Mars Exploration Program Analysis Group (MEPAG)

Jeffrey R. Johnson, *MEPAG Chair*

Report to Planetary Science Advisory Committee

February 23, 2018

Mars Science Laboratory
View toward path traversed
Sol 1856 (10/25/2017)
https://photojournal.jpl.nasa.gov/catalog/PIA22209

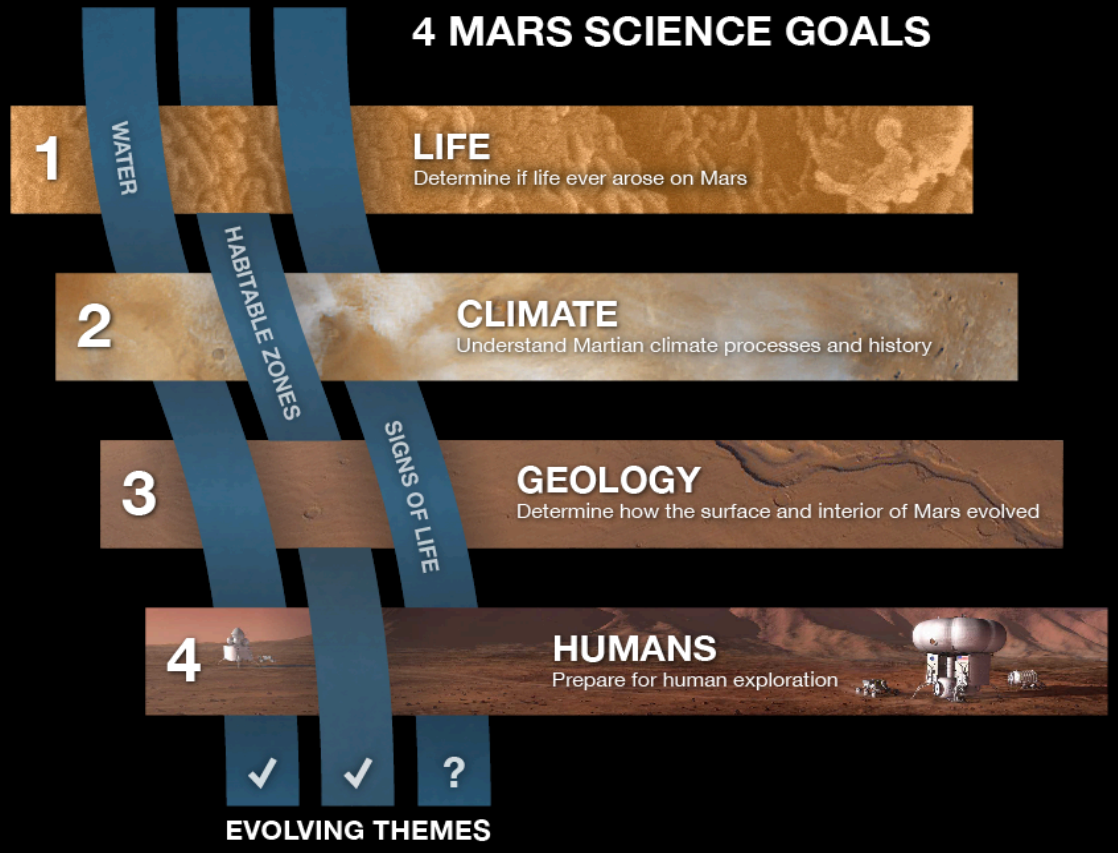
Outline

- MEPAG charter and committees
- Recent/Upcoming activities and meetings
- Future work
  - Next Mars architecture
  - Preparations for the next Planetary Decadal Survey
- Concerns
- Summary
- (Mars mission updates)

Mars Exploration Program Analysis Group (MEPAG)

*The **Mars Exploration Program** is an integrated program of robotic flight missions and research activities dedicated to:*

- *Understanding how Mars has evolved as a planet*
- *Whether there is evidence of life, past or present*
- *Preparations for future exploration by humans on Mars itself*



Can we determine if/when Mars was/is inhabited?

Mars Exploration Program Analysis Group (MEPAG)

What is MEPAG?

https://mepag.jpl.nasa.gov/about.cfm

MEPAG is responsible for providing science input needed to plan and prioritize Mars exploration activities. MEPAG serves as a community-based, interdisciplinary forum for inquiry and analysis in support of Mars exploration objectives. To carry out its role, the MEPAG updates goals, objectives, investigations and required measurements for robotic and human exploration of Mars in response to new discoveries and directions on the basis of the widest possible community outreach.

