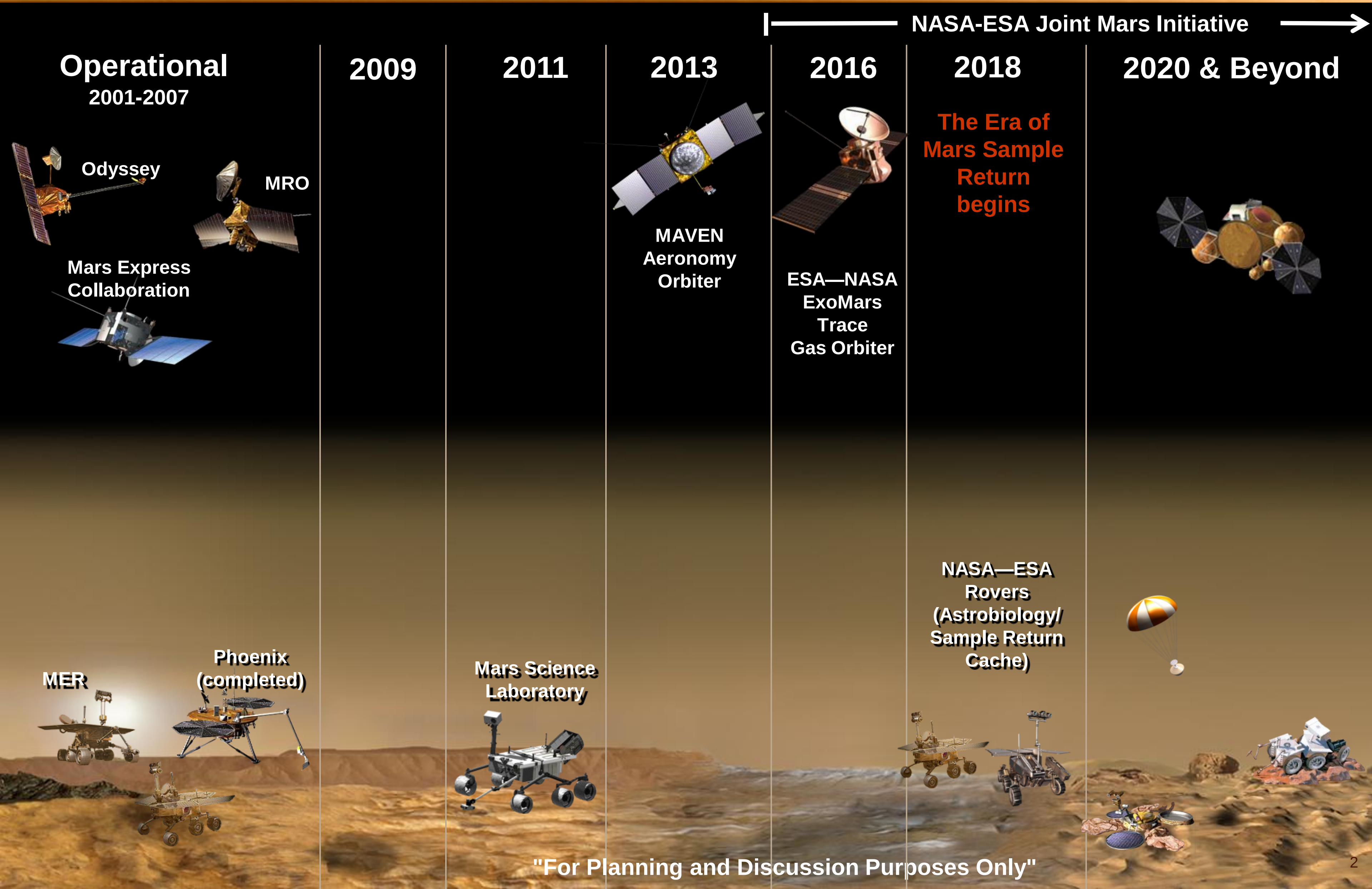
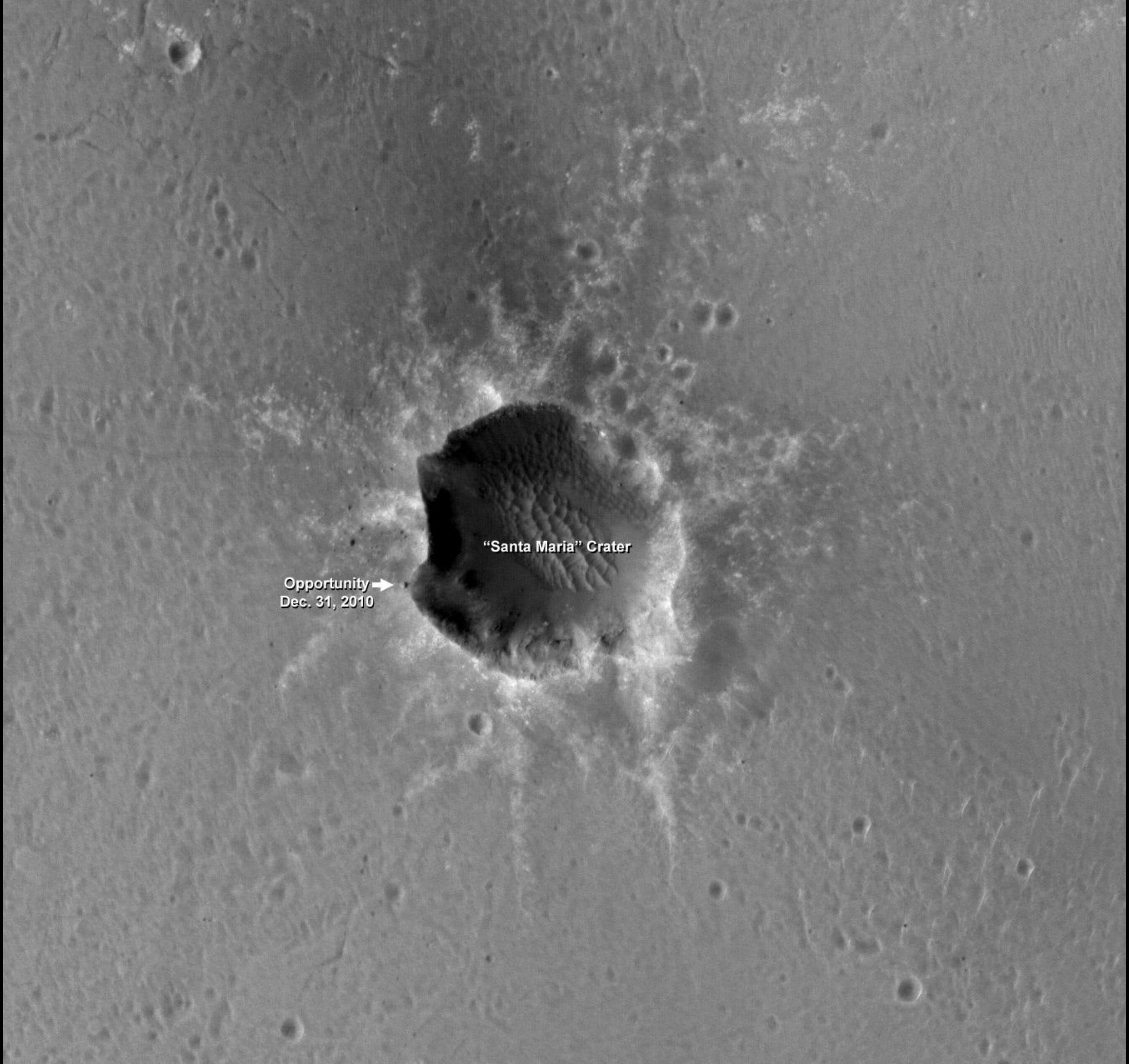
National Aeronautics and Space Administration

