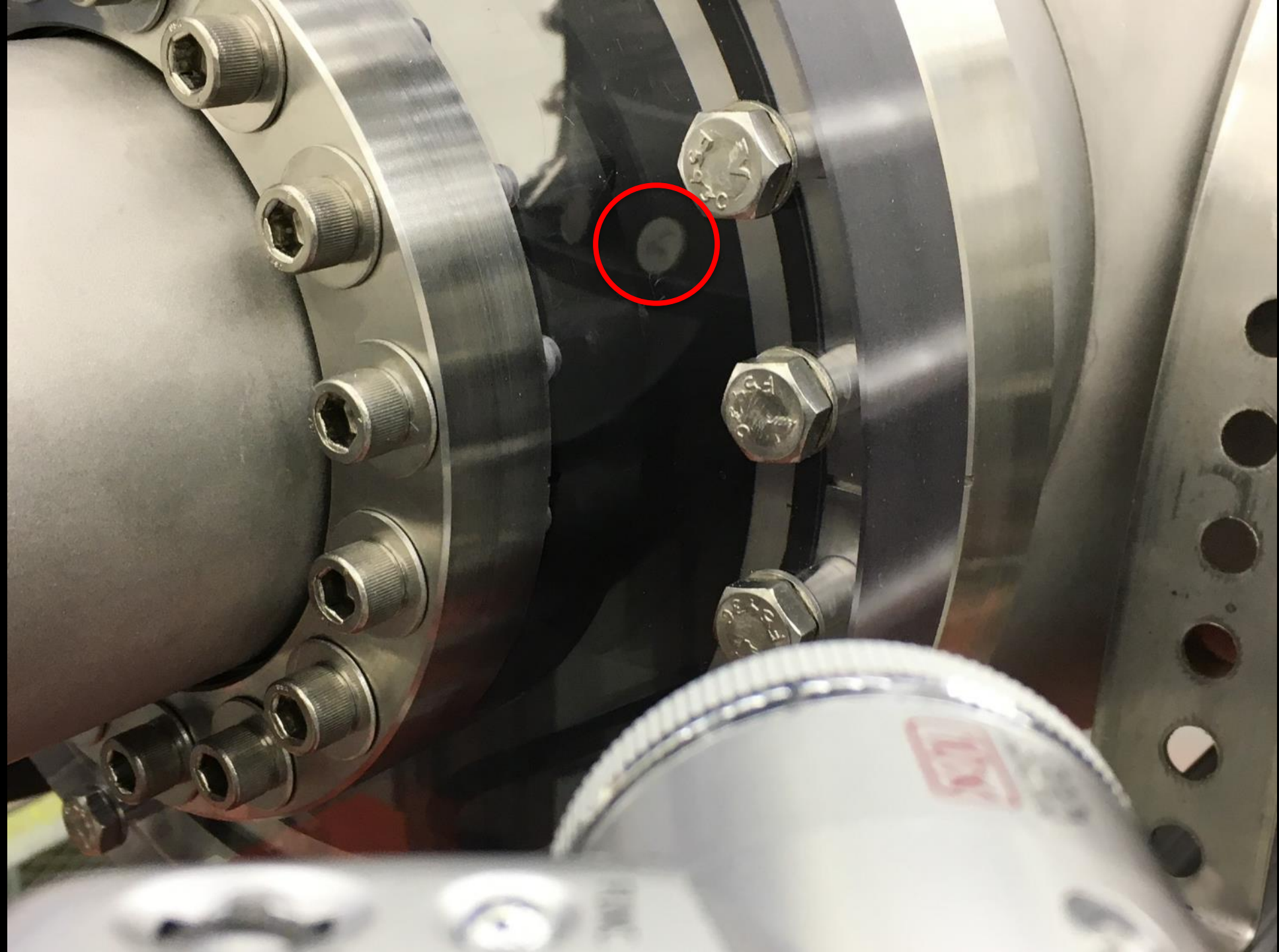
Raman & Time-resolved Fluoresence

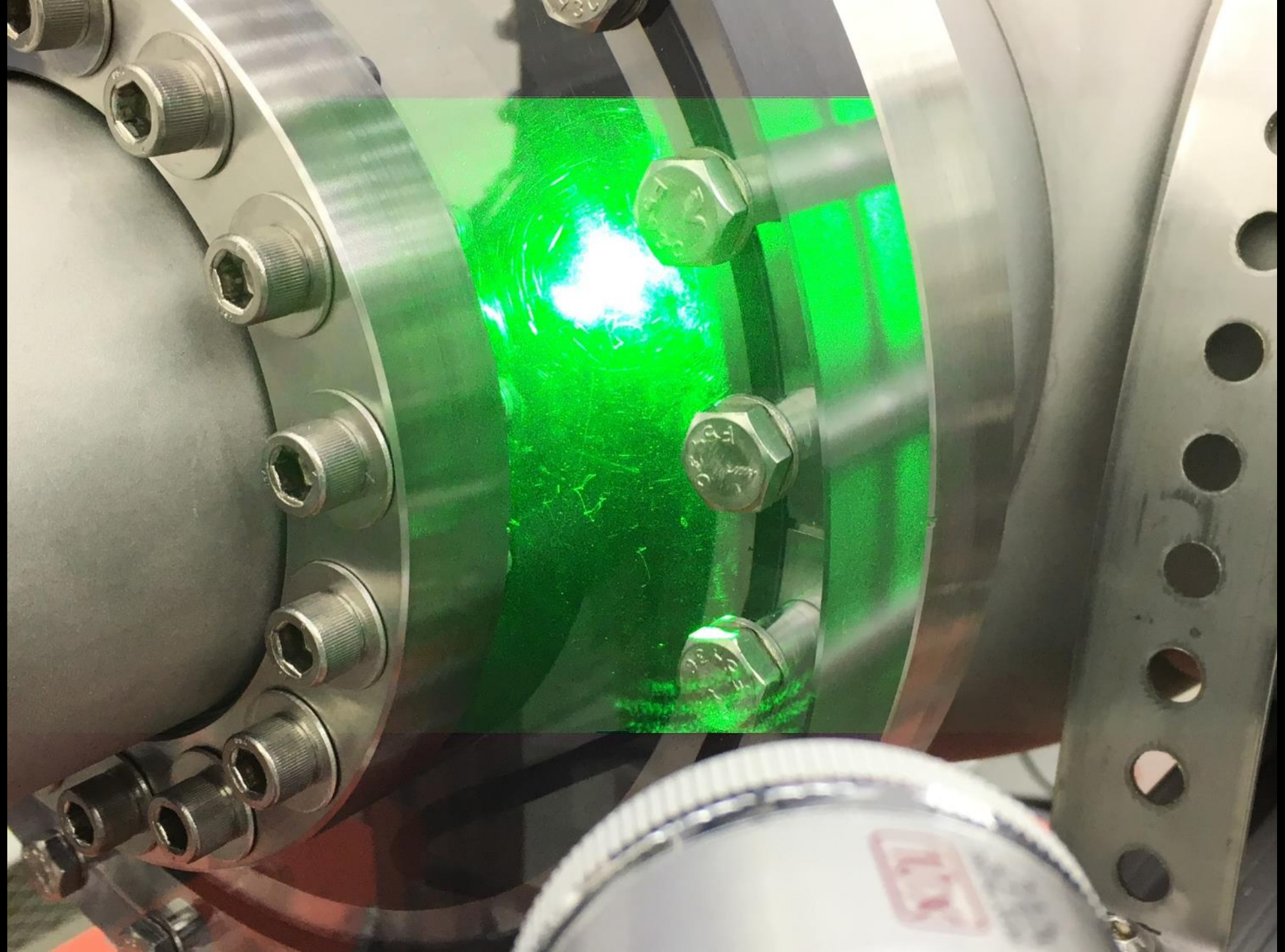


VISIR Spectra

Color Micro Imaging

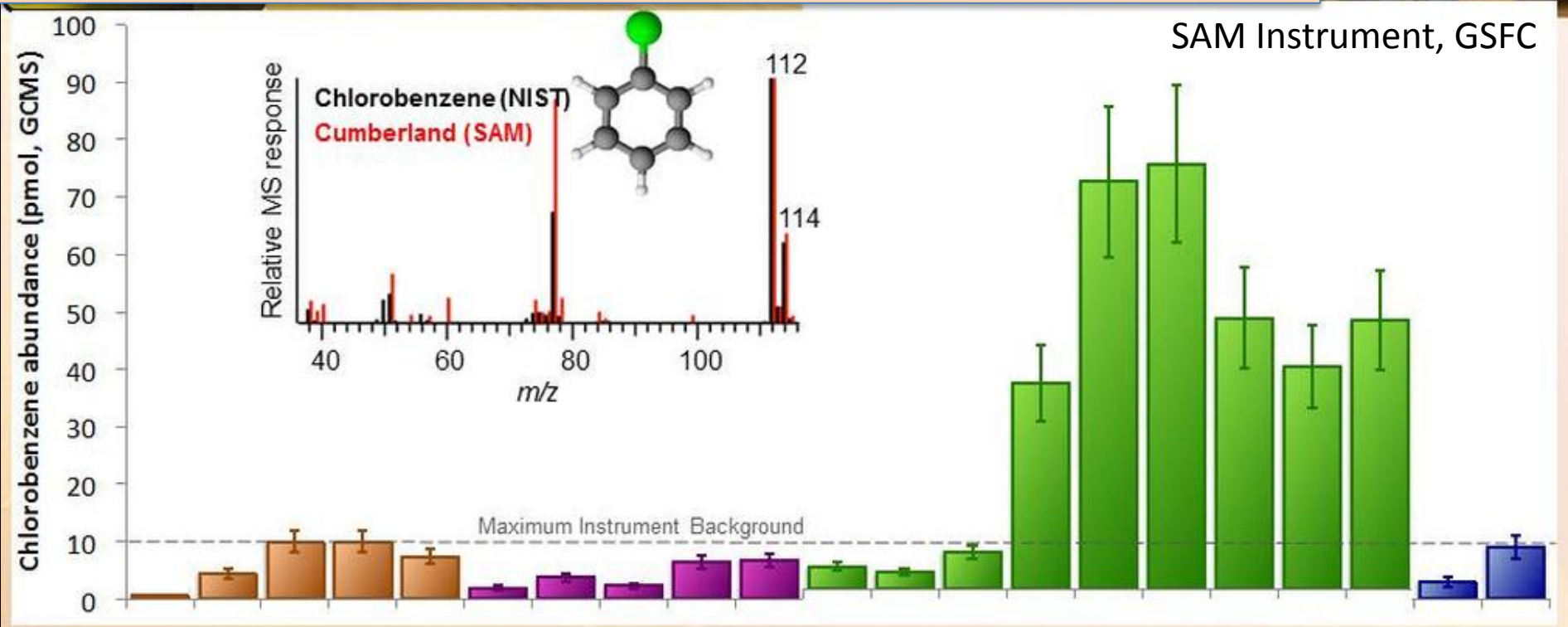




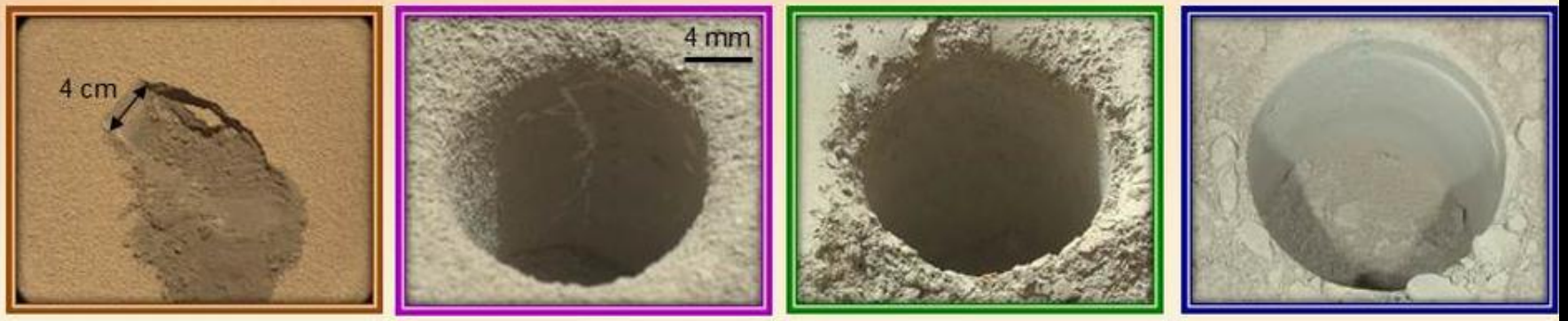


Organic Molecules Found On Mars

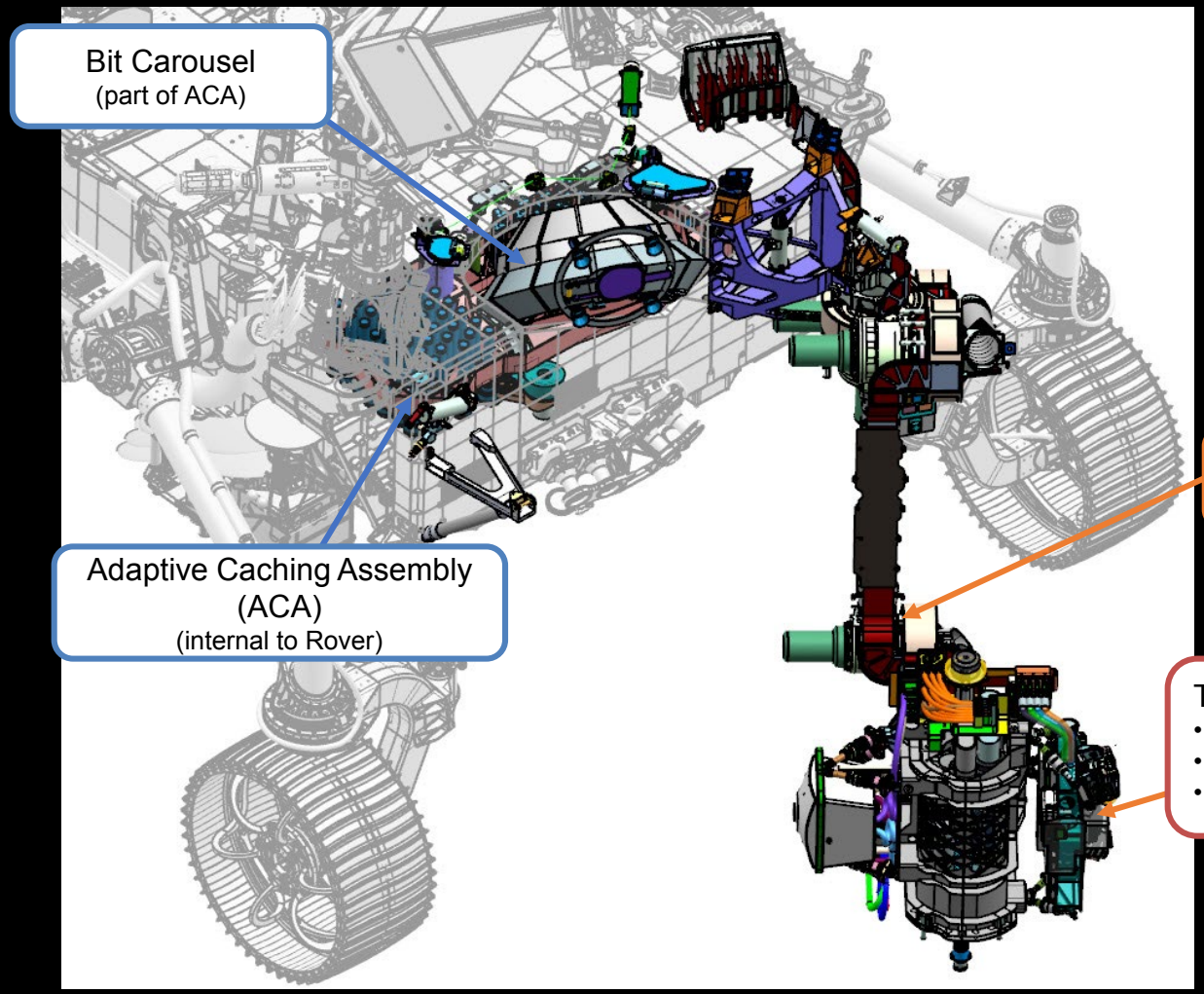
SAM Instrument, GSFC