Curiosity reaching the southern part of Murray Buttes - sol 1435 - NASA/JPL-Caltech/MSSS/Thomas Appéré

What is MEPAG?

Community: MEPAG meetings are open to all members of the planetary exploration community, particularly those scientists, engineers, project and program personnel, theoreticians and experimentalists, instrument scientists, and modelers who are interested in Mars exploration.

International participation is welcomed and solicited as appropriate, including reports of activities by the various space agencies.

Artist's concept of an astronaut to scale with Murray buttes, Curiosity right Mastcam, sol 1436 NASA / JPL / MSSS / Seán Doran

What is MEPAG?

Procedure: The MEPAG maintains the Goals Document and conducts analysis activities on topics of relevance to Mars-related exploration. http://mepag.nasa.gov/reports.cfm

- 4 Main Goals Aligned with *Decadal Survey*: 1) Life, 2) Climate, 3) Geology, 4) Preparation for Humans (not prioritized)
- Prioritized Hierarchy within each Goal: Objectives, Sub-objectives, and Investigations
- Cross-cutting and interdisciplinary themes identified and articulated

- Analysis tasks may be requested by NASA, including its Mars Exploration Program (MEP), its Science and Human Exploration & Operations Mission Directorates (SMD, HEOMD), and its advisory committees, such as the ~~Planetary Science Subcommittee (PSS)~~ Planetary Science Advisory Committee (PAC).
- Tasks may also be requested through NASA by committees of the National Academy of Sciences (NAS) Space Sciences Board. MEPAG may choose to organize Science Analysis Groups (SAGs) to deal with specific issues; these SAGs report their findings to the full community. Findings are reported to the requestors and posted to the community on the MEPAG website, and status reports are routinely made to MEP and ~~PSS~~ PAC.

What is MEPAG?

Organization:

- Chair: appointed by the MEPAG Executive Committee in consultation with NASA Headquarters.
- MEPAG Executive Committee : MEPAG Chair (lead), the previous MEPAG Chair, the MEP Lead Scientist, the Mars Program Office Chief Scientist, the Goals Committee Chair, and up to 5 additional members of the MEPAG community. HEOMD Chief Scientist for Exploration is an ex officio member.
- Goals Committee nominally has two members for each of the four goal areas, in addition to its Chair.
- Membership of the Executive and Goals Committees are solicited from the MEPAG community and determined by the Chair and Executive Committee.
- Typical terms ~2-3 years depending on activity
- Logistical and organizational support to the MEPAG, including its analysis groups, is provided through the Mars Program Office, located at the Jet Propulsion Laboratory.

MEPAG Programmatics

- Committees:
  - Executive Committee (J. Johnson, Chair, appointed 3/16)
    - W. Calvin (Univ. Nevada Reno)
    - J. Eigenbrode (GSFC)
    - L. Pratt (Indiana Univ./ NASA HQ)→ Planetary Protection Officer
    - D. Banfield (Cornell)
    - S. Hubbard (Stanford University)
    - D. Beaty, R. Zurek (JPL)
    - M. Meyer (NASA HQ)
    - B. Bussey (HEOMD, NASA HQ) Ex Officio member
  - Goals Committee (D. Banfield, Chair)
    - Goal I <*Life*> (S.S. Johnson, Georgetown University, J. Stern, GSFC)
    - Goal II <*Climate*> (R. Wordsworth, Harvard University, D. Brain (Univ. Colorado), P. Withers (Boston Univ.)
    - Goal III <*Geology*> (S. Ruff, Arizona State University, A.Yingst, Planetary Science Institute)
    - Goal IV <*Human Exploration*> (J. Bleacher, GSFC, R. Whitley, JSC)

MEPAG Reports

https://mepag.jpl.nasa.gov/reports.cfm

MEPAG Reports/updates since 2011

- Report from Mars International Collaboration SAG (MIC-SAG) 3/2017
- Report from Next Orbiter SAG (NEX-SAG) 12/2015
- Candidate Scientific Objectives for Human Exploration of Mars, and implications for the identification of Martian Exploration Zones (HSO-SAG) 7/2015
- Mars Science Goals, Objectives, Investigations and Priorities (Update) 6/2015
- New Analysis of Mars 'Special Regions': Findings of the 2nd MEPAG Special Regions SAG (SR-SAG2) 11/2014
- Humans to the Martian System Summary of Strategic Knowledge Gaps (SKGs) P-SAG (joint between MEPAG and SBAG) 6/2012
- Is Mars Sample Return Required prior to Sending Humans to Mars? 2012