Mars Exploration

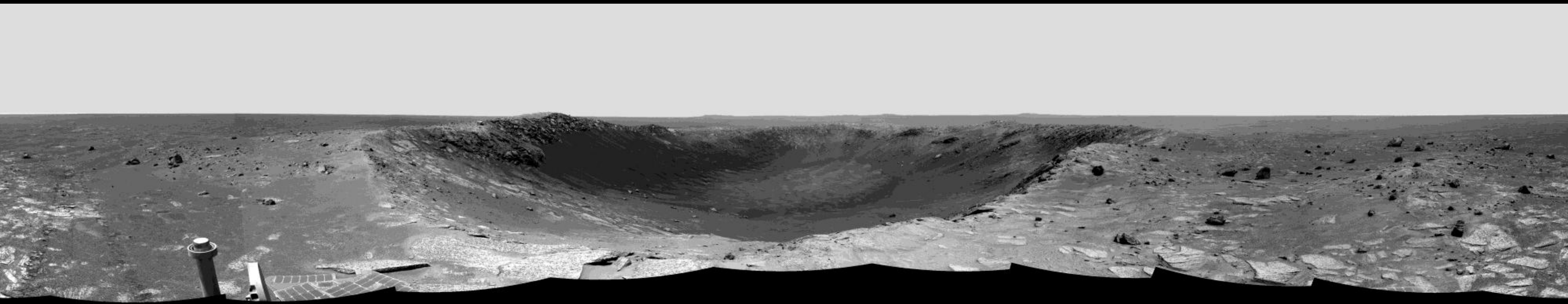
Michael Meyer
Lead Scientist, Mars Exploration Program

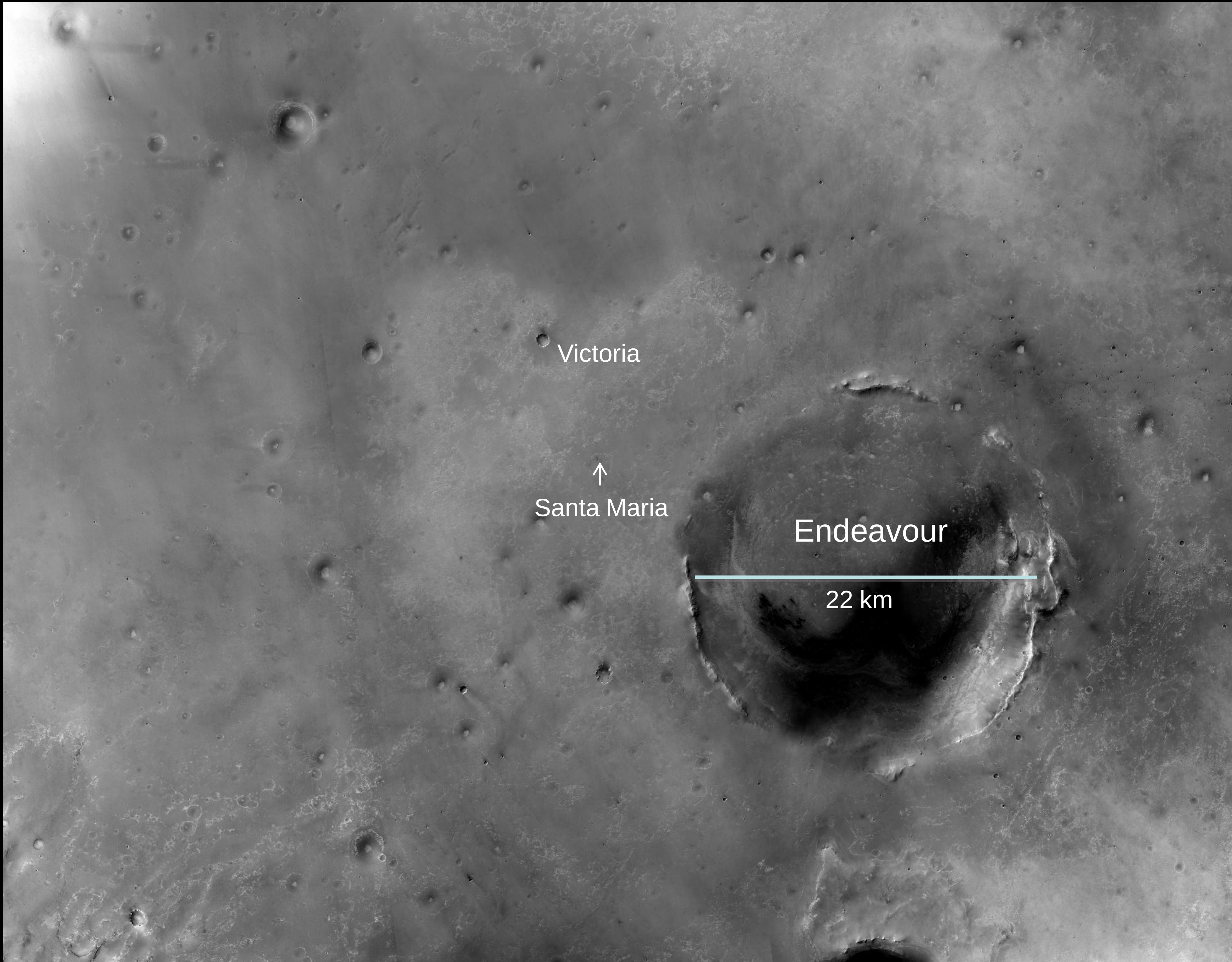
Planned MEP Portfolio *WITH* the Joint Program