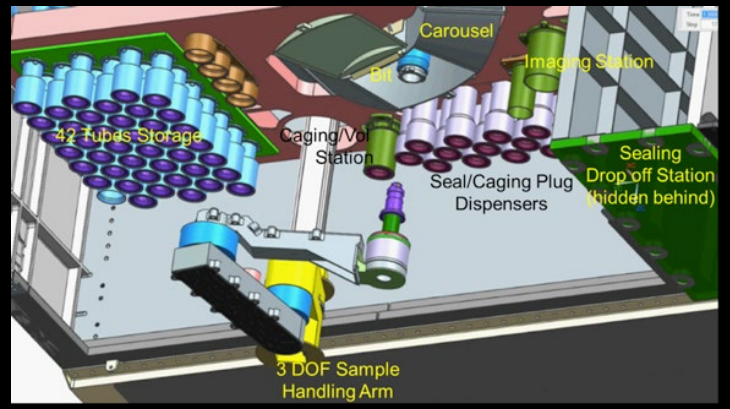


ROCKNEST | JOHN KLEIN | CUMBERLAND | CONFIDENCE HILLS



Sampling & Caching Subsystem





~ 42 sample tubes

Image Credit: NASA/JPL-Caltech

Coring

Hermetically sealed sample tube

Coring bit

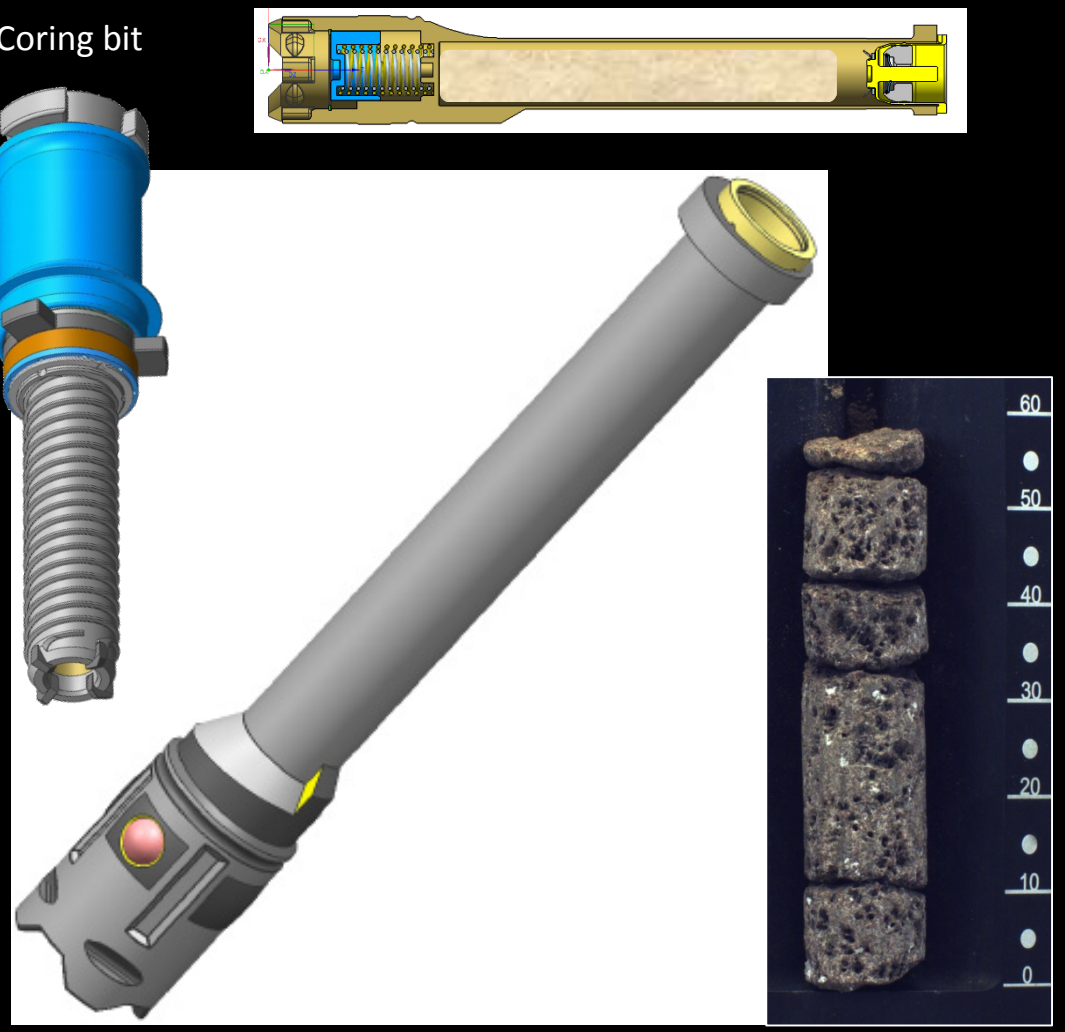
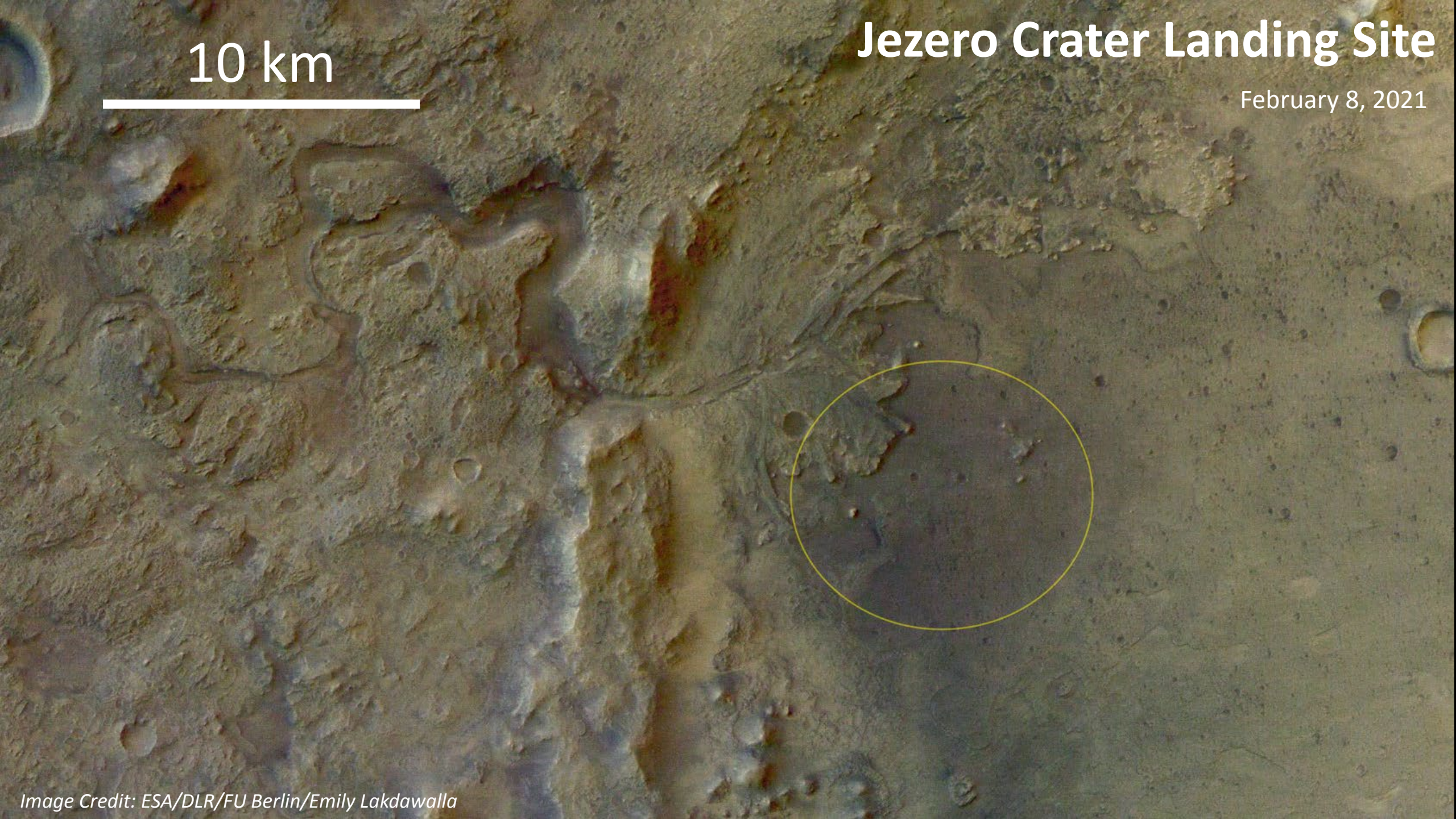