Supported by MEPAG:

- The Value of Participating Scientist Programs to NASA's Planetary Science Division 5/2017
- Mars Water In-Situ Resource Utilization (ISRU) Planning (M-WIP) Study 4/2016
- ISRU & Civil Engineering Needs for Human Mars Missions (ICE-SAG) 10/2015

Samples of Recent MEPAG Activities

- Presentations to Decadal Survey Mid-term Review (Review of Progress Implementing *Vision & Voyages*)
  - May 4: http://sites.nationalacademies.org/cs/groups/ssbsite/documents/webpage/ssb_180557.pdf
  - July 13: http://sites.nationalacademies.org/SSB/CurrentProjects/SSB_177619

- Virtual MEPAG meetings

  At MEPAG #33 face-to-face meeting (Feb. 2017) we discussed ideas for more frequent, shorter, focused topical discussions held as webcasts (i.e., virtual meetings) to augment face-to-face meetings

  - **MEPAG #34 (July, 2017): 2-hour telecon, including review/preview of presentations given to the Mid-Term Decadal Survey Review**
    - https://mepag.jpl.nasa.gov/meetings.cfm?expand=m34
  - **MEPAG #35 (Sept., 2017): 3-hour virtual meeting included NASA remarks on Mars architecture planning (J. Watzin), and presentations on Mars system Planetary Science Deep Space SmallSat Studies (PSDS3) projects**
    - https://mepag.jpl.nasa.gov/meetings.cfm?expand=m35
  - **MEPAG VM #1 (Feb. 20)-- (now numbered to take advantage of VM flexibility)**
    - NASA MEP planning in the context of the released FY19 federal budget
    - Mars Sample Return technology studies from Chad Edwards (JPL Mars Program Office)
      - P. Wooster (SpaceX)

Upcoming MEPAG Activities

- March 22 (12-1:15 pm): LPSC "meet and greet" scheduled
  - Not a "town hall", more an informal opportunity to meet MEPAG members, ask questions, provide feedback
  - To be accompanied by poster displayed Tuesday night (Abstract #2403)
- April 3-5: MEPAG face-to-face meeting
  - Polar science community inputs/changes to MEPAG Goals Document
  - Identifying mission objectives and concepts that address high-priority Mars science questions, with an emphasis on preparation for the next Decadal Survey (2023-2032) during the era of MSR
- July: COSPAR meeting
  - MEPAG abstract/presentation on "Forward planning for Mars scientific exploration"
  - Participate in panel on "International Coordination of Space Exploration Activities"

Discoveries/Questions That Require Follow-up as of 2018

- Did Mars ever have life? Is it still there?
  - Science-driven sample return is critical to answering this question.
- How, when, and how often did Mars experience great transition(s) from a much wetter environment to the cold, dry, oxidizing world of today?
  - We have discovered 10+ distinct potential habitats, comprising a key environmental record in the strata from first billion years. How many more of these habitats are there and what is their time history? Need to characterize and date materials from many different locations.
- How do terrestrial planets like Mars respond to early processes like giant impacts and warming from a faint young sun in our solar system?
  - What is the timing/intensity of these processes? How did different Mars habitats respond to these changes?
- How is water involved in the near-surface today?
  - RSLs: what are these seasonally changing streaks? Gullies and salts in last few million years?
- How do obliquity cycles affect atmospheric pressure and episodic modern water cycle?
- What does water ice on Mars tell us about the earlier climate and environmental changes?
- What is the temporal variability, amount, and source of methane?

Preparing for the Next Planetary Decadal Survey and the Next Mars Architecture: Key Factors

- Science-driven Mars Sample Return (MSR) remains a high priority for Mars and Planetary Science
- New and ongoing missions will continue to make new discoveries
  - Including Trace Gas Orbiter and InSight
- Mars is now a target for many other space agencies and commercial entities
  - ESA, ISRO, CSA, JAXA, China, UAE, SpaceX, etc.
- New capabilities are upcoming
  - Solar Electric Propulsion (SEP), small satellites, etc.
- There are several non-MSR science objectives under study that could/should be pursued
  - polar science, Recurring Slope Lineae (RSLs), etc.
- Major uncertainties include:
  - future budgets
  - relationship of the robotic and human Mars exploration activities
    - Dual-purpose missions? Robotic precursors?