"Santa Maria" Crater
Opportunity
Dec. 31, 2010





Victoria
Santa Maria
Endeavour
22 km

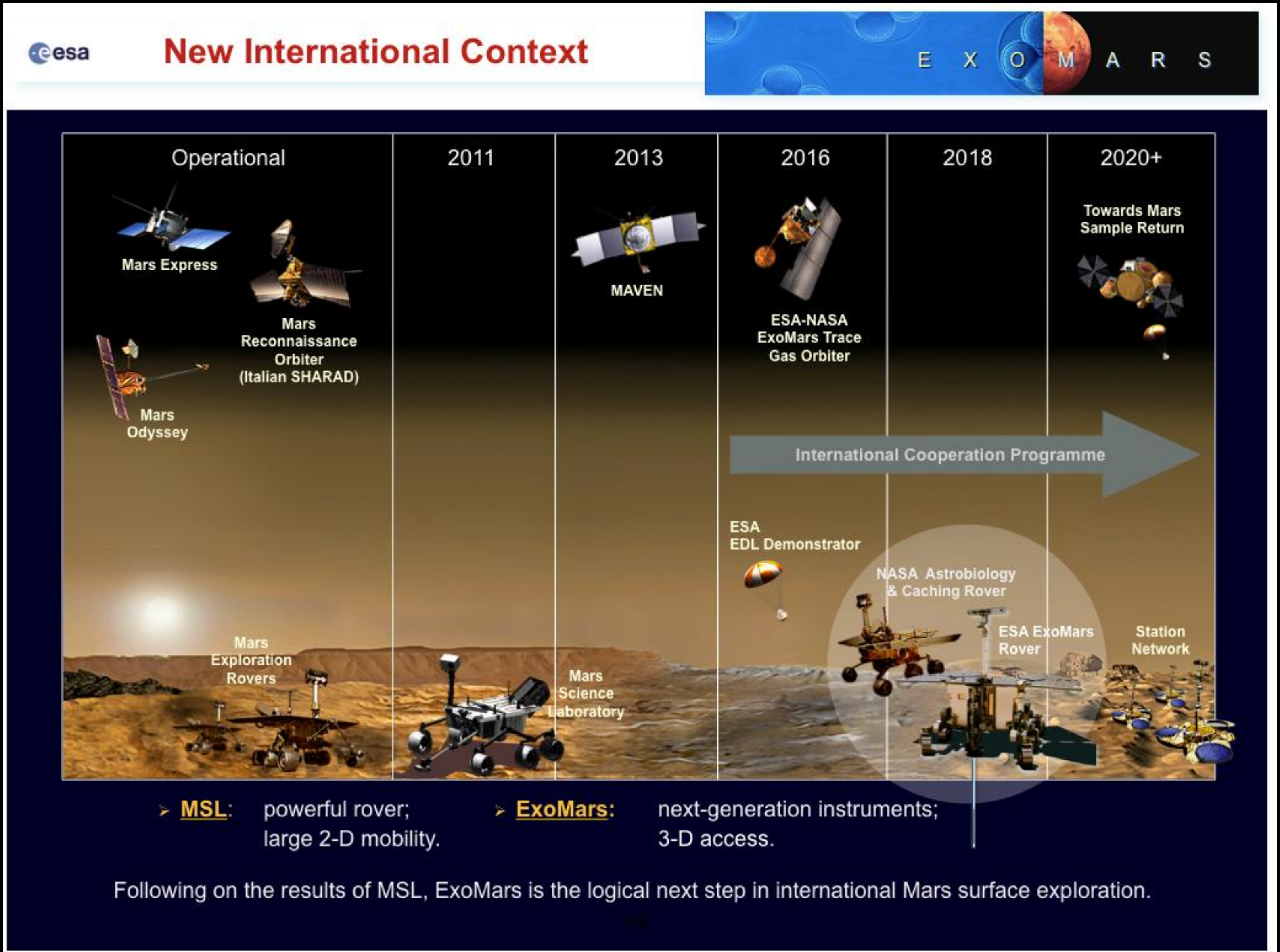
Mars: Where we stand

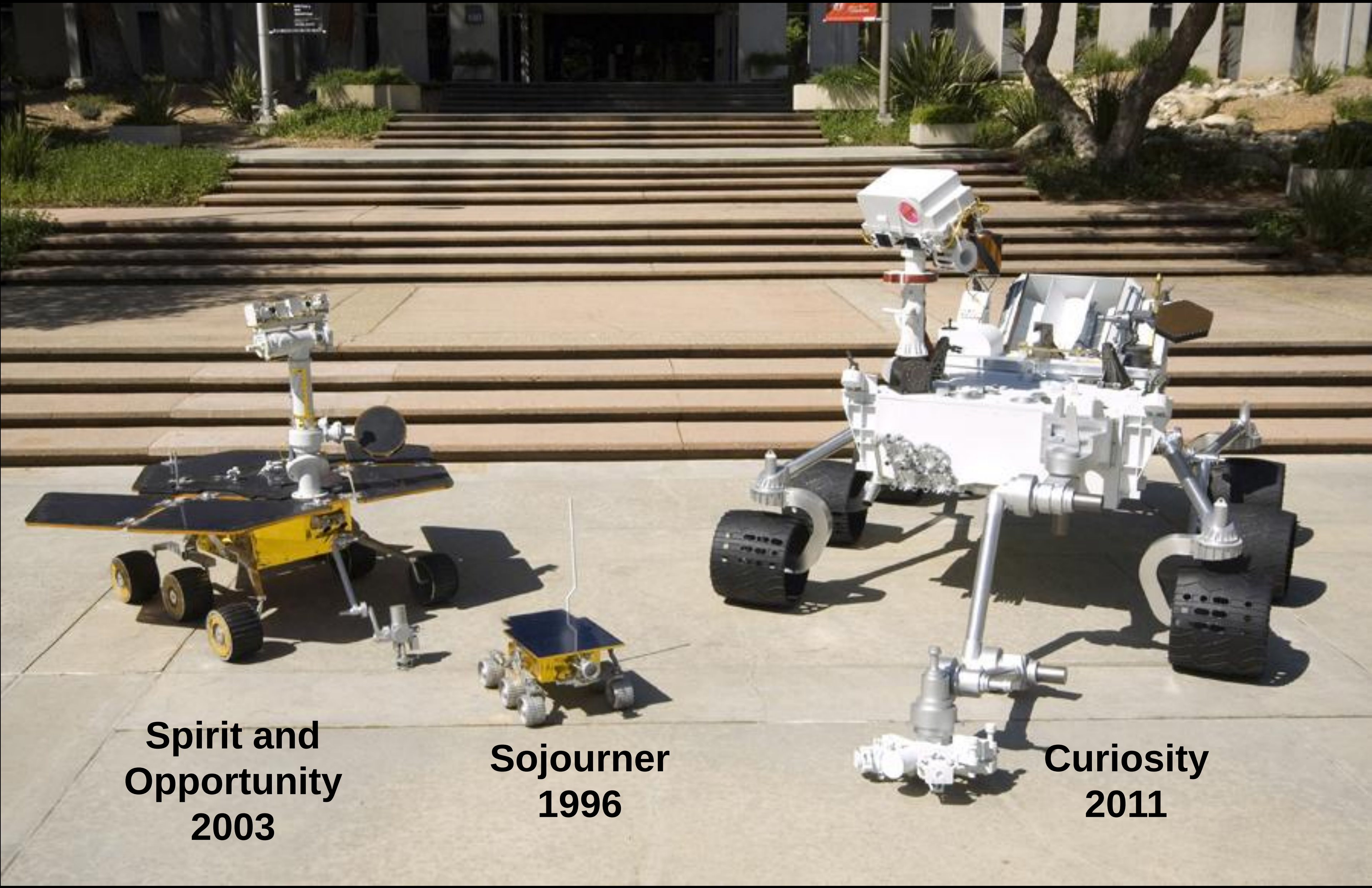
- Mars passed through a stage during which water on or near its surface became more ephemeral and very acidic, but Mars is much more complex.
  - Evidence for the persistence of local, non-acidic environments includes the carbonate deposits detected both from orbit by MRO and on the surface by MER Spirit at Gusev Crater
  - MRO has detected the mineral serpentine. Formation of this mineral releases hydrogen gas, which can support anaerobic metabolism or form methane, a gas detected in Mars' present atmosphere.
  - Hydrated silica, found contemporaneous with formation of large shield volcanoes, similar to those investigated at Home Plate by MER/Spirit, suggesting formation of silica in hot springs.

- Mars Global Surveyor (MGS) and MRO observations of new impacts have exposed clean water ice in the middle latitudes where such shallow ice is unstable today.