Image Credit: NASA/JPL-Caltech



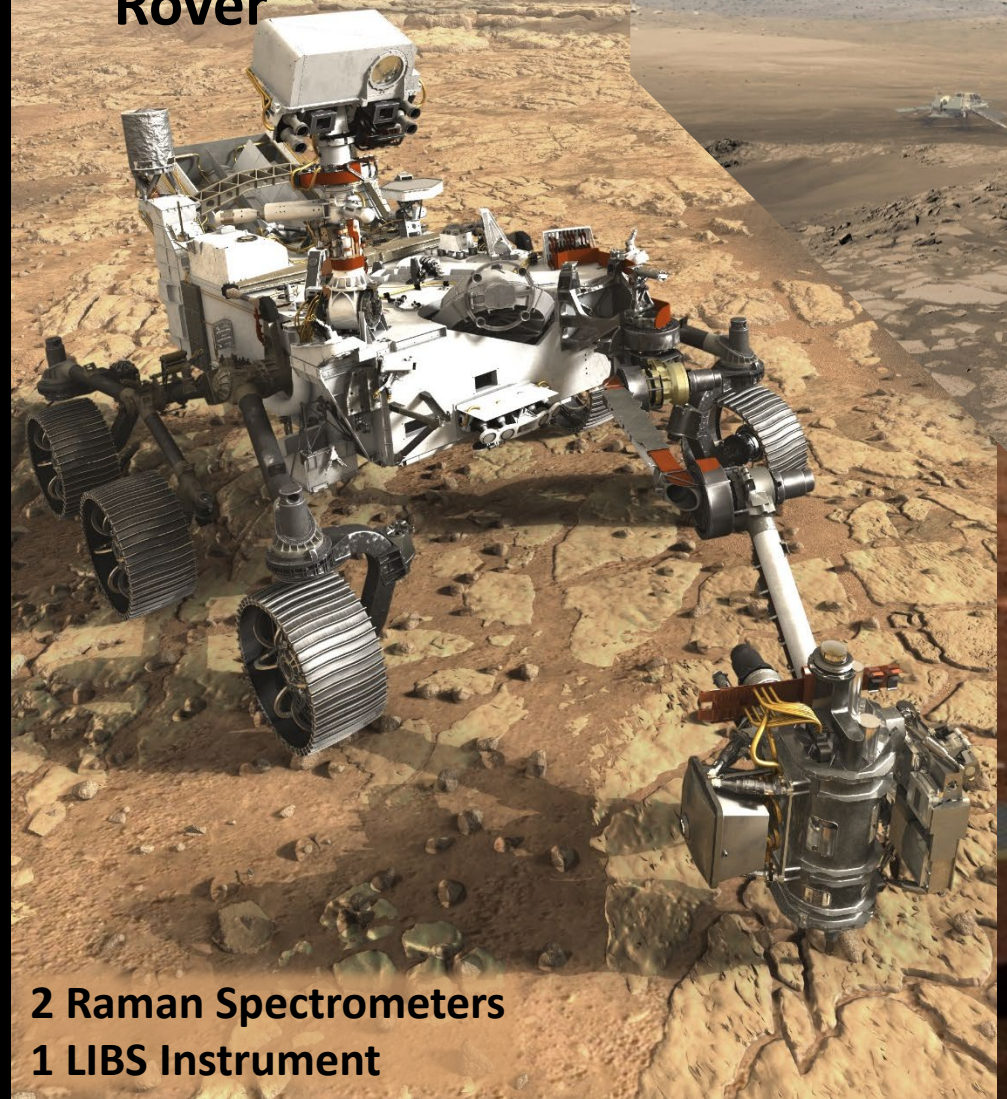
Jezero Crater Landing Site

February 8, 2021

Image Credit: ESA/DLR/FU Berlin/Emily Lakdawalla

Missions to Mars in 2020

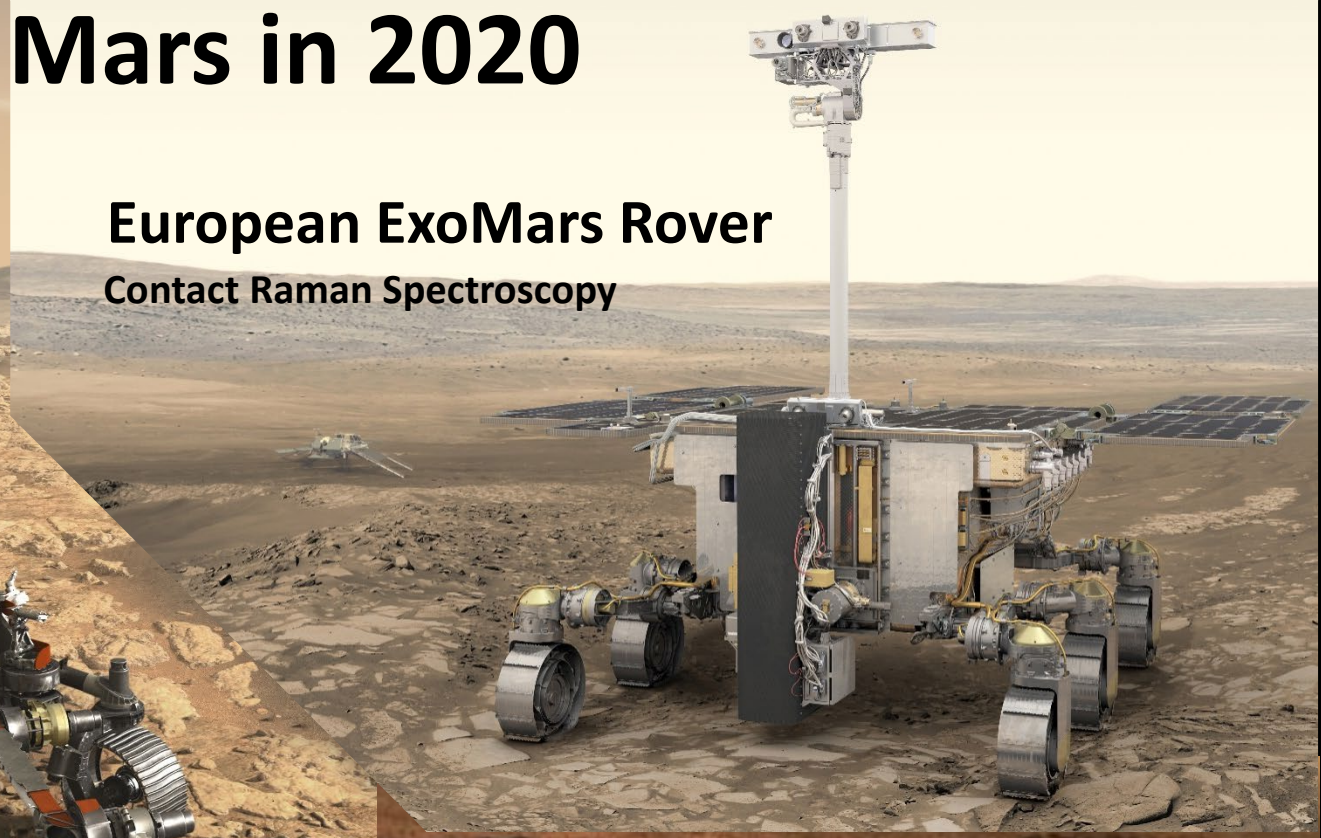
NASA
Mars 2020
Rover



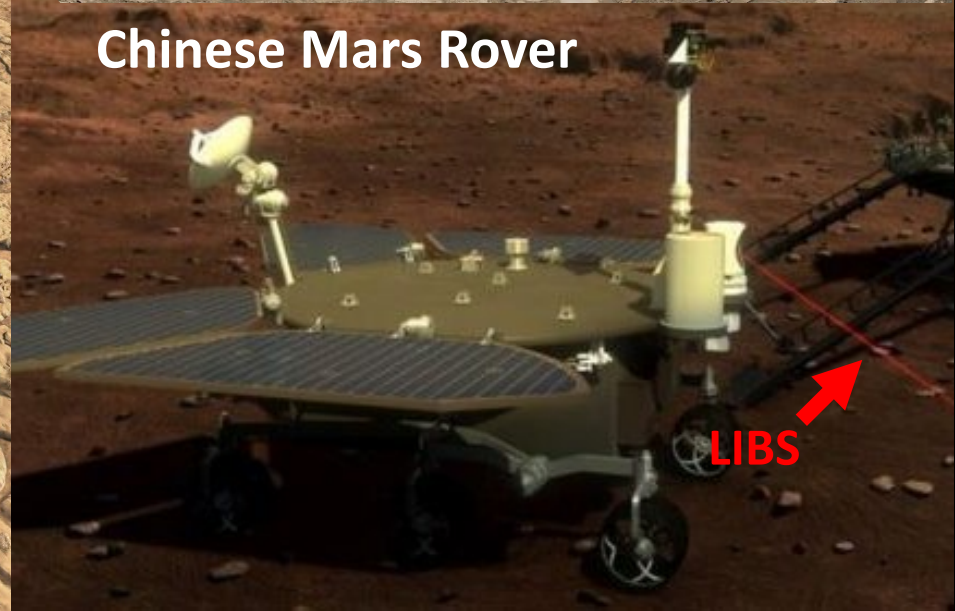
2 Raman Spectrometers
1 LIBS Instrument

European ExoMars Rover

Contact Raman Spectroscopy

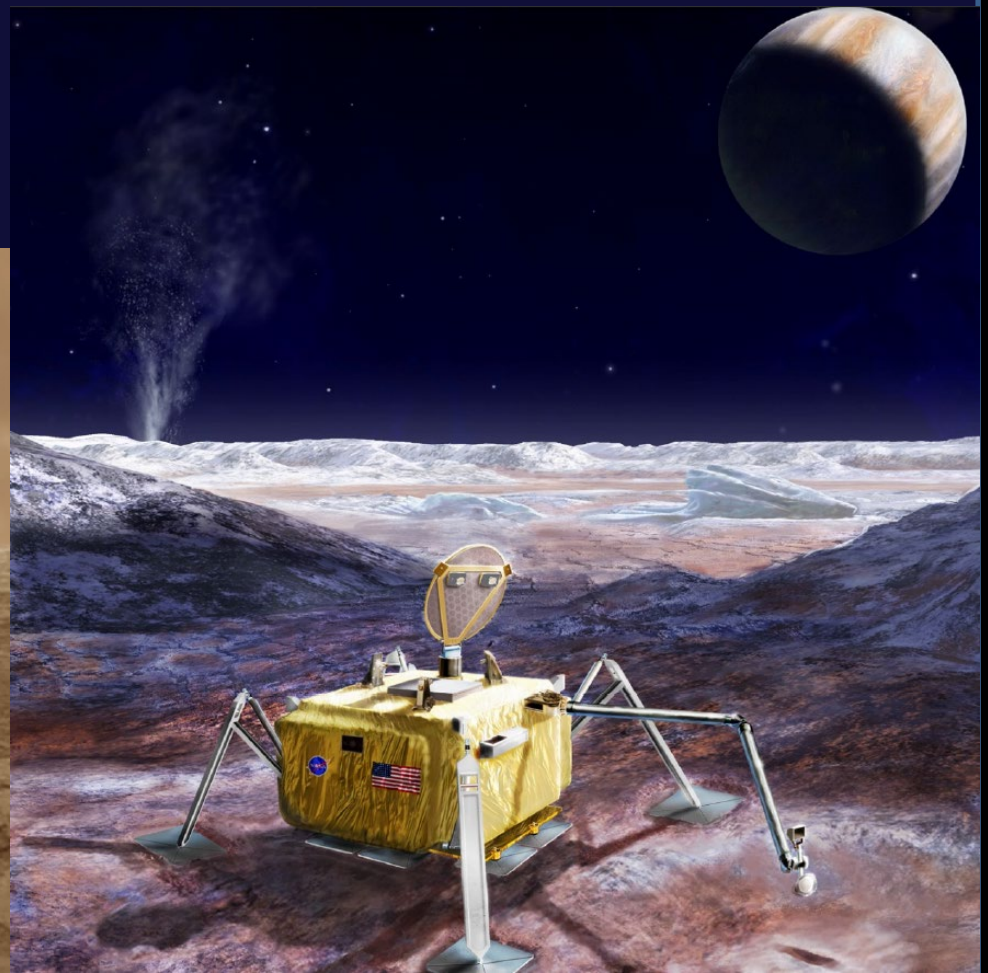


Chinese Mars Rover

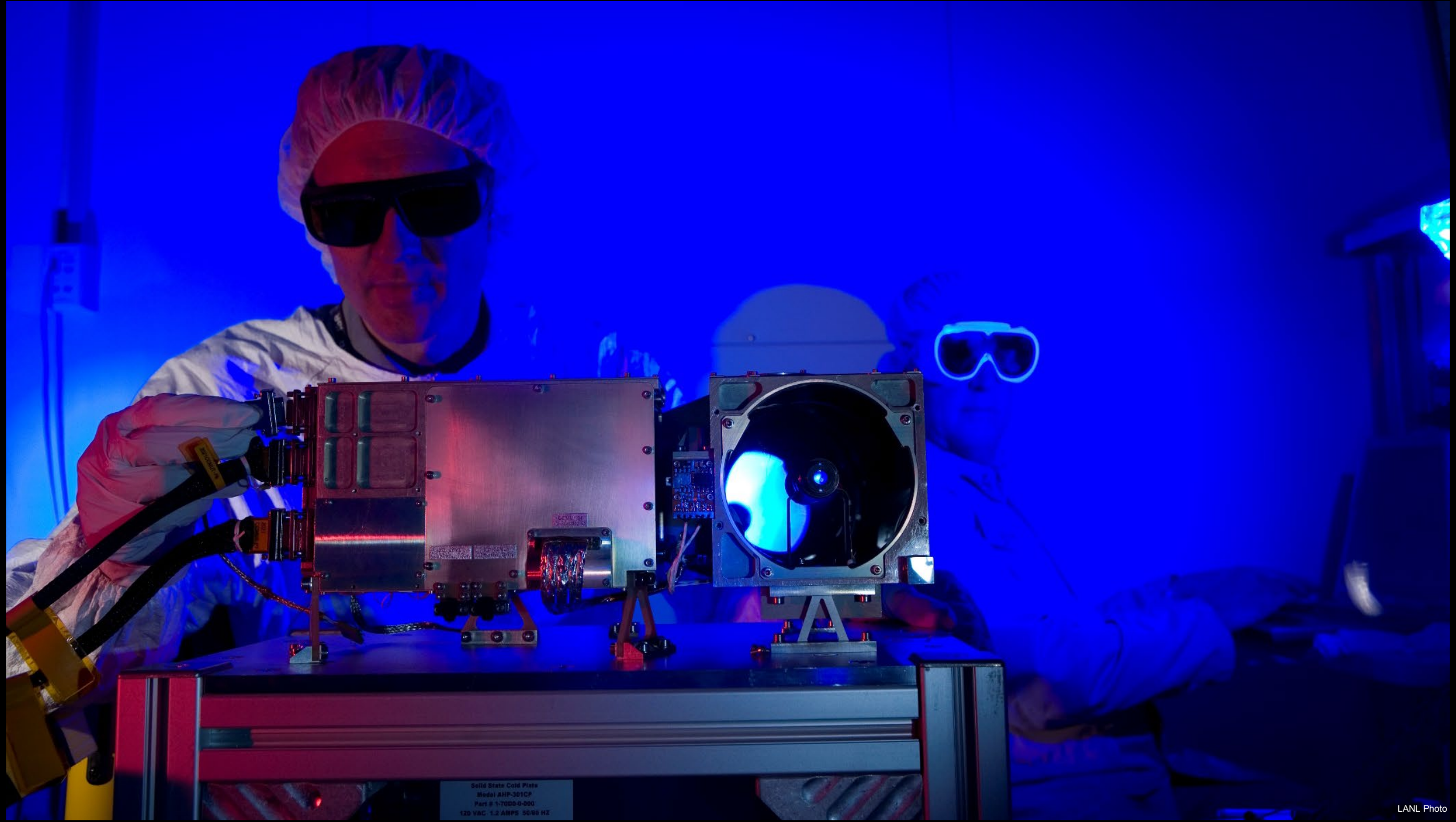


Analyses on Other Worlds

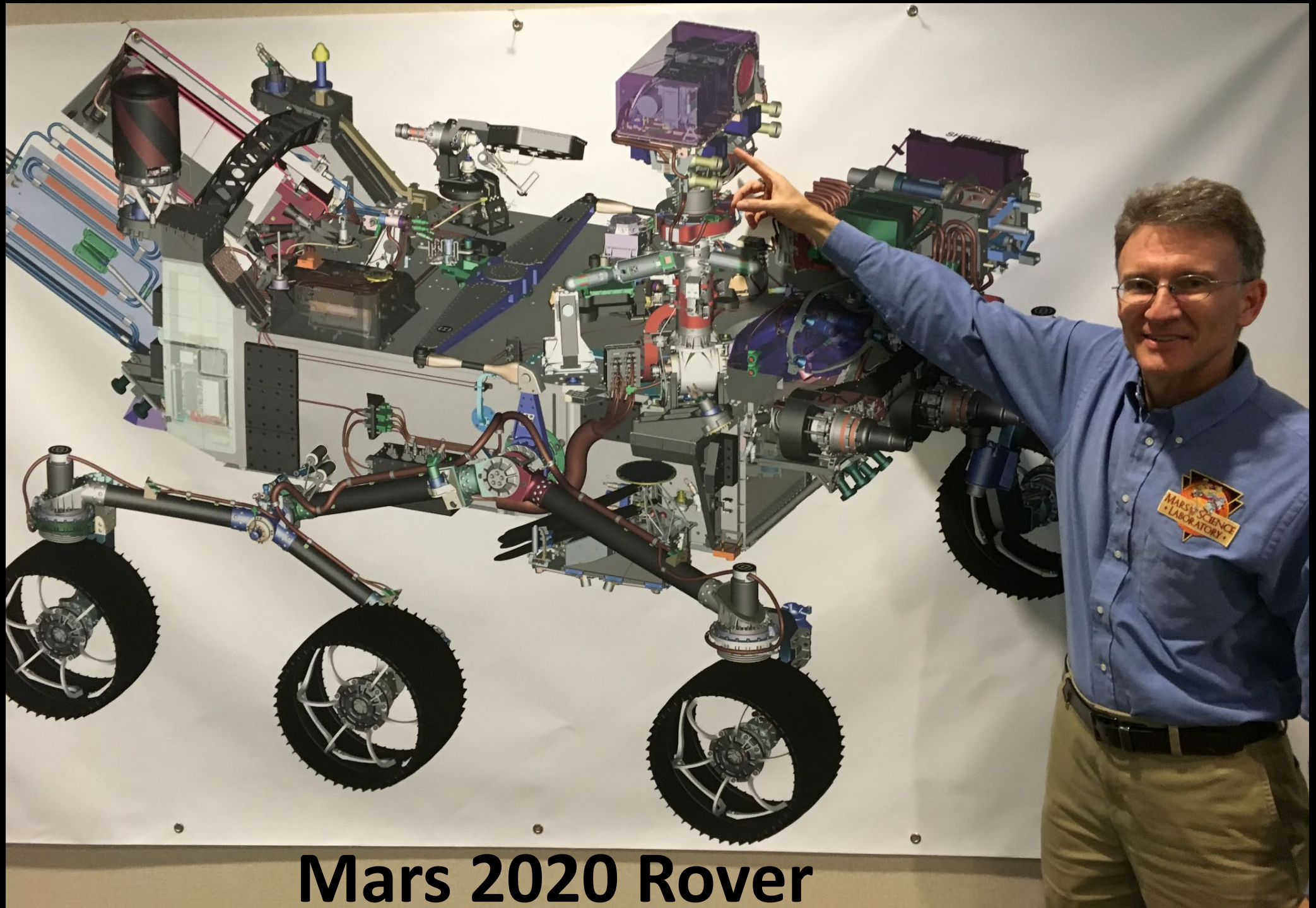
Internal funding for Organics Fluorescence Imager (OrganiCam) for Ocean Worlds missions



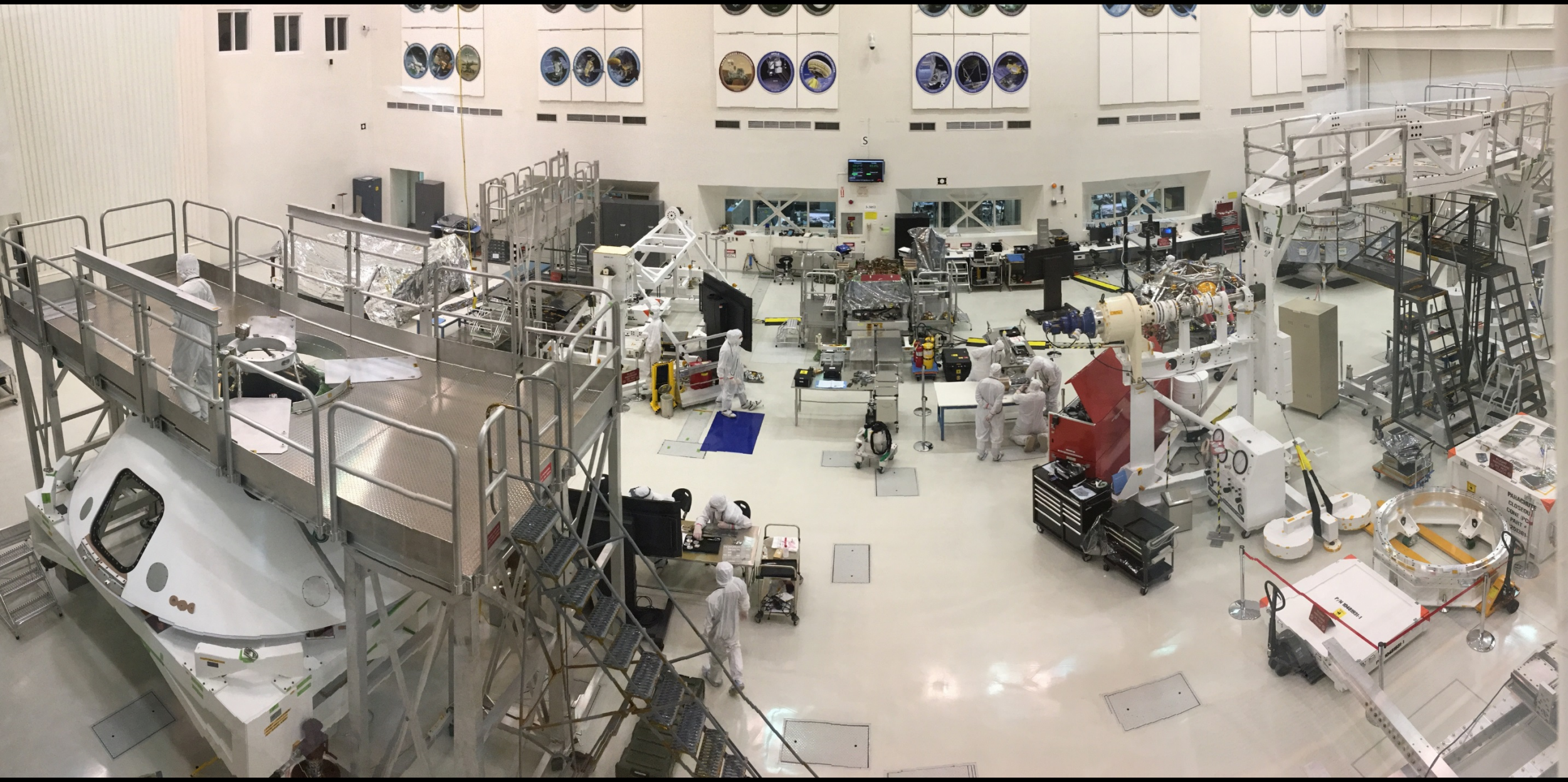
Venus Elemental & Mineral Camera (VEMCam) to receive maturation funding from the New Frontiers Mission Office (NASA press release, December)