MEPAG Roles (1 of 2)

- Continue support for the 2020 Mars rover and press for comprehensive planning of the next missions needed to complete Mars sample return (MSR)

- Investigate opportunities to pursue non-MSR science, including R&A
  - Mars is a complex planet. The scientific questions now being asked require new analysis, new laboratory work on volatile and aqueous processes, and continued work on/in Earth analog field sites, all of which the community is prepared/excited to pursue.
  - Facilitate coordination of possible small satellite, commercial space, and international opportunities to fly science instruments/investigations
  - Study possibility of competed, PI-led small satellite missions carried to Mars by strategic missions (with data returned through those missions)

MEPAG Roles (2 of 2)

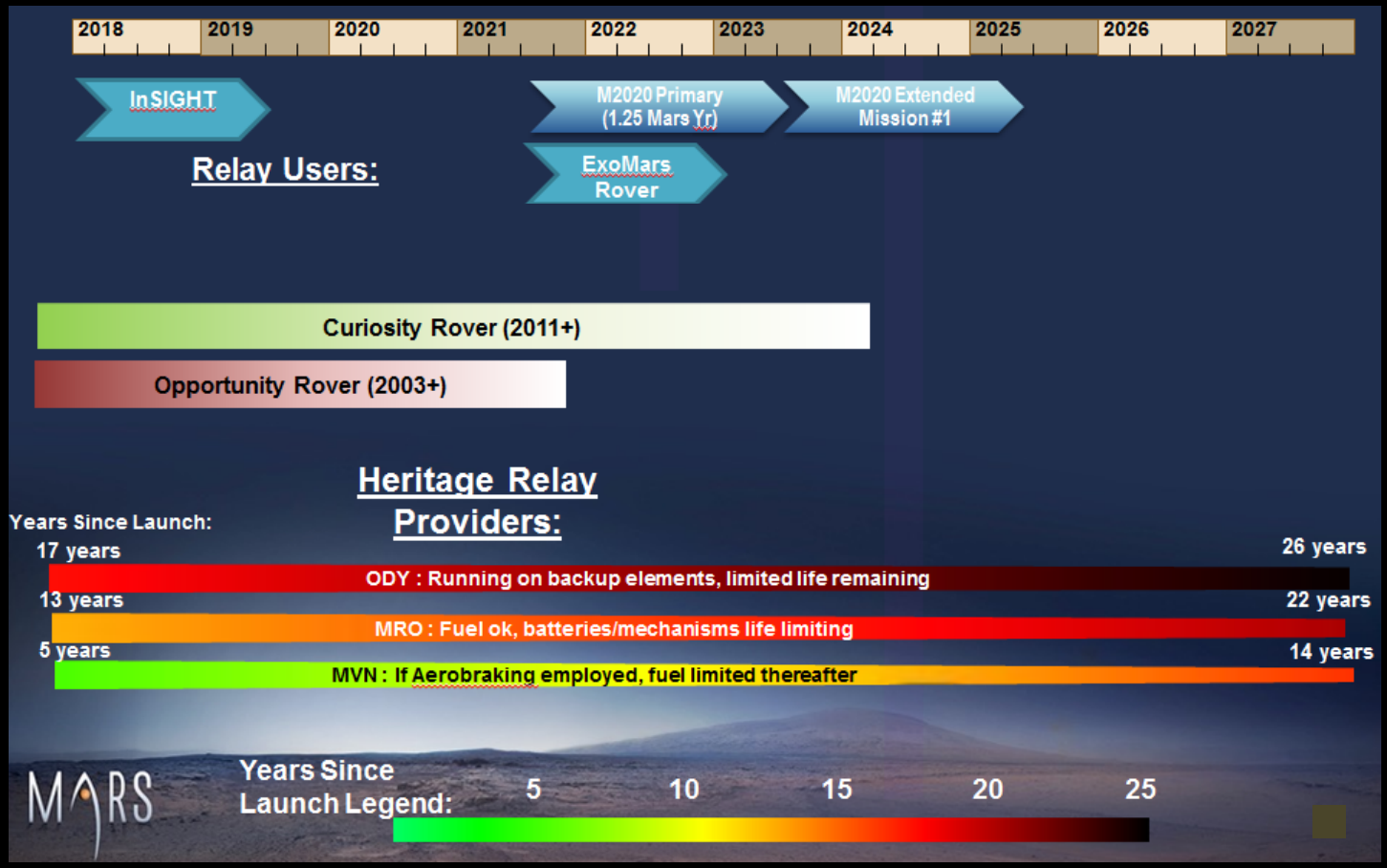
- Update the Goals Document to maintain consistency with new discoveries
- Identify possible New Frontiers candidates to be approved for study in the next Planetary Decadal Survey
- Investigate how to assist planning for human missions, including dual missions supporting both science and exploration
  - See next slide