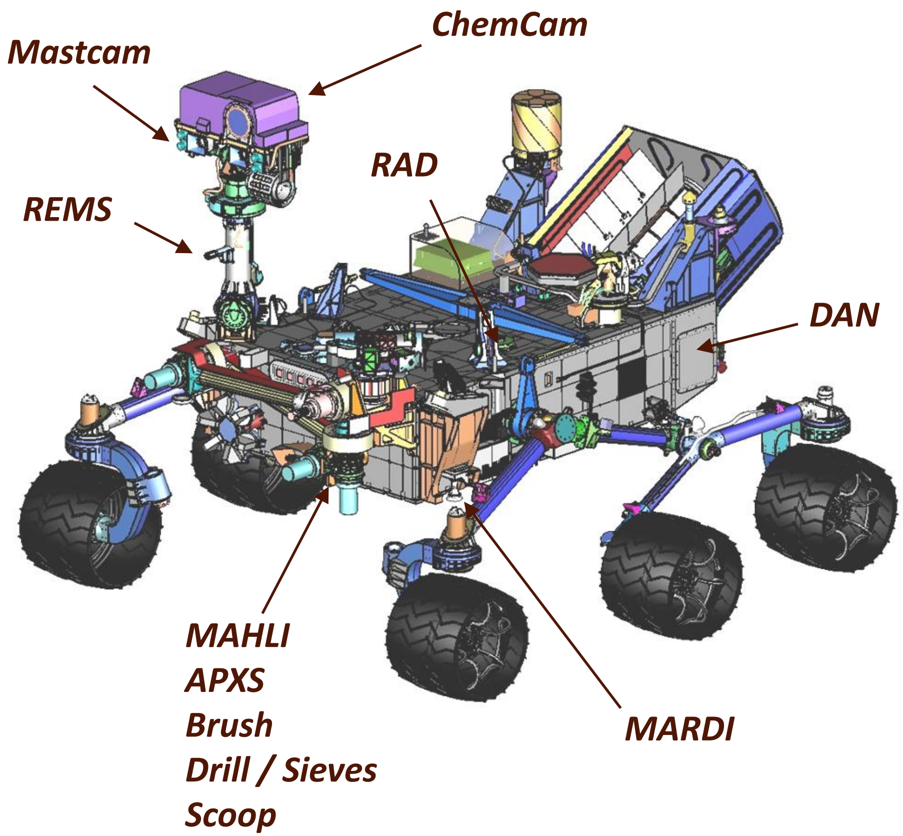
- A global feature map produced from Odyssey THEMIS daytime imaging in the thermal infrared; at 100 meters/pixel, this is the highest resolution global map yet of the Mars surface and will provide a standard base map for both scientific data analysis and the planning of future surface operations.

2016-20…
the era of collaboration




Spirit and
Opportunity
2003
Sojourner
1996
Curiosity
2011

MSL Science Payload



Rover Width:	**2.8 m**
Height of Deck:	**1.1 m**
Ground Clearance:	**0.66 m**
Height of Mast:	**2.2 m**

REMOTE SENSING

Mastcam (M. Malin, MSSS) - Color and telephoto imaging, video, atmospheric opacity

ChemCam (R. Wiens, LANL/CNES) – Chemical composition; remote micro-imaging

CONTACT INSTRUMENTS (ARM)

MAHLI (K. Edgett, MSSS) – Hand-lens color imaging

APXS (R. Gellert, U. Guelph, Canada) - Chemical composition

ANALYTICAL LABORATORY (ROVER BODY)

SAM (P. Mahaffy, GSFC/CNES) - Chemical and isotopic composition, including organics

CheMin (D. Blake, ARC) - Mineralogy

ENVIRONMENTAL CHARACTERIZATION

MARDI (M. Malin, MSSS) - Descent imaging

REMS (J. Gómez-Elvira, CAB, Spain) - Meteorology / UV

RAD (D. Hassler, SwRI) - High-energy radiation

DAN (I. Mitrofanov, IKI, Russia) - Subsurface hydrogen

Curiosity's Science Goals

Curiosity's primary scientific goal is to explore and quantitatively assess a local region on Mars' surface as a potential habitat for life, past or present

Objectives include:

- Assessing the biological potential of the site by investigating any organic and inorganic compounds and the processes that might preserve them
- Characterizing geology and geochemistry, including chemical, mineralogical, and isotopic composition, and geological processes
- Investigating the role of water, atmospheric evolution, and modern weather/climate
- Characterizing the spectrum of surface radiation

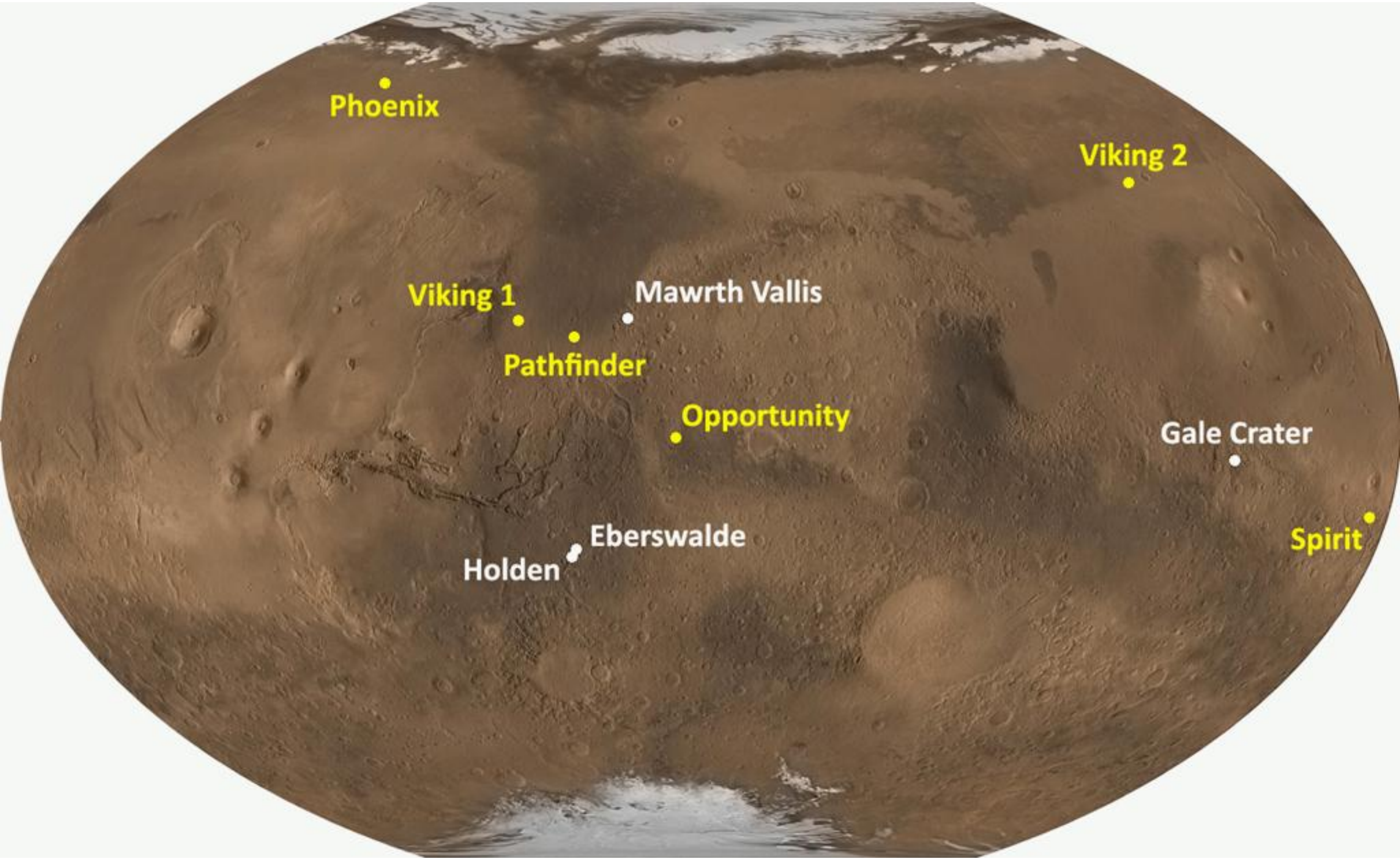
Curiosity Milestones

- Call for Participating Scientist proposals
  - ~18 expected selections
  - 4 ½ years duration
  - Proposals due March 22, 2011