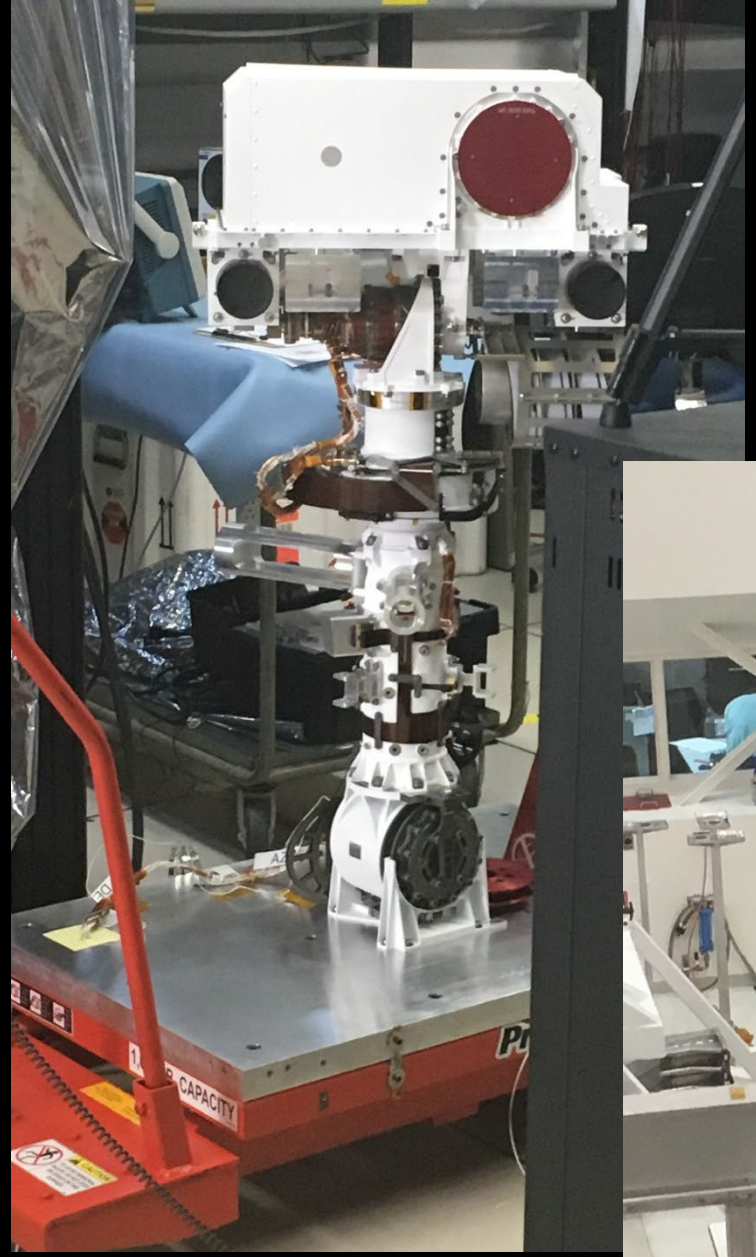

Solid State Cold Plate
Model AHP-301CP
Part # 1-7000-0-000
120 VAC, 1.2 AMPS 50/60 HZ

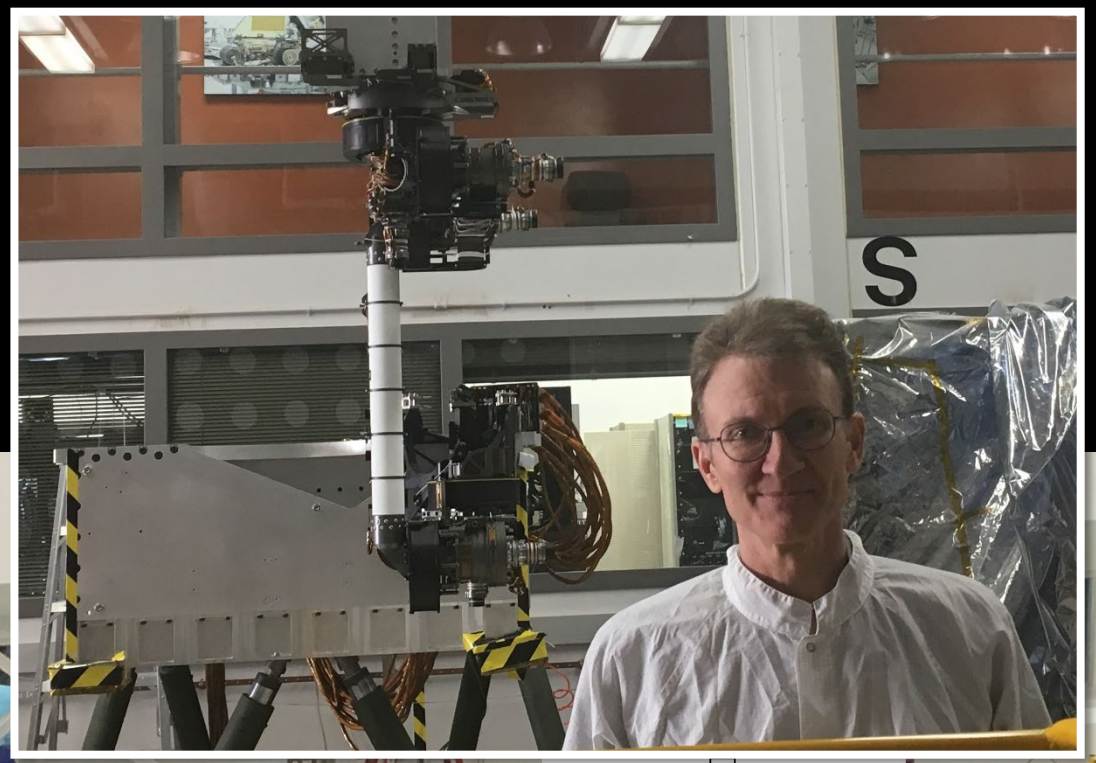
LANL Photo

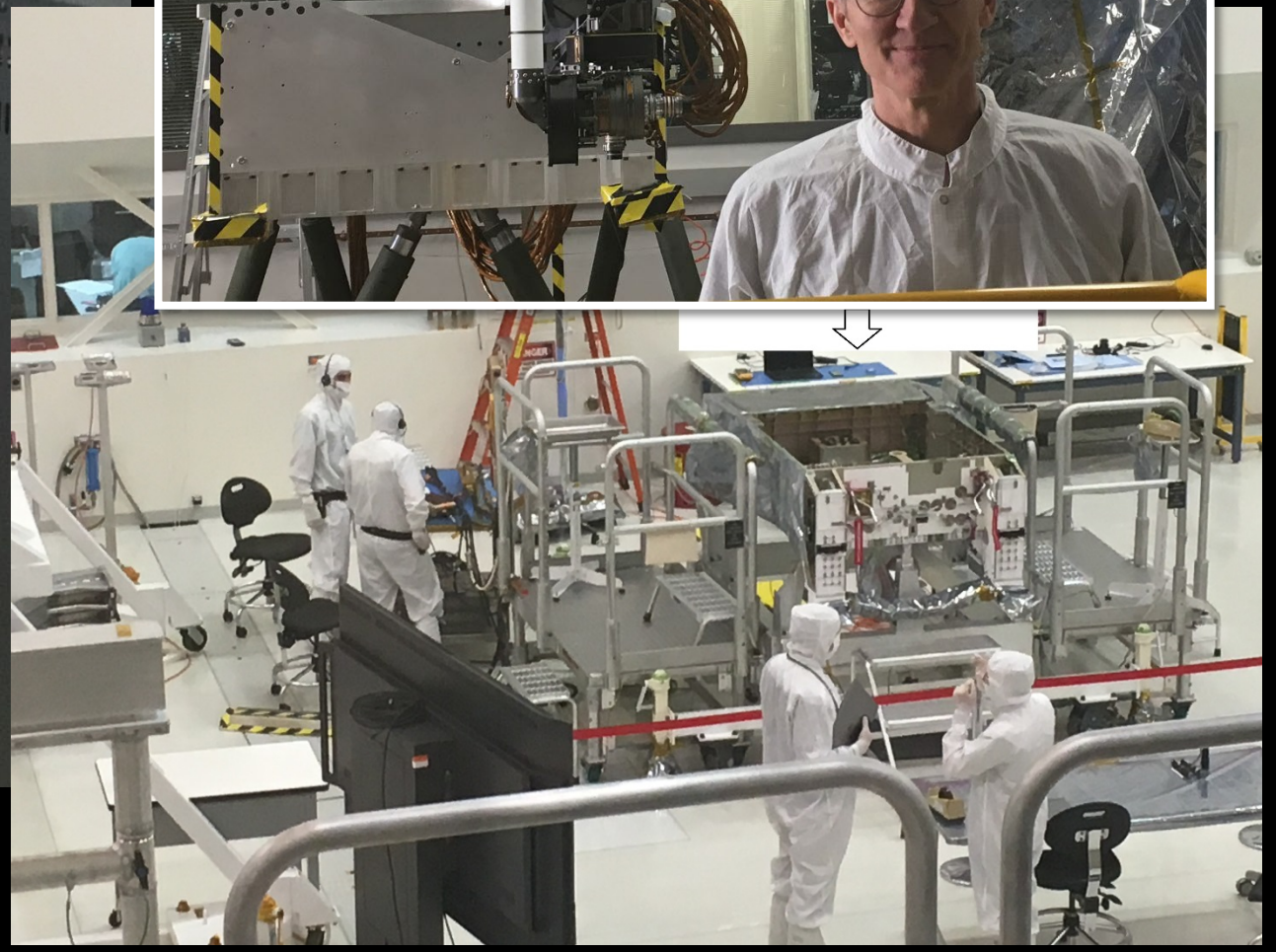


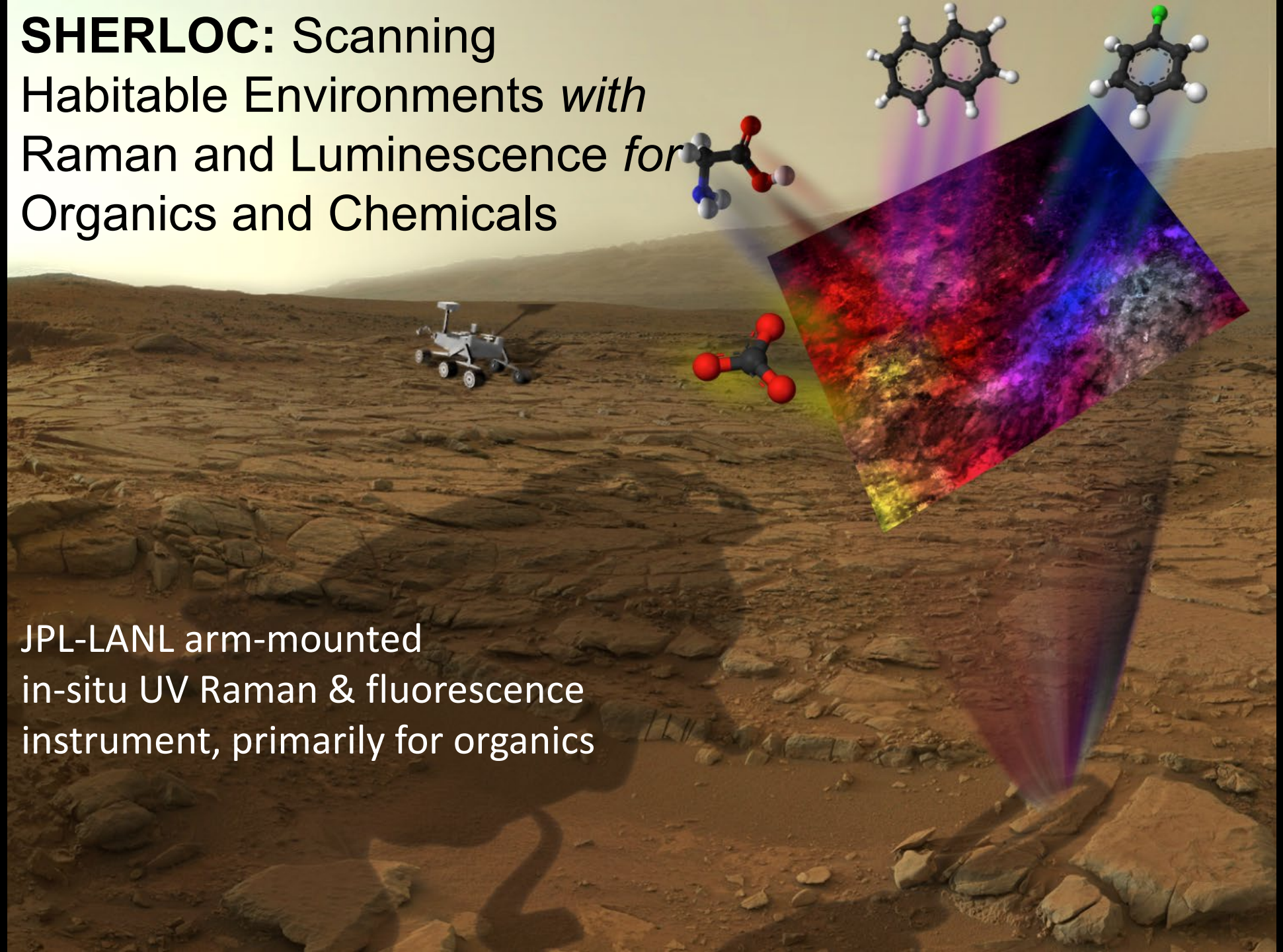
Mars 2020 Rover



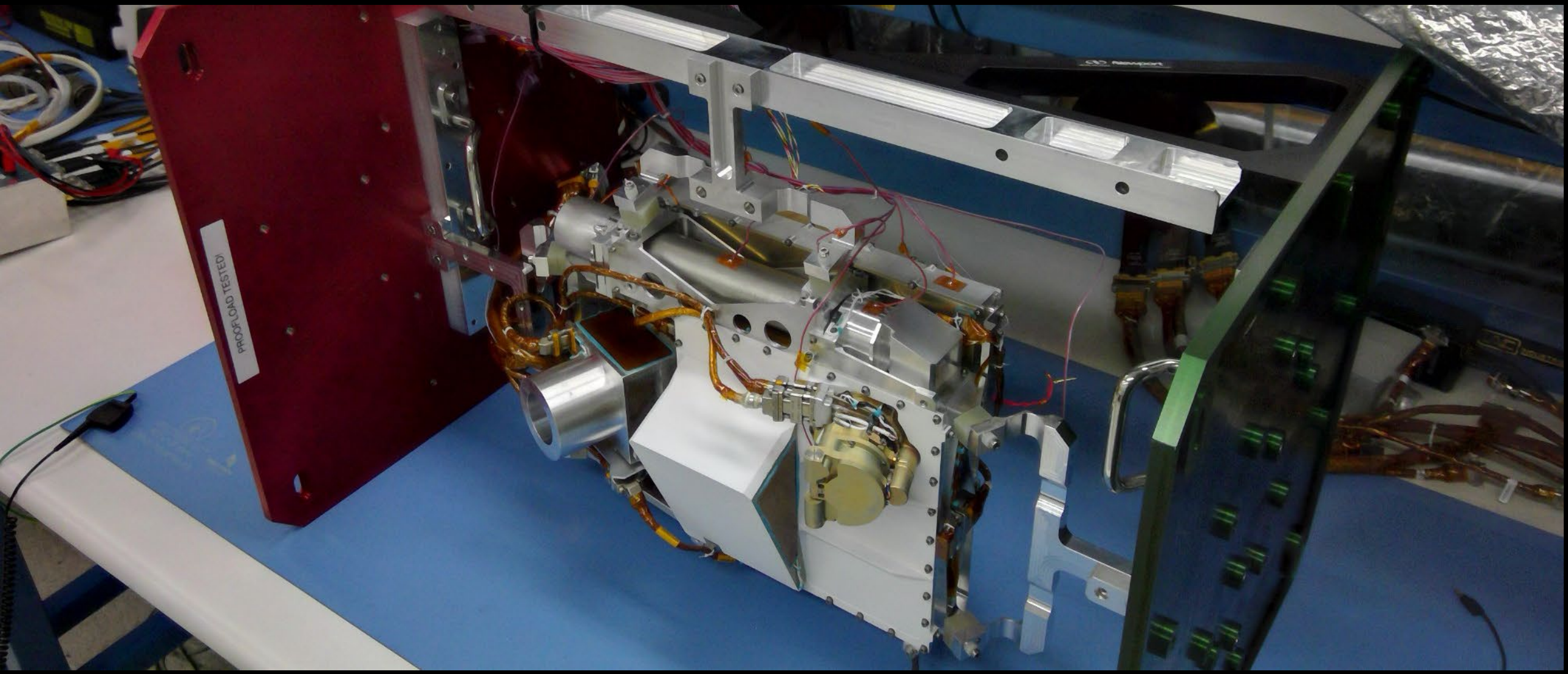







SHERLOC: Scanning
Habitable Environments *with*
Raman and Luminescence *for*
Organics and Chemicals
JPL-LANL arm-mounted
in-situ UV Raman & fluorescence
instrument, primarily for organics