Preparations for Humans

- ***Mars is the logical destination for humans in deep space***
  - What do we need to know to make that journey possible while minimizing cost and risk?
  - Can humans live on Mars? Where are the resources? What are the hazards?
    - Where can water be extracted? From shallow ice? From hydrated minerals?
    - Planetary protection policy must be addressed if these resources are to be used.
    - What are the nature of the hazards and how can they be mitigated?
  - What should humans do on Mars to advance our understanding of Mars, Earth, and all planets?

- ***MEPAG can assist exploring answers to these questions***
  - A human flight architecture is needed to set priorities in precursor missions, but MEPAG feels that analysis of returned samples would be a great benefit.
  - Joint workshops are an excellent way to bring the most relevant questions and plans into focus (e.g., the Human Landing Site workshop)
  - Existing and future orbital remote sensing analyses and new approaches can contribute
    - e.g., see Next Orbiter SAG report: https://mepag.jpl.nasa.gov/reports/NEX-SAG_draft_v29_FINAL.pdf

MEPAG Concerns: 1--MEP Infrastructure is Nearing Exhaustion

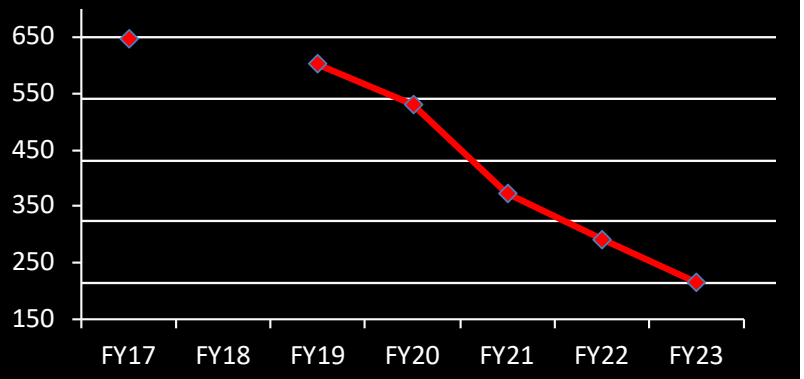


MEPAG Concerns: 2

- A prime concern of the MEPAG community has been the absence of high-level commitment to missions needed to carry out the return of the samples to be collected by 2020 caching rover now in development.
  - For a time, NASA avoided even discussion of such return. That changed with Dr. Zurbuchen's presentation to the Mid-Term Decadal Committee (August, 2017)
  - However, the FY19 President's Budget only "studies a potential Mars Sample Return"
- A second major concern of the U.S. portion of the MEPAG community is the absence of flight opportunities for U.S. investigators to address outstanding questions in Mars science (e.g., polar climate science) in parallel with, or perhaps as part of, the orbiter and rover missions required for sample return.

MEPAG Concerns: Mars Notional Budget

	Actual FY 17	Enacted FY 18	Request FY 19	Notional FY 20	FY 21	FY 22	FY 23
Science	5,762.2		5,895.0	5,859.9	5,841.1	5,822.4	5,803.6
Planetary Science	1,827.5		2,234.7	2,199.6	2,180.8	2,162.1	2,143.3
Planetary Science Research	230.1		258.0	247.6	247.6	247.6	247.6
Planetary Defense	60.0		150.0	150.0	150.0	150.0	150.0
Lunar Discovery and Exploration	19.0		218.0	218.0	218.0	218.0	218.0
Discovery	194.6		381.2	476.6	375.0	355.6	348.5
New Frontiers	134.0		130.2	163.7	245.0	327.6	388.4
Mars Exploration	647.0		601.5	529.7	371.9	290.8	215.3
Outer Planets and Ocean Worlds	359.5		285.6	213.8	373.3	372.5	375.5
Technology	183.3		210.2	200.2	200.0	200.0	200.0



- Current MEP line reflects the roll-off of Mars 2020
- Definition of the next Mars architecture is required
  - Next pieces of MSR
  - Additional missions to address high-priority science questions

Summary (1 of 2)

- There remains much exciting science to do at Mars, and community momentum is strong to address fundamental questions about planetary evolution and origin of life
  - New and ongoing discoveries have challenged many previous views of Mars–this will continue, given new and long-lived assets at Mars, supported by data analysis