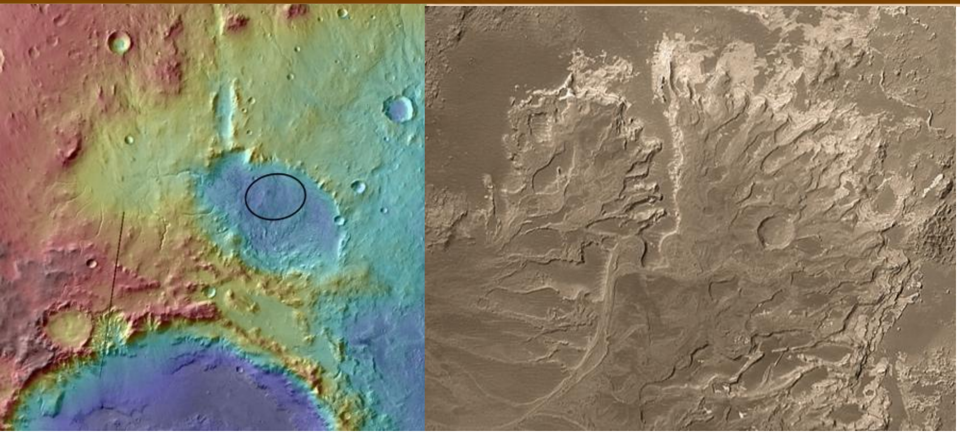
- Launch Window opens, Nov. 25, 2011

- Landing on Mars, Aug. 2012

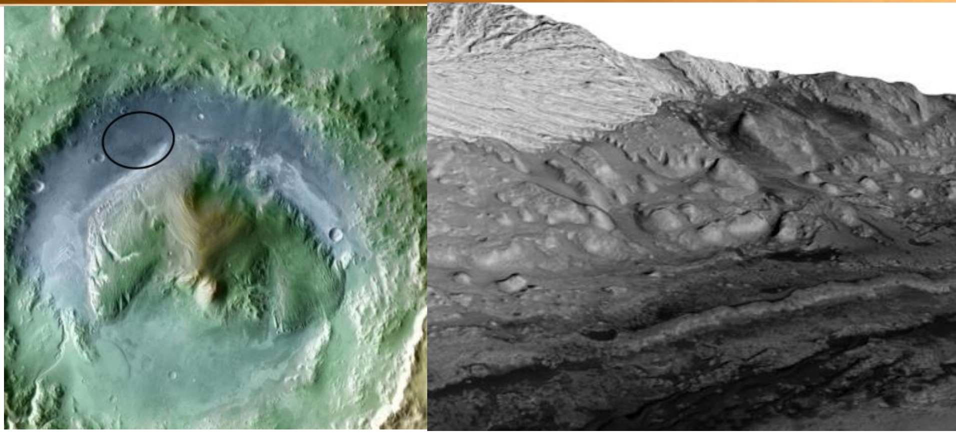
Mars Landing Sites
(Previous Missions and MSL Candidates)



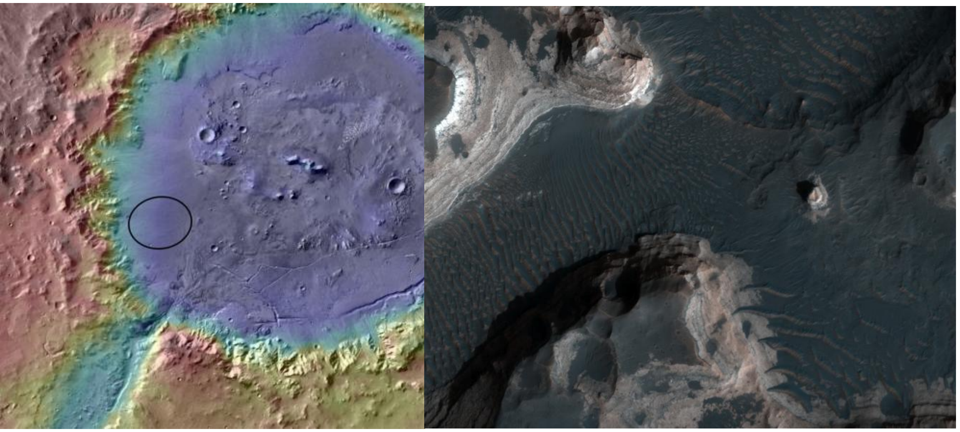
Candidate Landing Sites



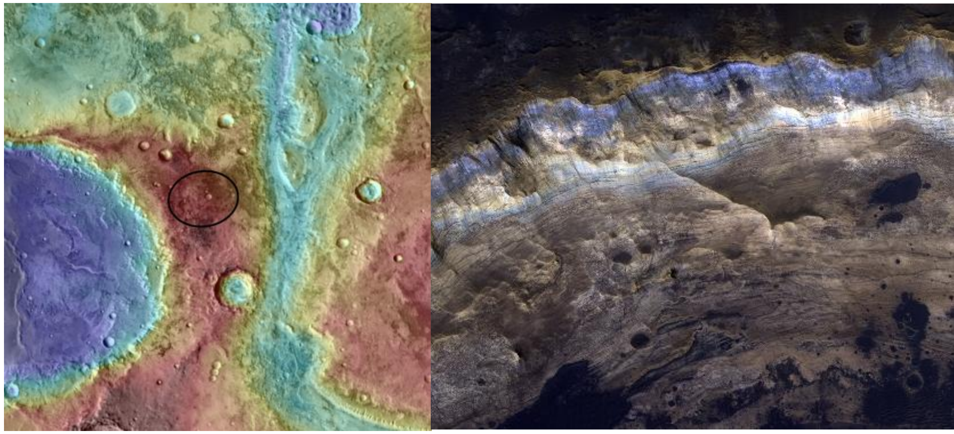
Eberswalde Crater (24°S, 327°E, -1.5 km) contains a clay-bearing delta formed when an ancient river deposited sediment, possibly into a lake.



Gale Crater (4.5°S, 137°E, -4.5 km) contains a 5-km sequence of layers that vary from clay-rich materials near the bottom to sulfates at higher elevation.