SHERLOC Engineering Model

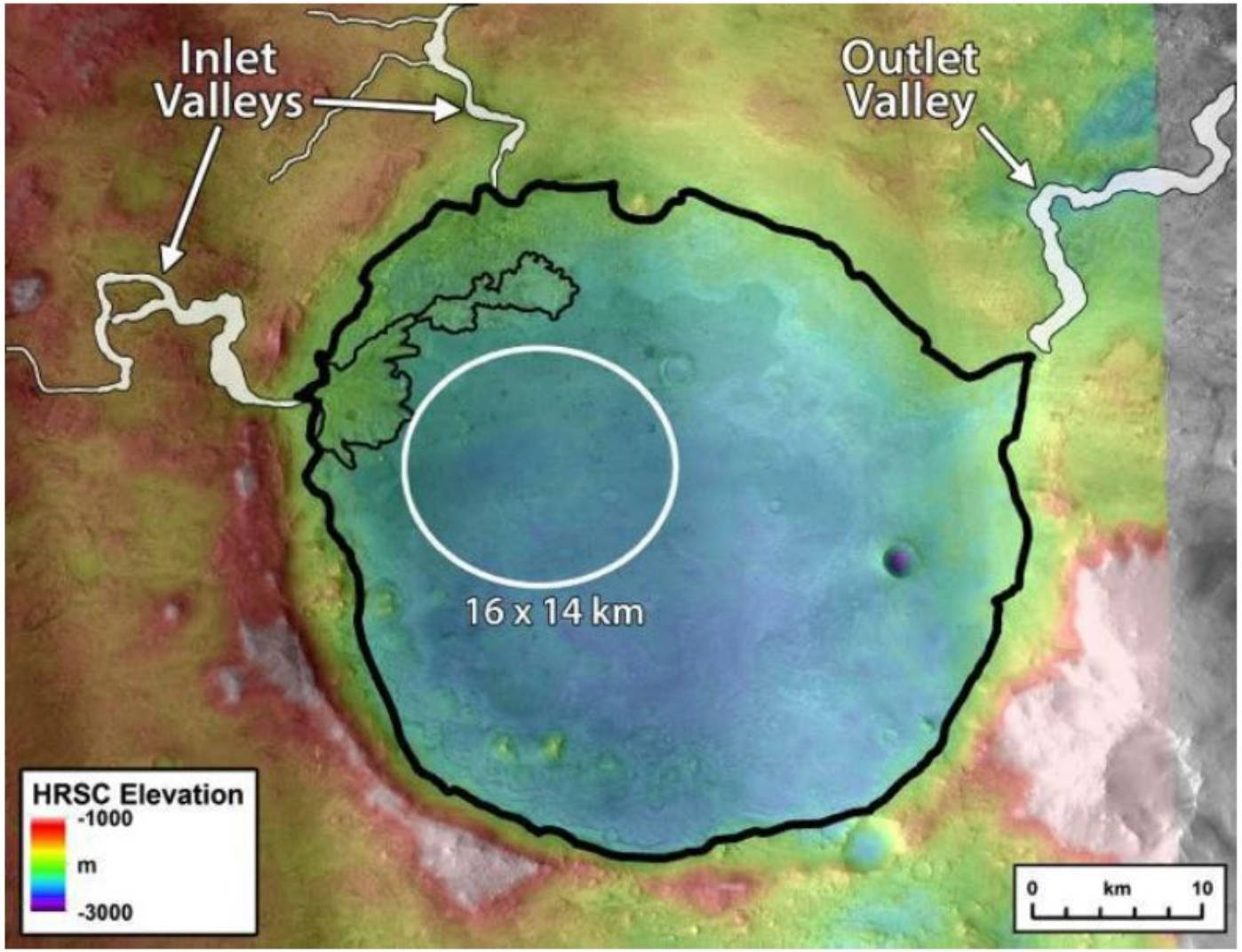


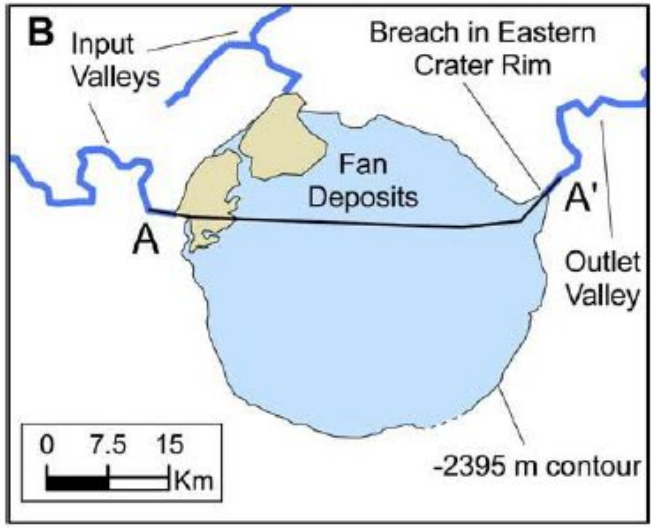
JPL-Led; Portions Built at Los Alamos; to be Mounted on the Rover Arm

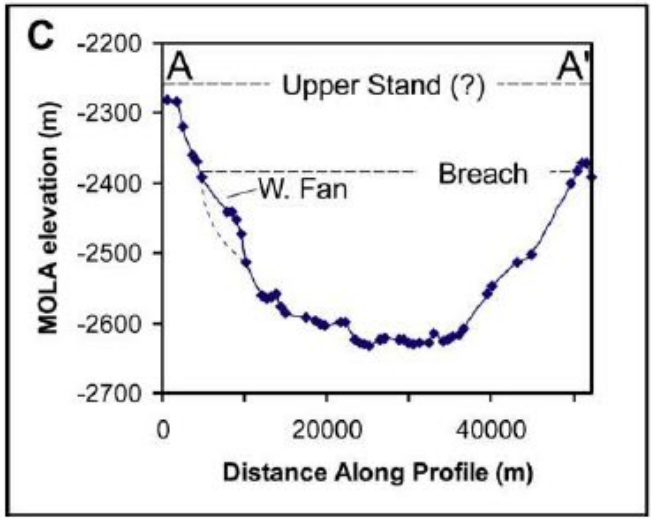
Tony Nelson, LANL SHERLOC Lead

Jezero Crater

Delta fan 5 km3



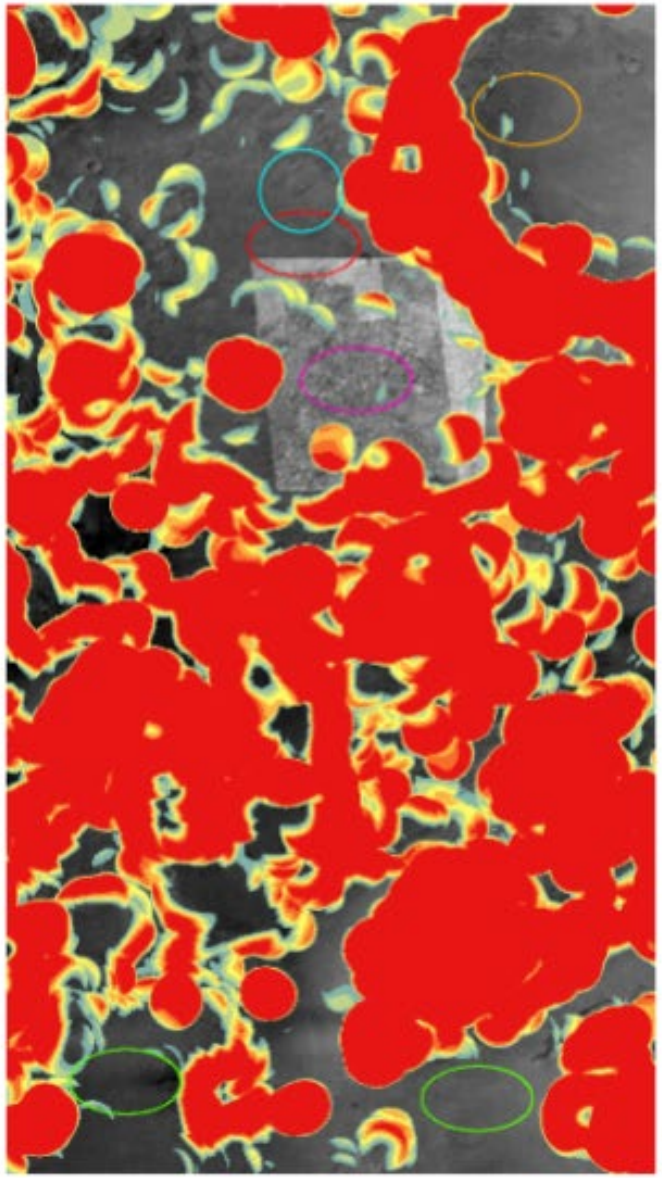




The -2400 m elevation for the delta and the breach at the eastern outlet is a robust observation favoring the presence of a lake.