- Progress is being made toward Mars Sample Return
  - 2020 Mars caching rover is on schedule and budget, with a capable payload for selecting samples and providing their geological context
  - Some technical studies in progress will help lower the cost and cost risk of future missions needed to complete sample return
    - Hopefully, these will be accelerated in the FY19 budget

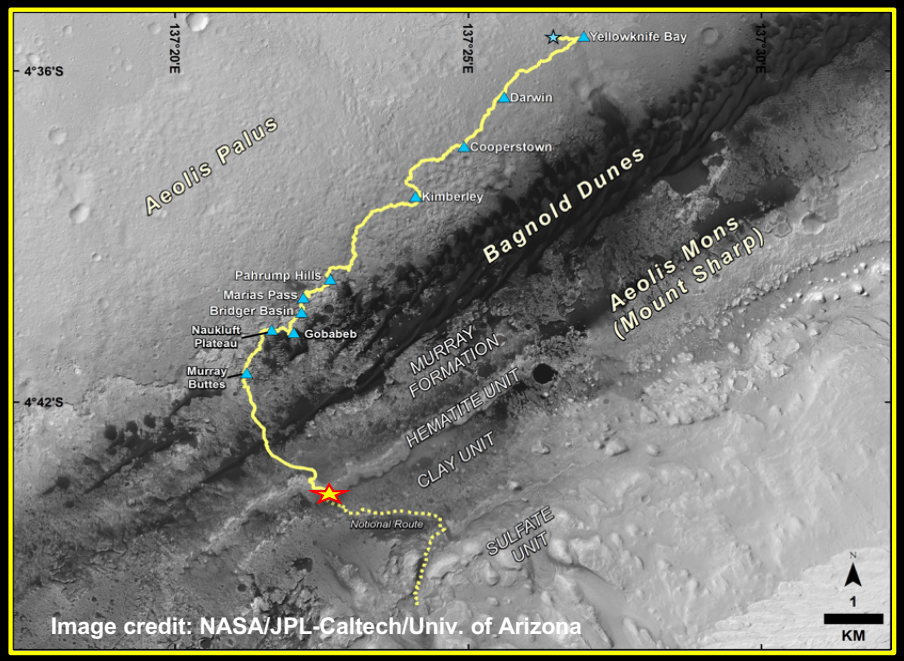
Summary (2 of 2)

- Major issues and concerns for both sample return and Mars science are:
  - An aging infrastructure
  - Lack of a confirmed post-2020 architecture with specific MSR follow-on
  - Lack of identified opportunities for non-MSR flight investigations
    - Competed “Scout-type” missions that often make the key discoveries
    - Role of small satellite missions
  - The relationship between the human and robotic exploration programs and the roles of commercial and international partners are not always clear when it comes to commitments to Mars exploration
- *MEPAG is ready to respond to calls for assistance with planning and analysis*
- *The question is: What does the agency want the Mars Exploration Program to do?*

Mars Mission Updates

Mission Status Highlights: Mars Science Laboratory (MSL) *Curiosity* (@ Sol 1973)

- Completed five years on Mars (August, 2017)
- > 18 km total traverse
- Driving on Vera Rubin Ridge ("Hematite Ridge")
- Drill ready for use again on Saturday!