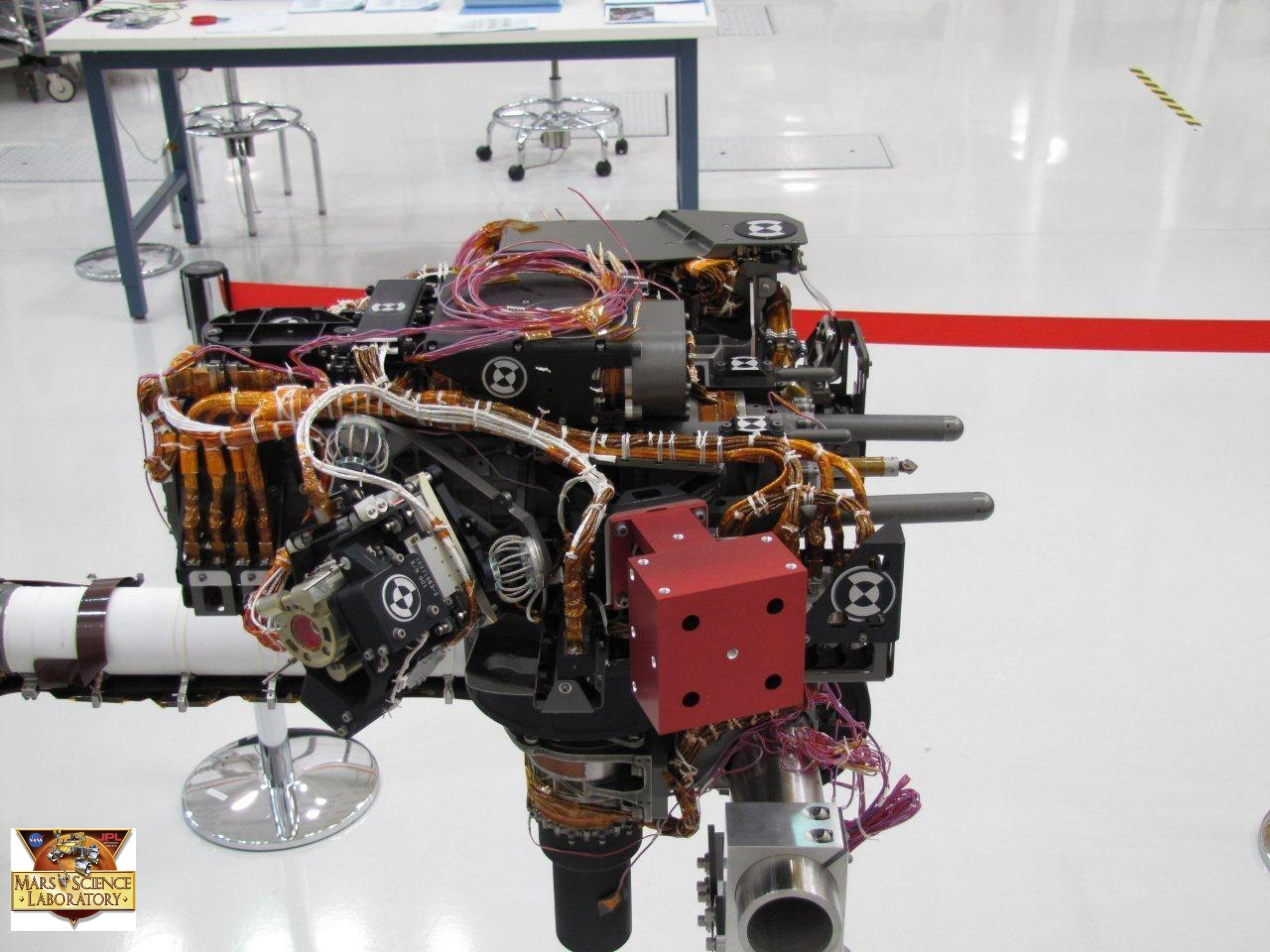


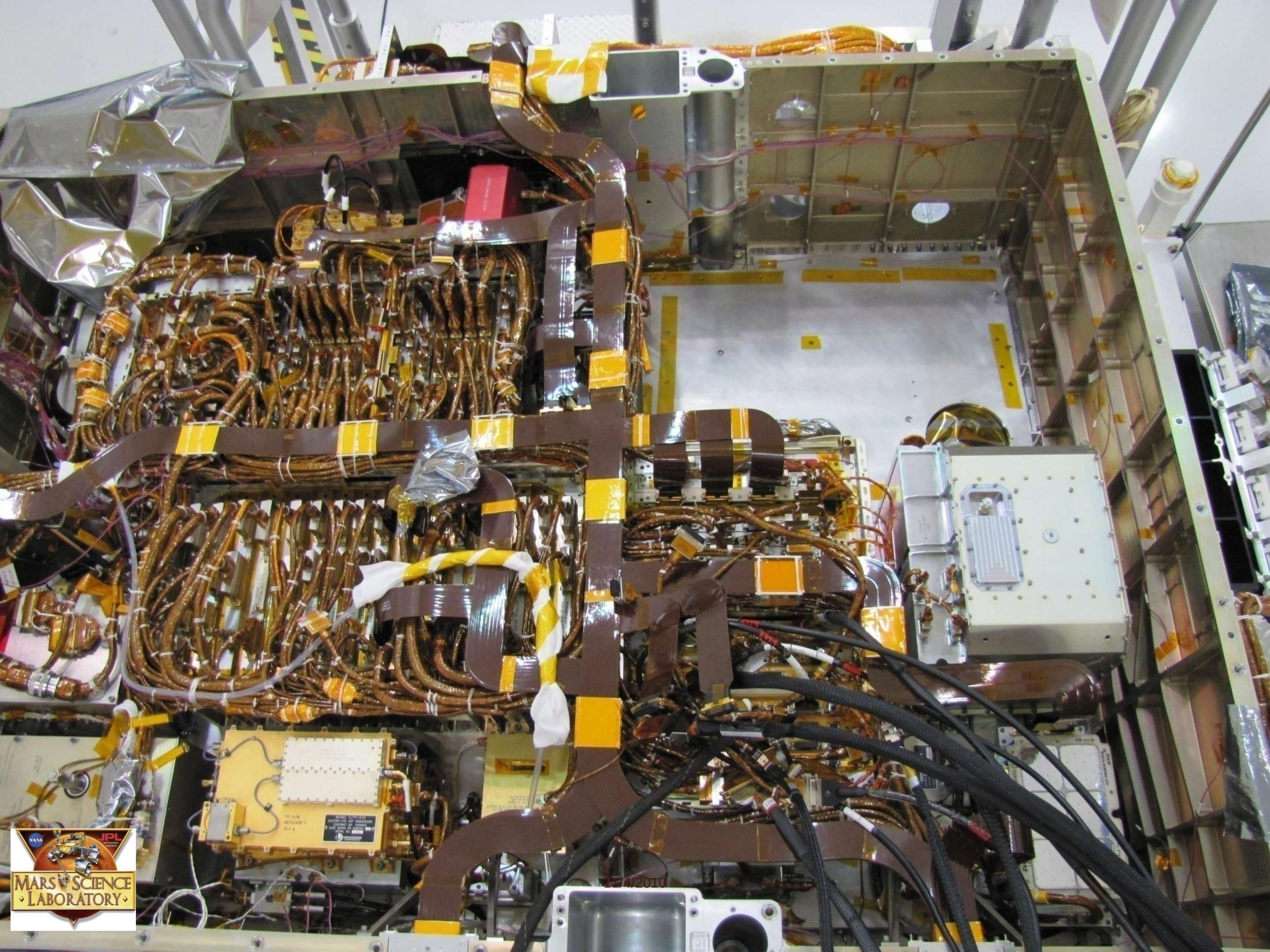
Holden Crater (26°S, 325°E, -1.9 km) has alluvial fans, flood deposits, possible lake beds, and clay-rich sediment.