Jezero, NE Syrtis, and Midway Locations

Jet Propulsion Laboratory
California Institute of Technology

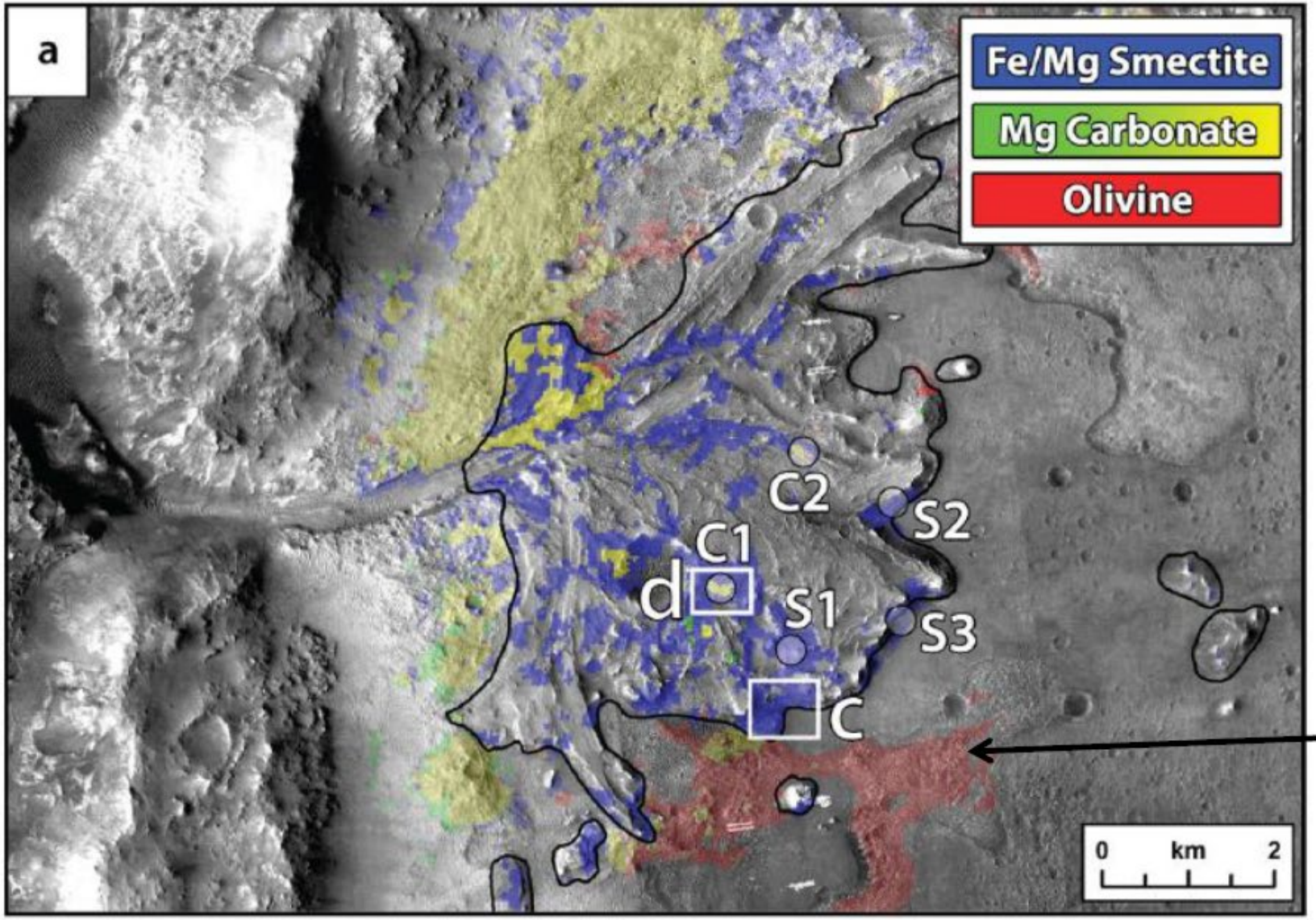


Relief hazards in the NE Syrtis Region using HRSC DEM

Yellow = 130-140 m
Orange = 140-150 m
Red > 150 m

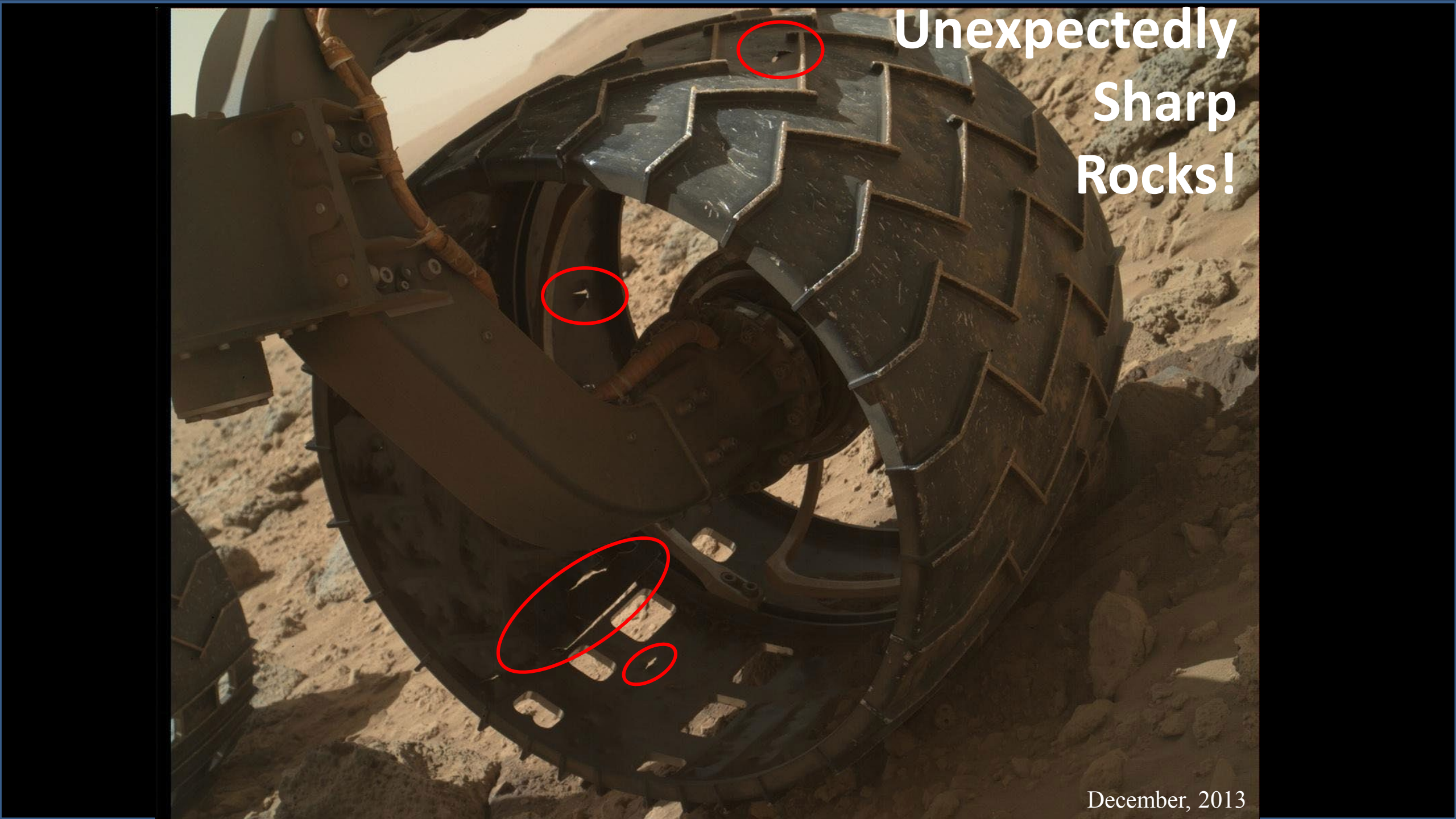
EDL team prefers no red in ellipse

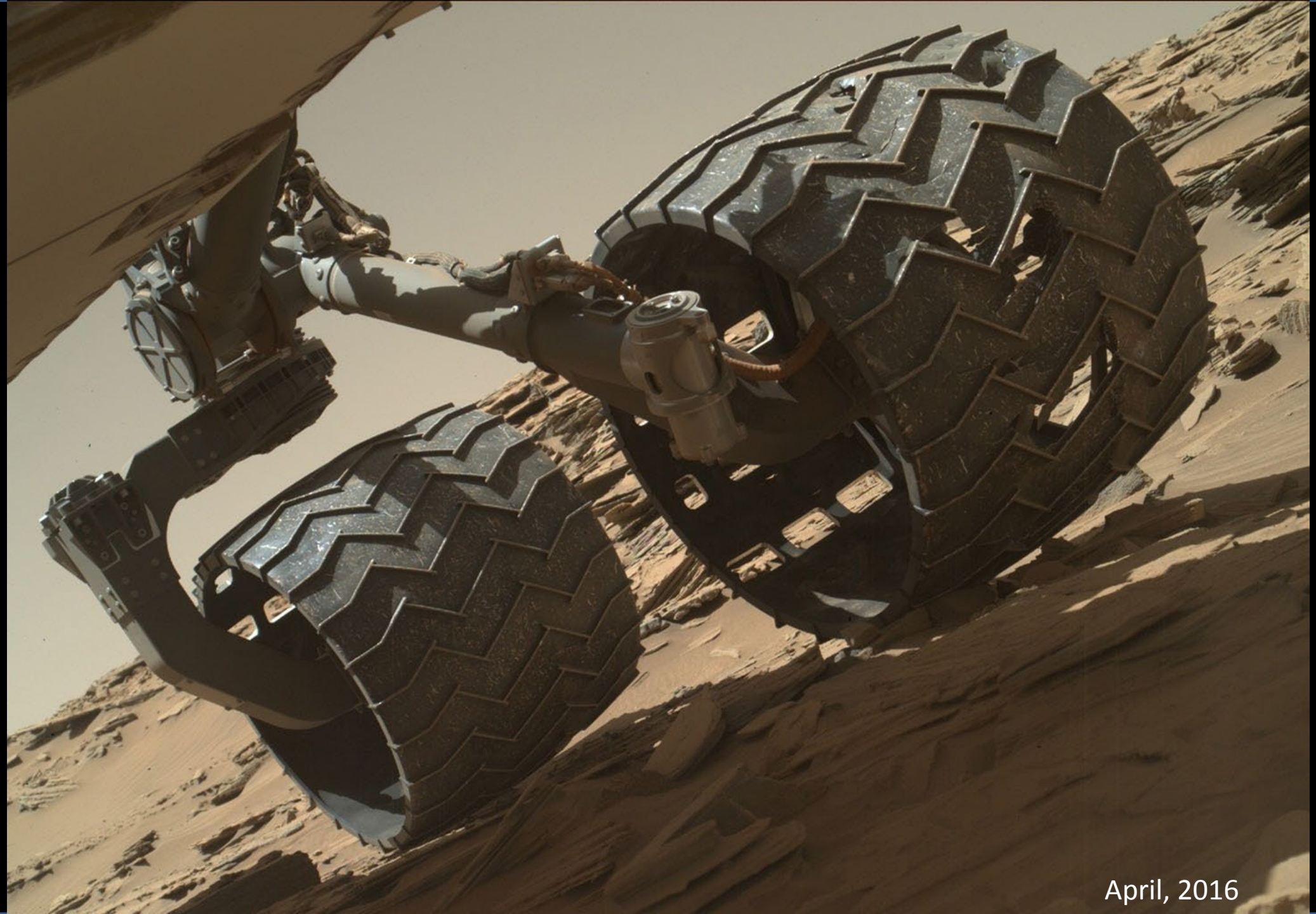
Richard Otero



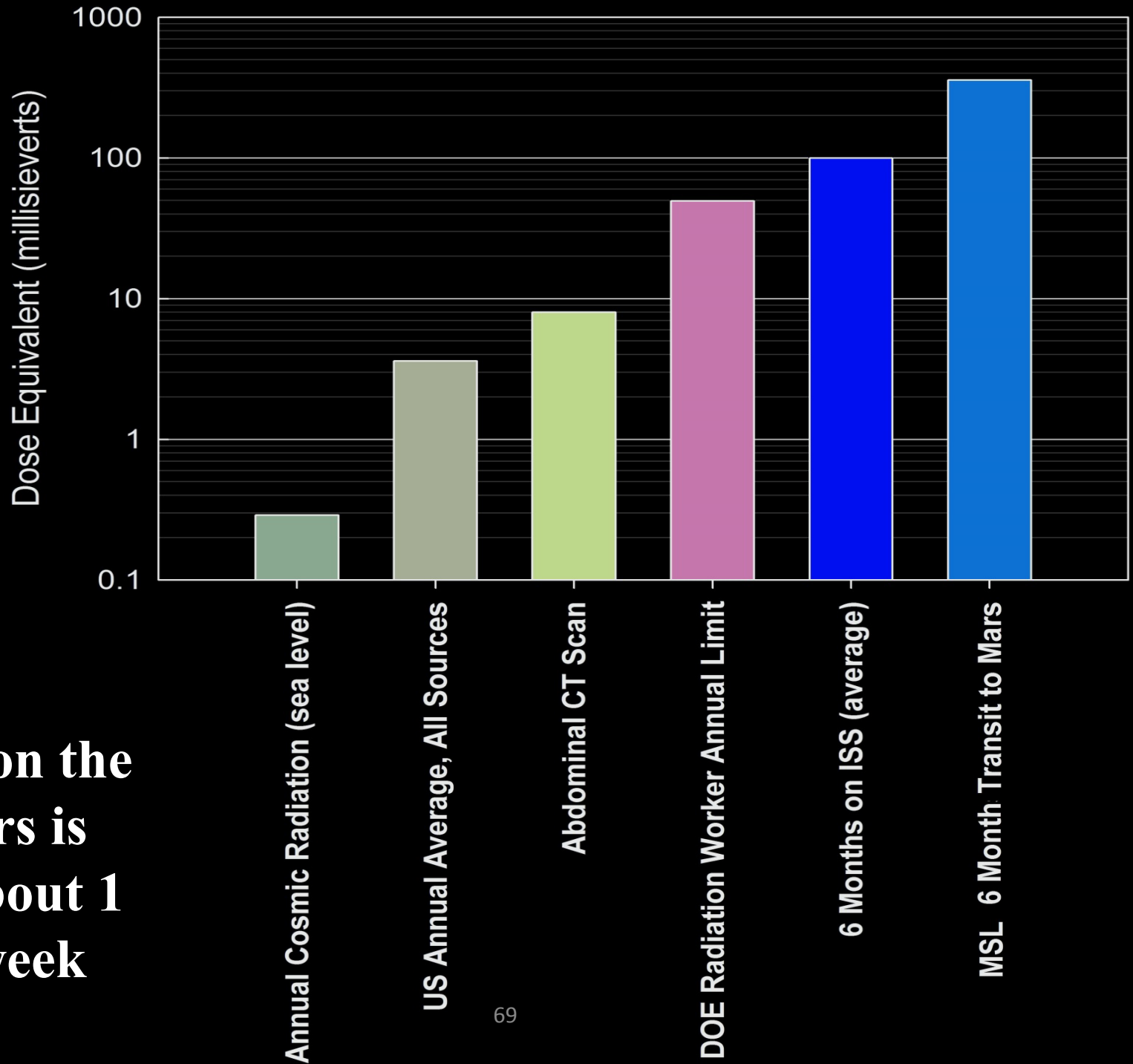
Mafic composition
Fresh lava flows

1st interest : Mafic material in the ellipse => Fresh lava flows good for geochronology
But questions were raised on the exact age from crater counts
as well as the origin (true lava flows, or mafic eolian unit)