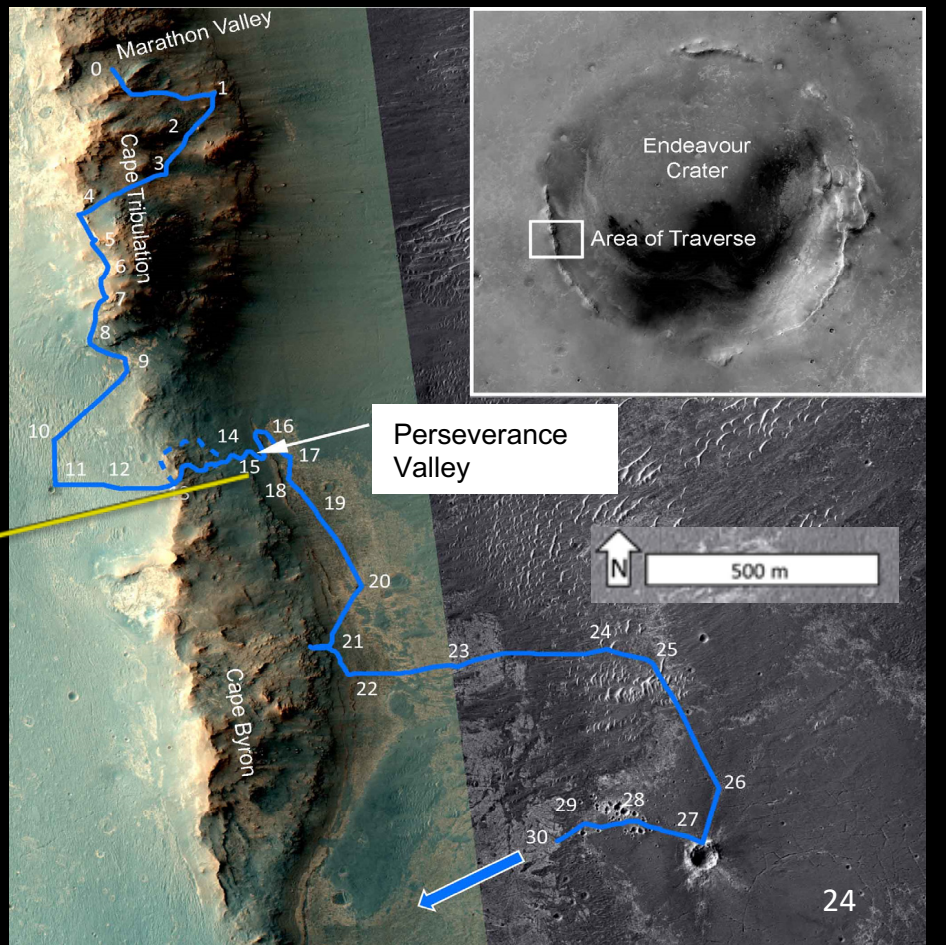
https://photojournal.jpl.nasa.gov/figures/PIA22210

Mars Exploration Rover (MER) Opportunity (@ Sol 5007)

14+ years, > 45 km odometry

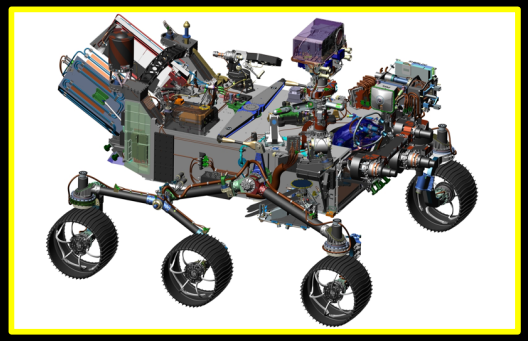
Exploring ~200 m long Perseverance Valley (PV) on the Cape Byron rim segment of 22 km Endeavour Crater

- Acquiring imaging/compositional data to test whether or not PV formed by fluvial activity, debris flows, dry mass flows, and/or wind action, and overall to understand the roles of water and ice in the valley's formation and modification.



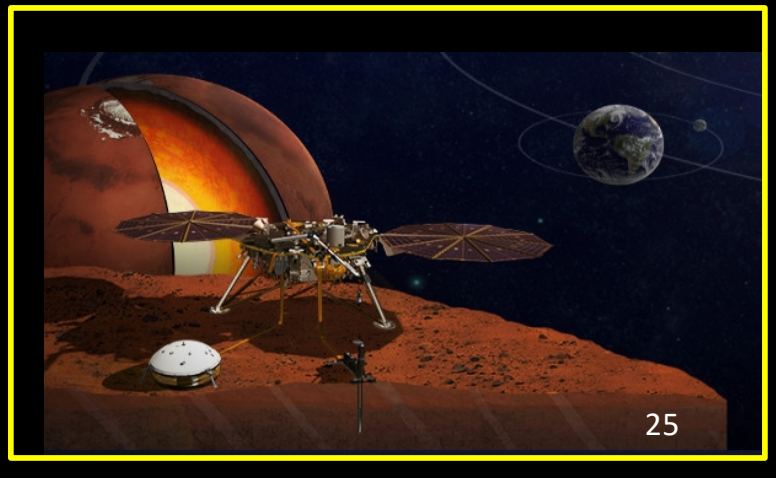
Mission Status Highlights: Mars 2020, InSight

- 2020 Mars rover instruments being built
  - launch summer 2020; arrive Feb. 2021