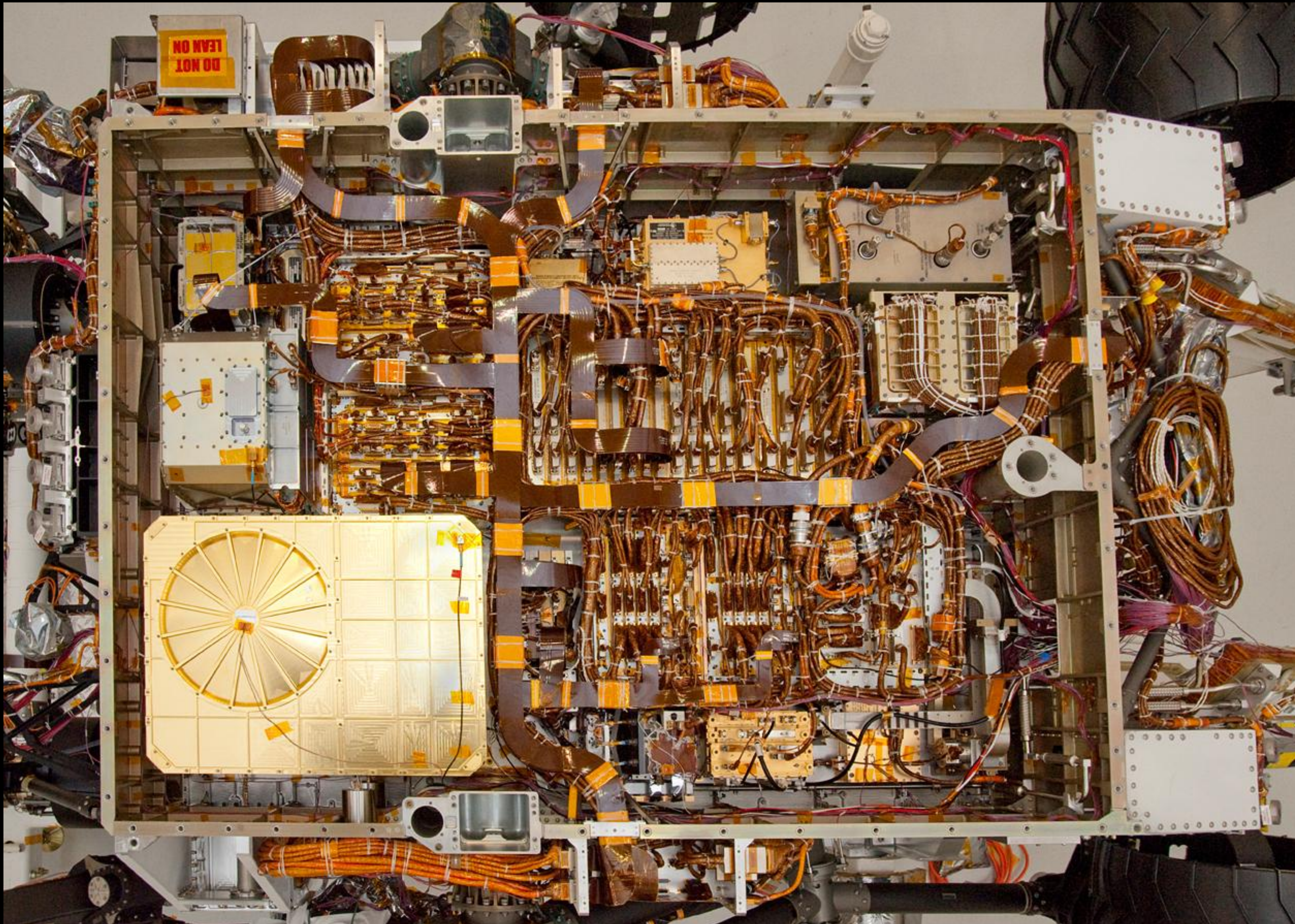


Mawrth Vallis (24°N, 341°E, -2.2 km) exposes layers within Mars' surface with differing mineralogy, including at least two kinds of clays.


117-HFJ
MARS SCIENCE LABORATORY


NASA
JPL
MARS SCIENCE
LABORATORY


JPL
MARS SCIENCE LABORATORY
11/4/2010


DO NOT
LEAN ON

NASA-ESA Partnership Progress

Background – Joint NASA/ESA Mars Exploration

- In 2008, ESA and NASA were both having budget difficulties
- Early in 2009, ESA and NASA discussed merging resources to join ESA's ExoMars and NASA's Mars Science Orbiter
- July 2009 bi-lateral meeting in Plymouth, England split ExoMars' objectives across two mission opportunities in 2016 and 2018
  - Agreement endorsed by the NASA Administrator and the ESA Director General in November 2009 and by the ESA Council in December 2009
- First mission of joint partnership, 2016 ExoMars Trace Gas Orbiter
  - 2016 Instruments announced August 2010 – decided through an open competition with joint review and selection
- 2018 mission takes two rovers to the surface of Mars
- These missions will serve as the foundation of a cooperative program that increases science return and moves the agencies towards a joint Mars sample return mission in the 2020s.

Partnership Synergy

- NASA expanded its scientific capabilities in the next decade
  - Conduct trace gas science/provide infrastructure needs in 2016
  - Conduct surface mission in 2018 to take advantage of the best “energetic” opportunity in next decade — accelerated from 2020

- ESA can accomplish the technology and scientific goals of ExoMars
  - ESA’s objectives more realistic when spread across the 2016/2018 opportunities
  - On-going shift by ESA management to a “program mind-set”

- Enables an affordable future Mars sample return mission—undoubtedly an international mission
  - NASA and ESA will learn how to conduct joint planetary missions with “clean interfaces,” even when both agencies are on the other’s critical path

A New Kind of SMD International Partnership

This is a partnership between **programs**

- Historically, partnership with ESA is on a single mission basis
- *Quid pro quo* is balanced across multiple missions, not within a single mission
- Leadership of missions is negotiated and alternated
- Partnership leverages resources, enabling increased mission content and launch frequency over a period of years
- Sharing risk and responsibility of technology developments (within ITAR)
- Each mission's risks and successes affect future missions, regardless of who is the "mission lead"
  - Intertwined critical paths
  - Technology and schedule risk

Overall risk posture increases when partnering at program level
–but–
The benefits outweigh the risks

NASA-ESA Joint Initiative Management Structure
Program Initiation and Mission Formulation

- Management structure established
  - Joint Mars Executive Board—meets regularly
  - Joint Engineering Working Group for future mission concepts
  - Joint Mars Architecture Review Team (jMART) established, first meeting in Feb.’11
- 2016 mission project office established in Mars Program Office at JPL
  - ESA orbiter mission under ExoMars program office
- Bi-Lateral (Dr. Southwood and Dr. Weiler)—meets regularly
- Overall governance, documentation, review and approval processes, etc., maturing
  - Presentated to NASA Agency Program Management Council
- MSR working group established