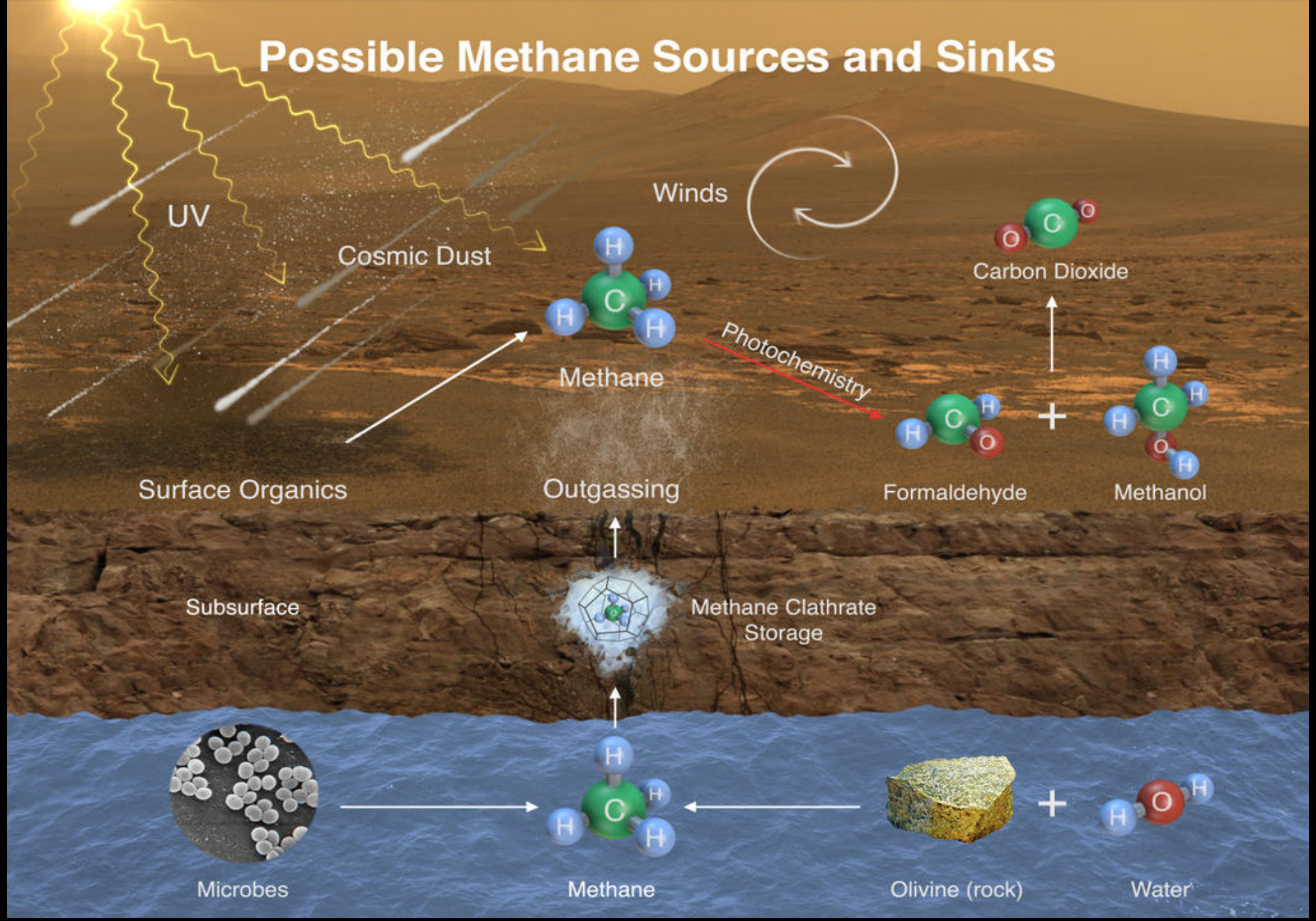

Unexpectedly Sharp Rocks!
December, 2013

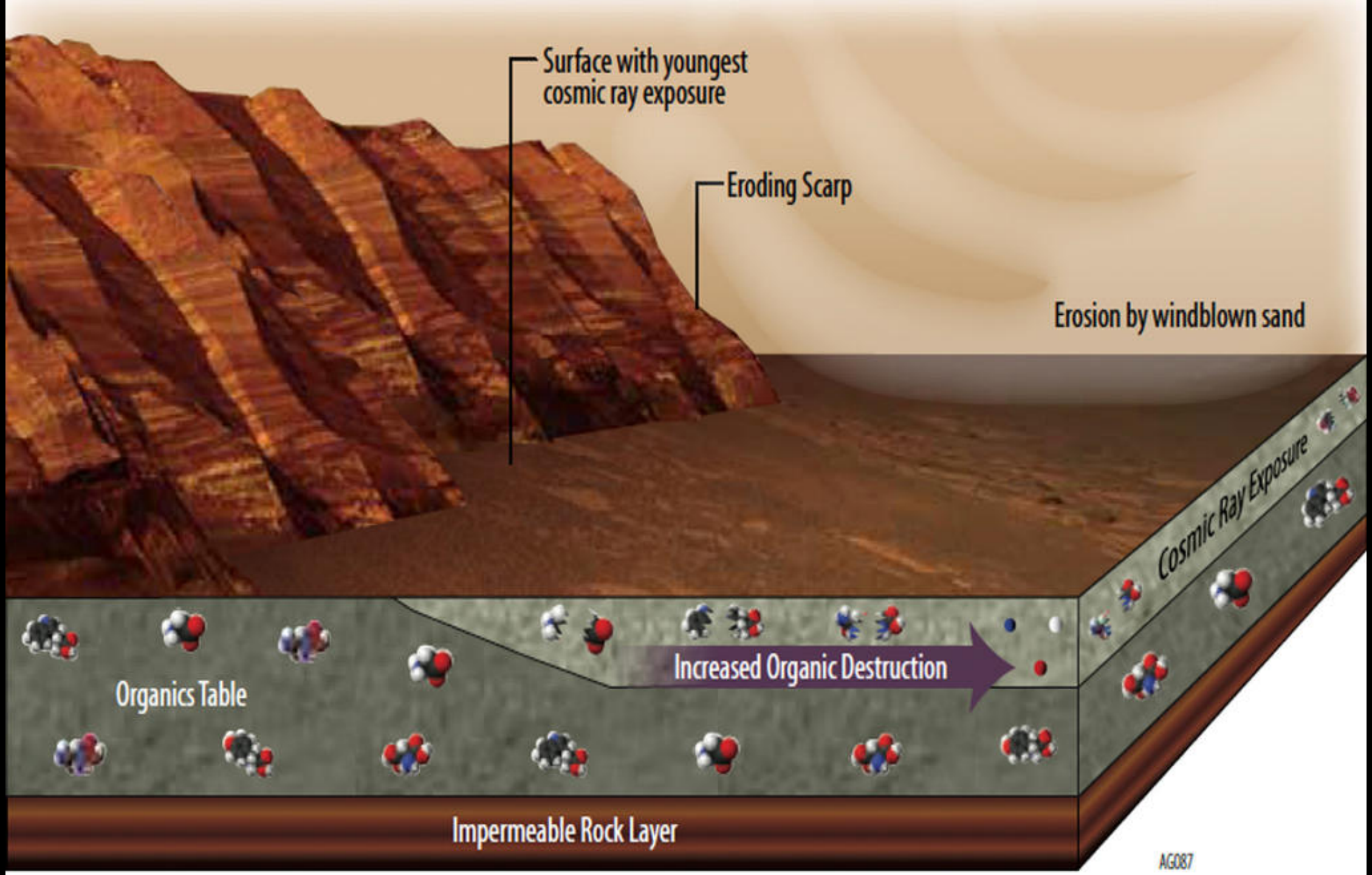

April, 2016


More Durable Wheels
Curiosity
Mars 2020
40 Mile Test



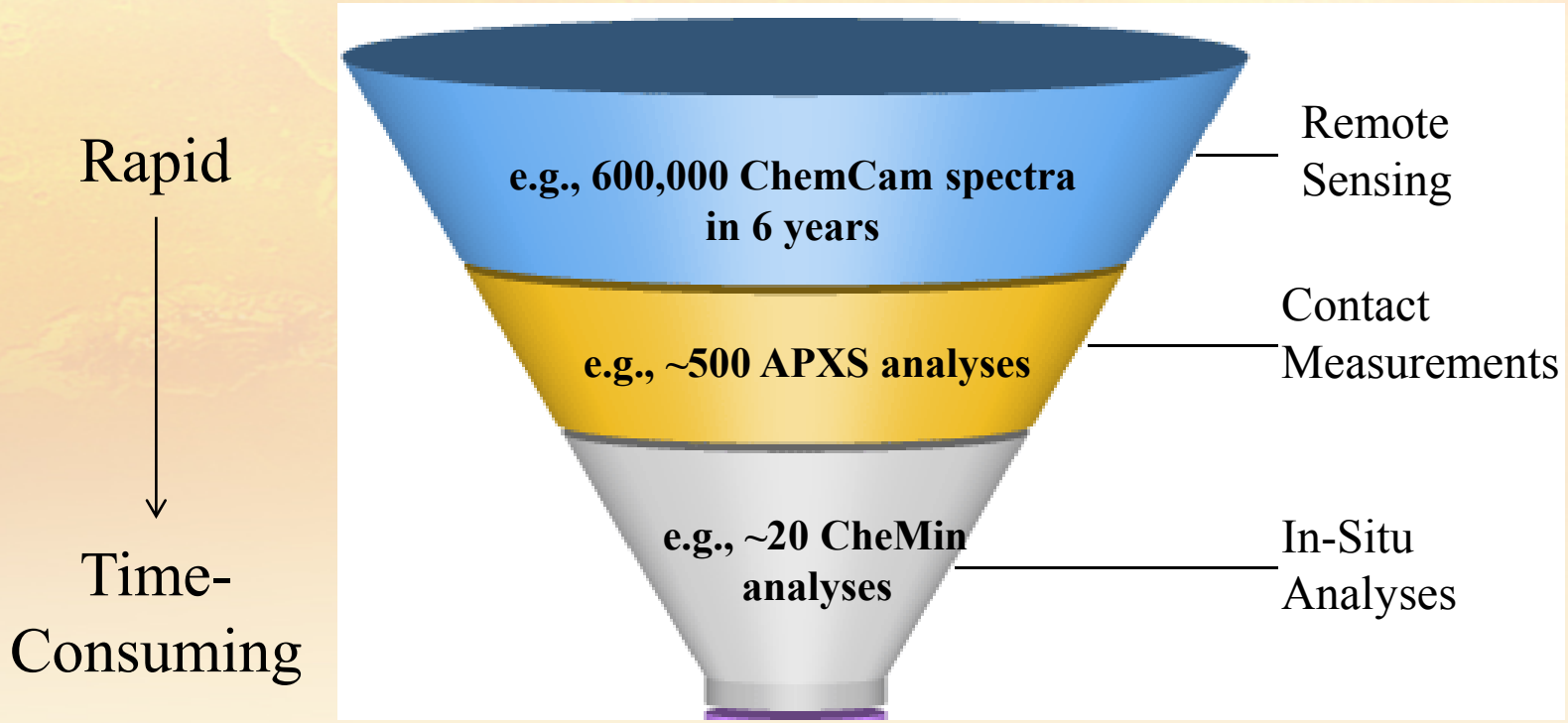
Radiation dose on the surface of Mars is equivalent to about 1 CT scan per week


Possible Methane Sources and Sinks
UV
Cosmic Dust
Winds
Methane
Photochemistry
Carbon Dioxide
Formaldehyde
Methanol
Surface Organics
Outgassing
Subsurface
Methane Clathrate
Storage
Microbes
Methane
Olivine (rock)
Water


Surface with youngest cosmic ray exposure
Eroding Scarp
Erosion by windblown sand
Cosmic Ray Exposure
Increased Organic Destruction
Organics Table
Impermeable Rock Layer
AG087

Rover Payload Architecture

- *Funnel concept:*
  - *Rapid analyses of a large number of samples (remote sensing)*
  - *More careful analysis of a smaller number of samples (contact)*
  - *Infrequent analysis with detailed instruments (in-situ mobile laboratory instruments)*

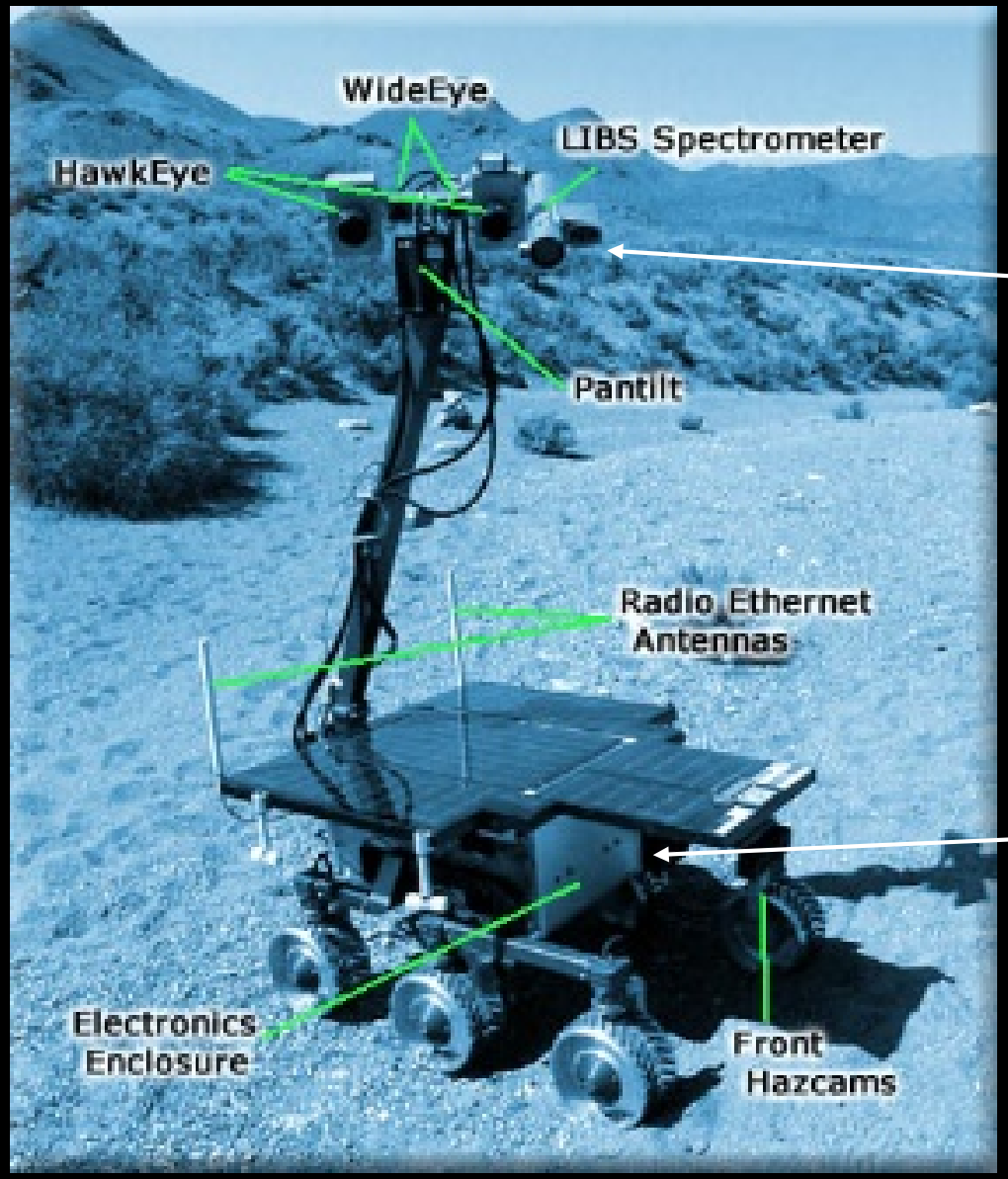


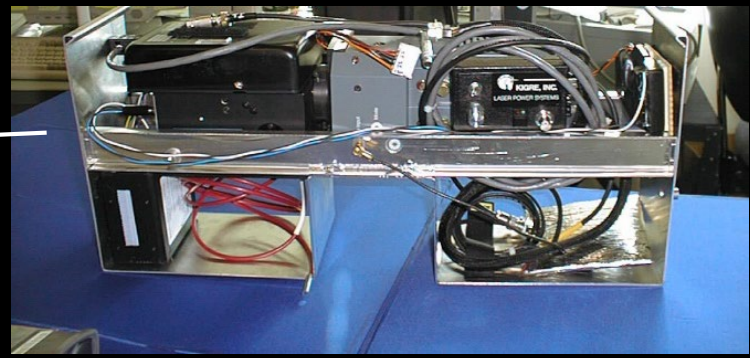
Meteorites on Mars!

2014

NASA/jPL-Caltech/MSSS/LANL/IRAP/CNES/LPGN/IAS

First Rover Test of LIBS



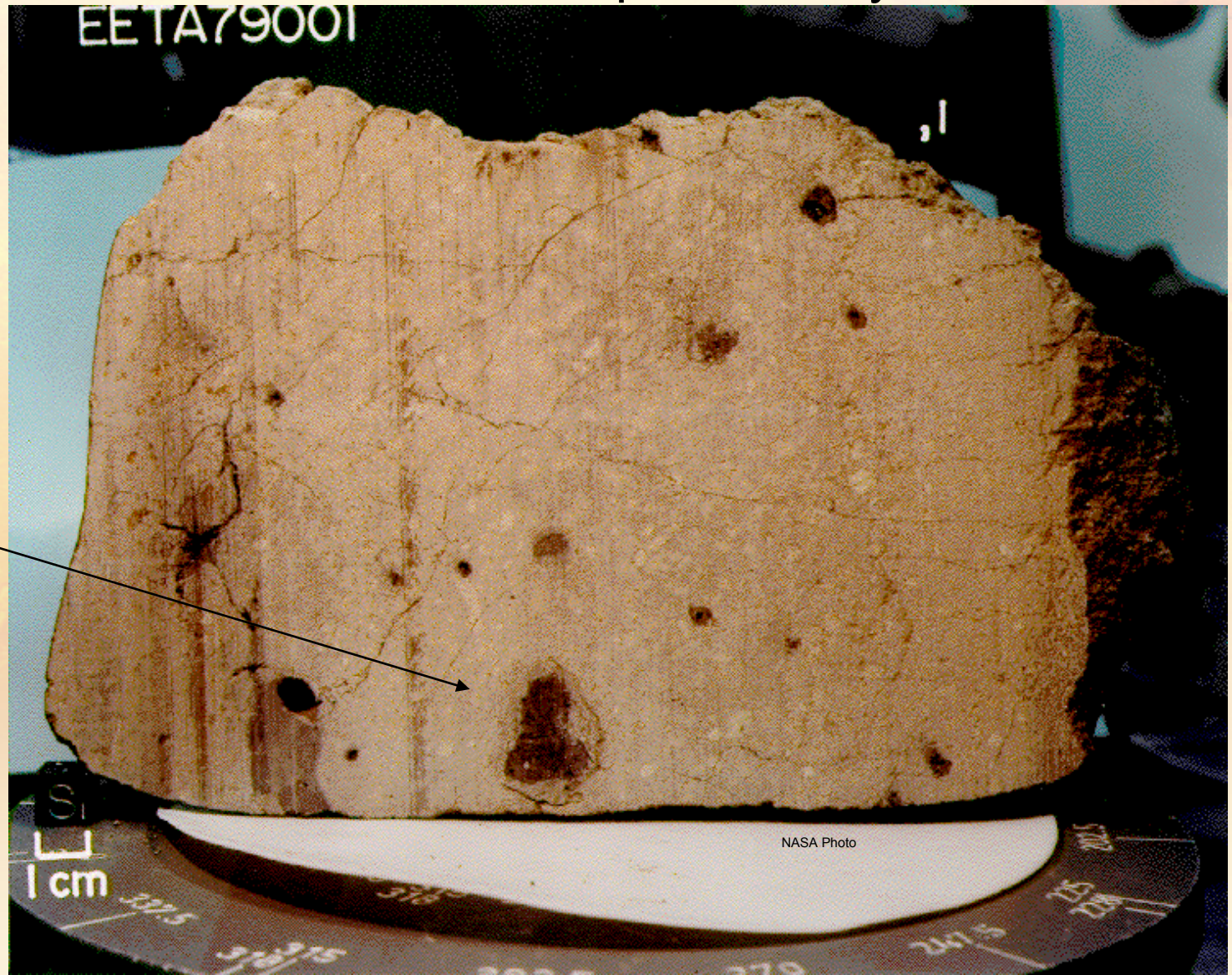


NASA & LANL Photos

Meteorites from Mars

First dissertation on the Mars atmosphere analyzed in the laboratory

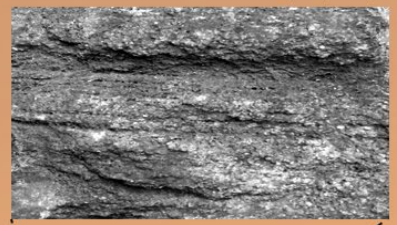
Glass produced by impact shock contains traces of Mars atmosphere



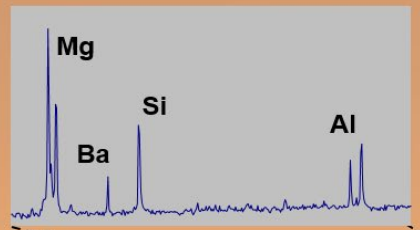
ChemCam

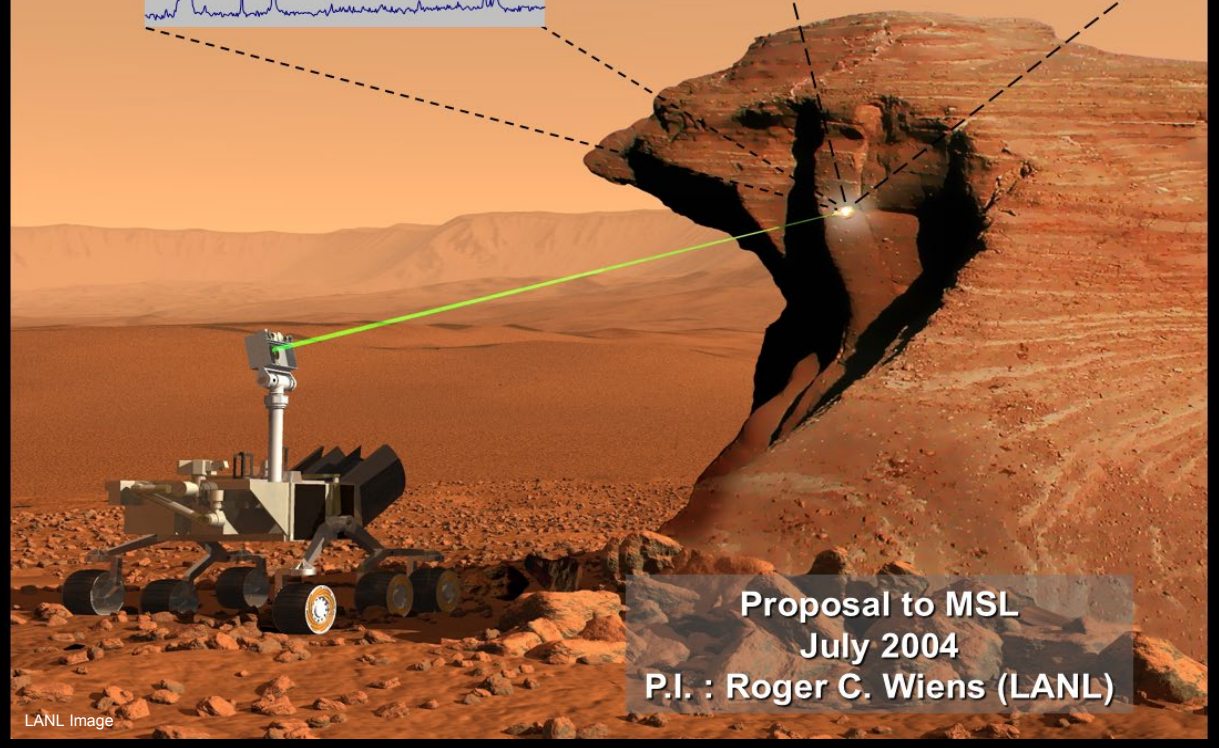
Laser-Induced Remote Sensing for Chemistry and Micro-Imaging