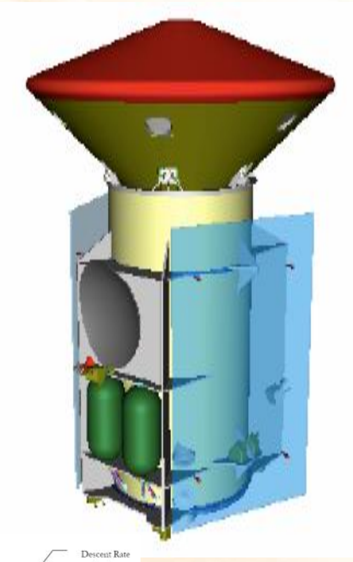
2016 NASA/ESA Orbiter Overview

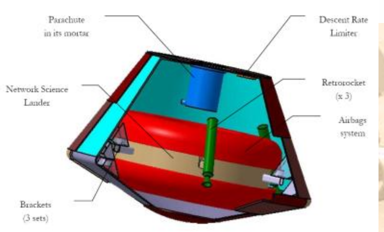
Mission Overview— ESA Mission Lead

- Orbital science and refresh telecommunications infrastructure
  - Critical ESA secondary mission—Entry, Descent and Landing (EDL) demonstrator
- Primary Science—Trace gas detection and characterization, incl. methane
  - Potential Secondary Science—moderate resolution imaging (2-3m)
  - Tertiary science--<5kg battery-only landed science, e.g. seismology, meteorology, etc.
  - All instruments jointly selected through AOs for orbiter & lander
  - Orbiter AO released January 15, 2010

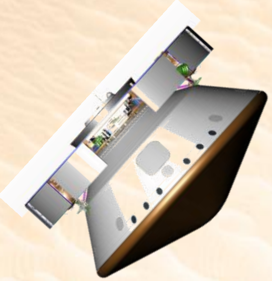
- Key NASA roles/deliverables
  - Orbiter science payload
  - Launch vehicle – Atlas V 400 series-class
  - Science operation lead; aerobraking design/operation lead; relay lead

- Key Milestones
  - Aug.'10 Joint instrument selection
  - Nov '10: Mission PDR
  - Jun '11: Mission/System Confirmation Review (øB -> øC)



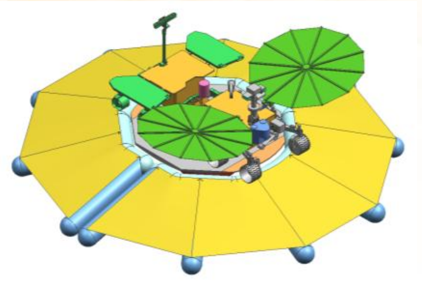


2018 NASA/ESA Rovers Overview

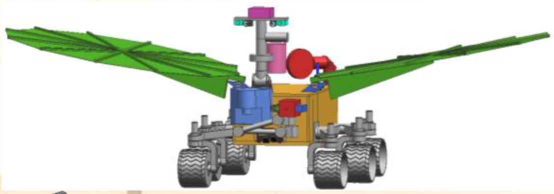


Mission Overview— NASA Mission Lead

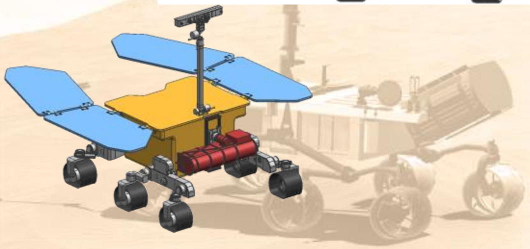
- Deliver NASA's and ESA's rovers to the surface of Mars
- Primary Science—astrobiology and caching samples
  - NASA: astrobiology and contact science, sample caching
  - ESA: critical technologies—roving and drilling
    - Exobiology science payload
- ISAG formed to help define complimentary science (MEPAG outbrief)



- Key NASA roles/deliverables
  - Rover—science payload selected through AO
  - Launch vehicle – Atlas V 531-class
  - SkyCrane-based entry, descent and landing system
  - Launch, cruise and EDL operations, operations for U.S. rover



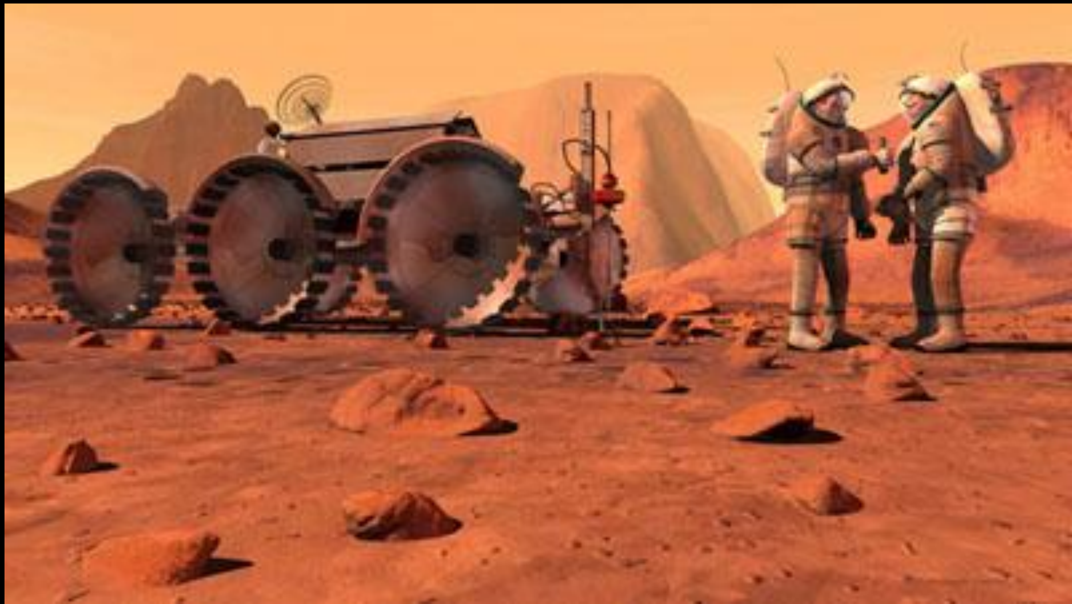
- Key Near-term Milestones
  - Mar '10: Concept Feasibility Review
  - Dec '10: Architecture Review
    - Mission designs do not close yet
  - Sept '11: ICD Version 1
  - Dec '11: Mission Concept Review (leads to KDP-A)



2020+

Returning samples

…and much more?



Acronyms

NASA	National Aeronautic & Space Administration
ESA	European Space Agency
MEP	Mars Exploration Program
ODY	2001 Mars Odyssey
MER	Mars Exploration Rovers
MSL	Mars Science Laboratory
MEPAG	Mars Exploration Program Analysis Group
AO	Announcement of Opportunity
ICD	Interface Control Document
KDP	Key Decision Point
ITAR	International Traffic in Arms Regulations
PDR	Preliminary Design Review
EDL	Entry, Descent, and Landing

Acronyms (cont.)

- Mast Camera (Mastcam)
- Mars Hand Lens Imager (MAHLI)
- Mars Descent Imager (MARDI)
- Alpha Particle X-Ray Spectrometer (APXS)
- Chemistry & Camera (ChemCam)
- Chemistry & Mineralogy X-Ray Diffraction/X-Ray Fluorescence Instrument (CheMin)
- Sample Analysis at Mars (SAM)
- Radiation Assessment Detector (RAD)
- Dynamic Albedo of Neutrons (DAN)
- Rover Environmental Monitoring Station (REMS)

- MSSS - Malin Space Science Systems
- LANL - Los Alamos National Laboratory
- CNES - Centre National d'Etudes Spatiales (Center for National Space Studies, France)
- GSFC - Goddard Space Flight Center
- ARC - Ames Research Center
- CAB - Centro de Astrobiologia (Center for Astrobiology, Spain)
- SwRI - Southwest Research Institute
- IKI – Space Research Institute of Russia