Most Detailed Remote Images Ever from the Remote Micro-Imager (RMI)



Elemental Abundances from Laser-Induced Breakdown Spectroscopy (LIBS)

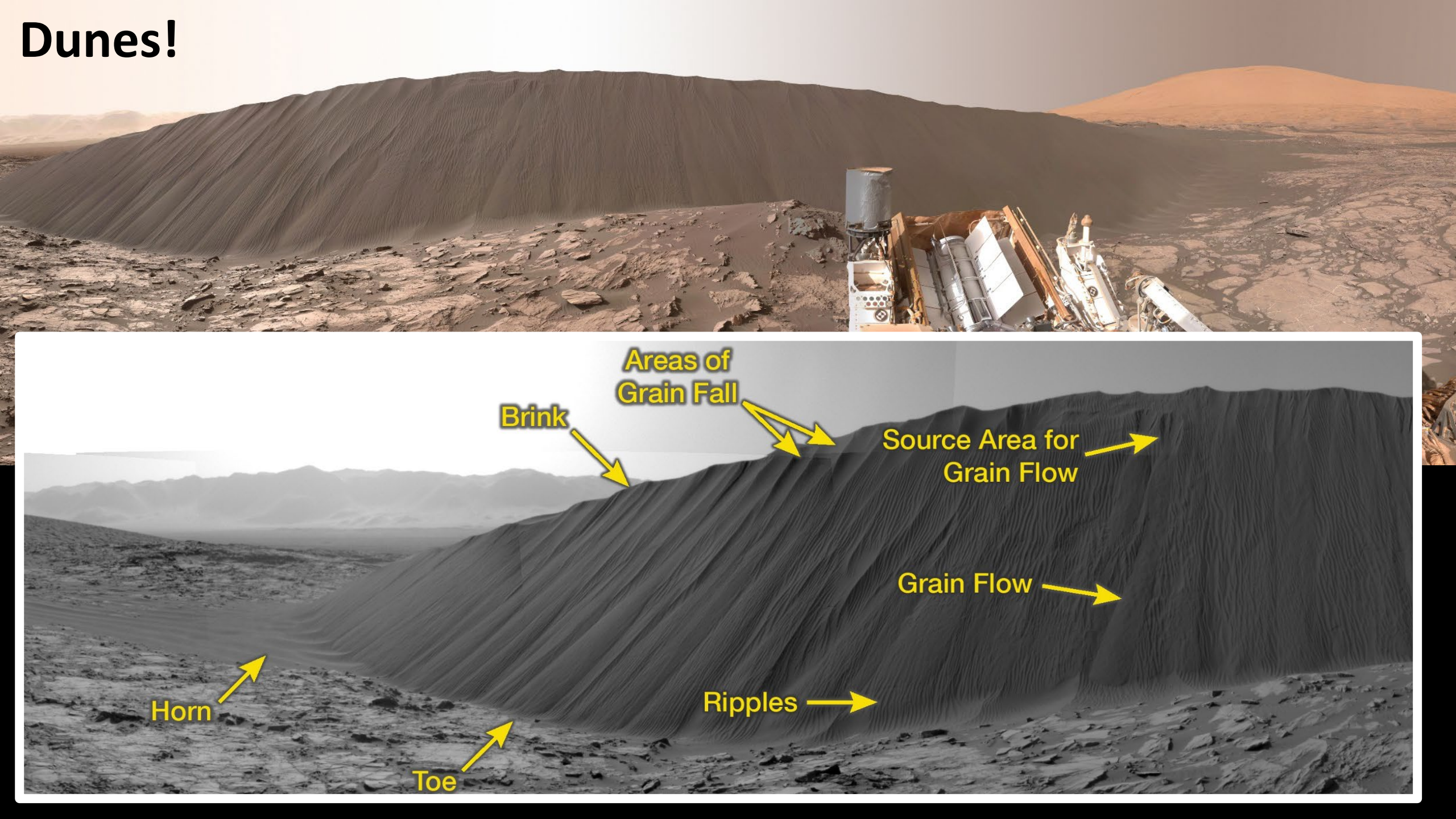




Proposal to MSL
July 2004
P.I. : Roger C. Wiens (LANL)

LANL Image

Dunes!


Areas of
Grain Fall
Brink
Source Area for
Grain Flow
Grain Flow
Ripples
Horn
Toe

Bagnold Dunes

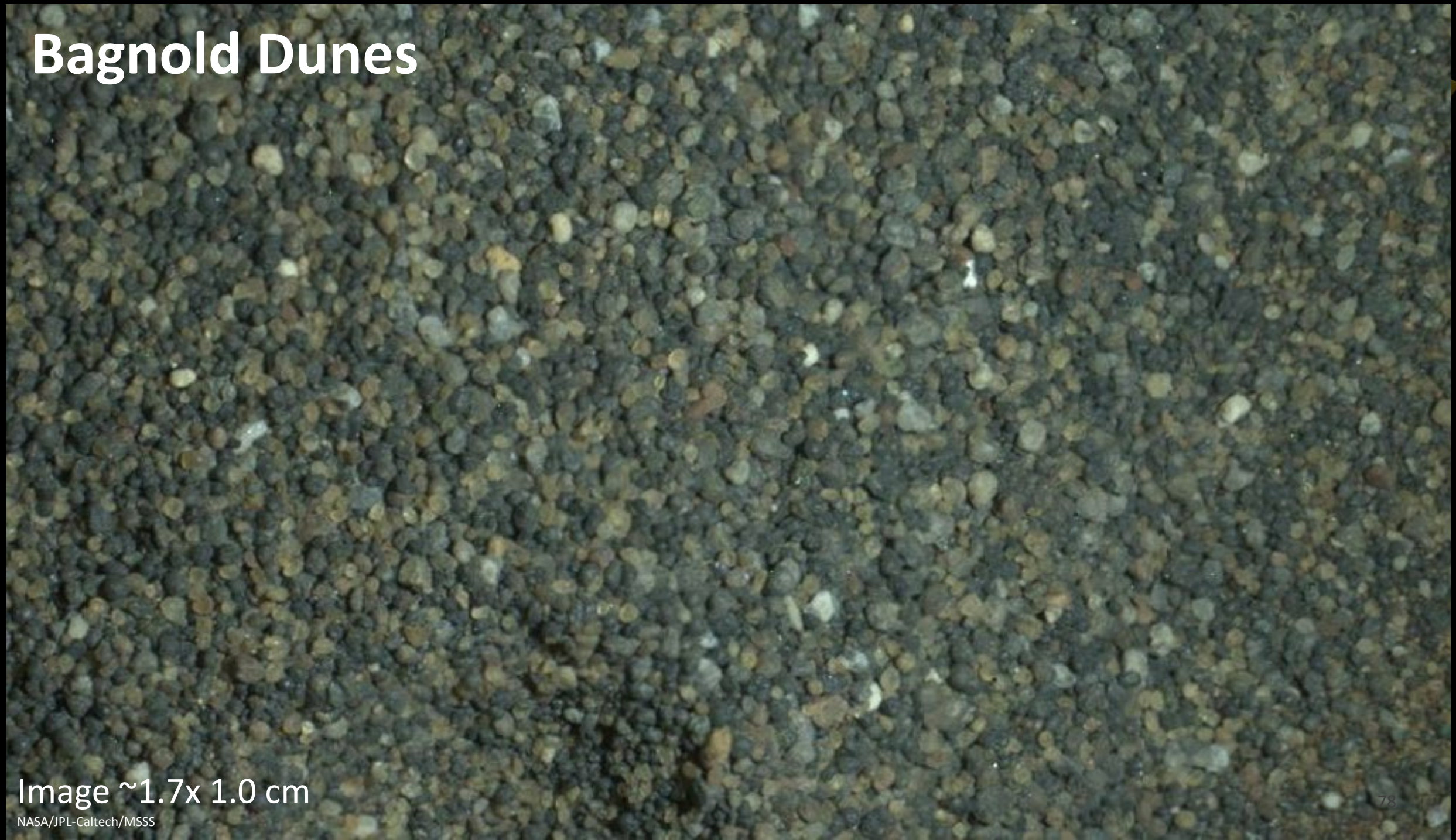
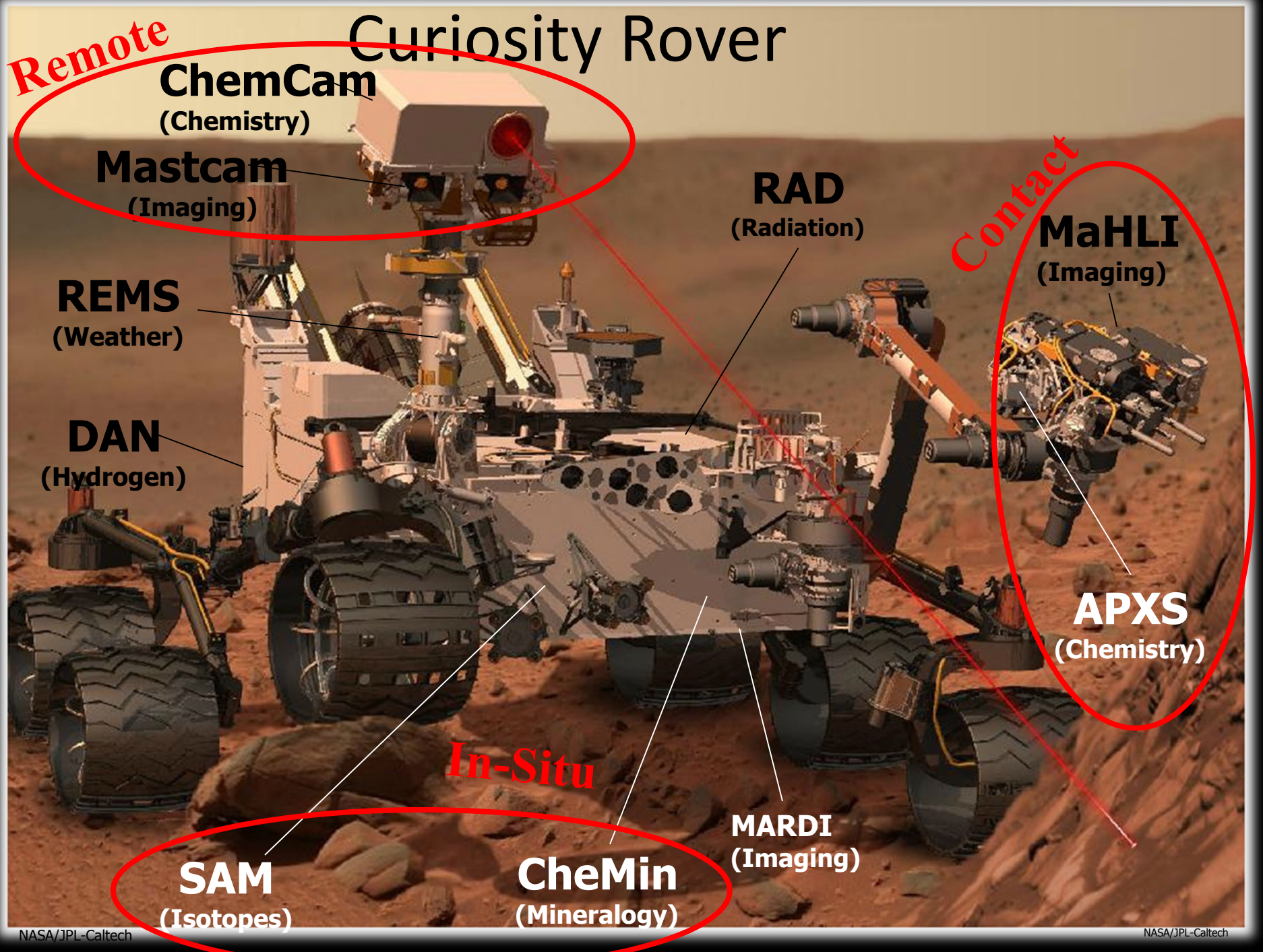
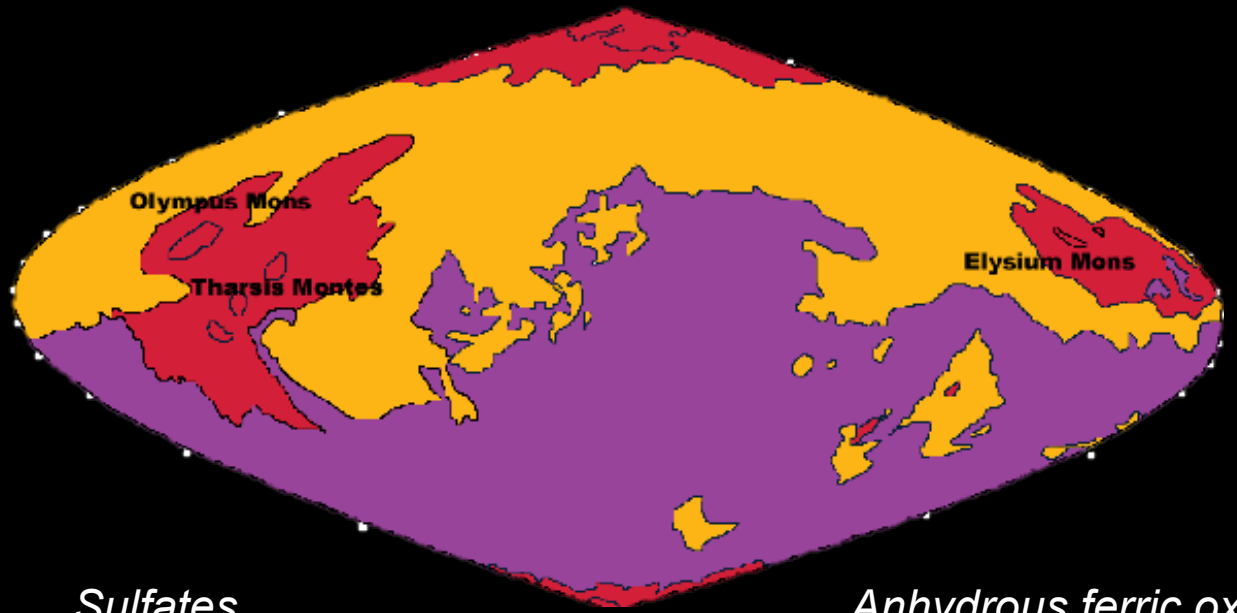


Image ~1.7x 1.0 cm

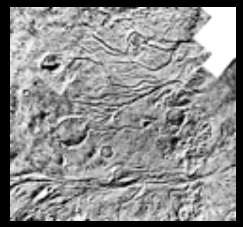
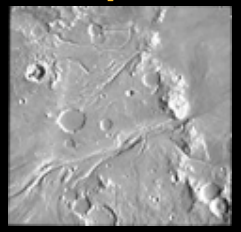
NASA/JPL-Caltech/MSSS

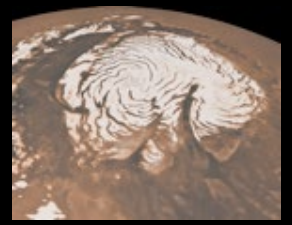

Curiosity Rover
Remote
ChemCam
(Chemistry)
Mastcam
(Imaging)
REMS
(Weather)
DAN
(Hydrogen)
RAD
(Radiation)
Contact
MaHLI
(Imaging)
APXS
(Chemistry)
In-Situ
SAM
(Isotopes)
CheMin
(Mineralogy)
MARDI
(Imaging)
NASA/JPL-Caltech
NASA/JPL-Caltech



Clays *Sulfates* *Anhydrous ferric oxydes*

Noachian **Hesperian** **Amazonian**




today

4.6 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0

Billions of years

Water on Earth

Life confirmed on Earth

- Volcan
- Outflo
- Oceans ?

- low impact rates
- Volcanism
- Outflow channels
- Polar caps
- Cold/dry

→ ***"Late Mars"***

→ ***"Early Mars"***

Agnes Cousin