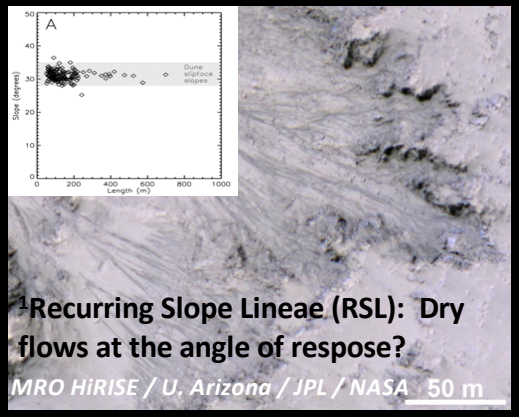
Animated gif showing example Mastcam-Z Engineering Qualification Model photos of houses on a distant ridge outside the Malin Space Science Systems, Inc. laboratory in San Diego.
http://www.planetary.org/blogs/guest-blogs/2018/0130-mastcam-z-eqm.html

- InSight launch window opens May 5, 2018 to study martian interior
  - Touchdown Nov. 26, 2018

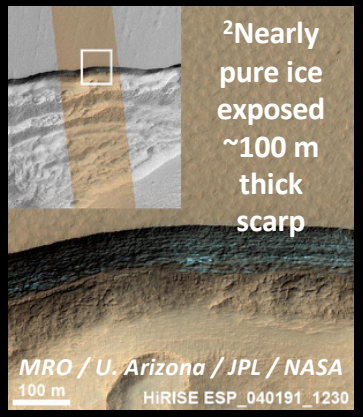


Mars Exploration Program Analysis Group (MEPAG)

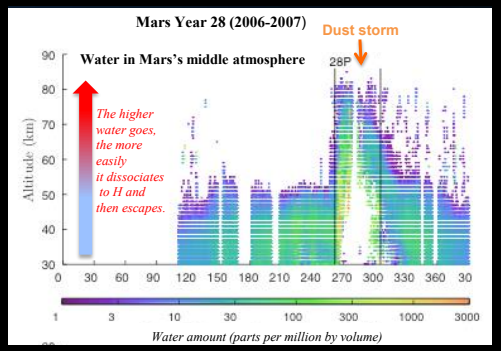
Mission Status Highlights: Mars Reconnaissance Orbiter (MRO), Odyssey (ODY)



[1]Recurring Slope Lineae (RSL): Dry flows at the angle of respose?

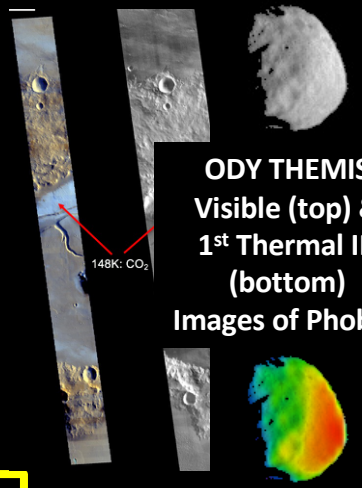


[2]Nearly pure ice exposed ~100 m thick scarp

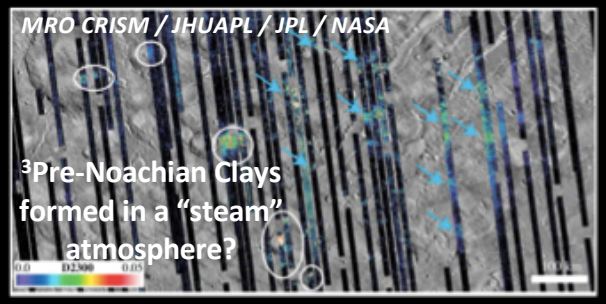


[5]MRO MCS: Explaining the seasonal variation of the Mars hydrogen corona

ODY Low-latitude CO_2 Mars frost



ODY THEMIS Visible (top) & 1st Thermal IR (bottom) Images of Phobos

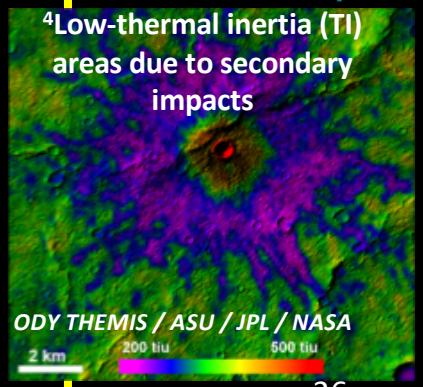


[3]Pre-Noachian Clays formed in a "steam" atmosphere?

MRO (12 yrs at Mars, 320 Tb sci. ret.)

ODY (16 yrs of Mars operations)

Both orbiters continue to characterize landing sites for future missions and to provide relay for MER-B & MSL

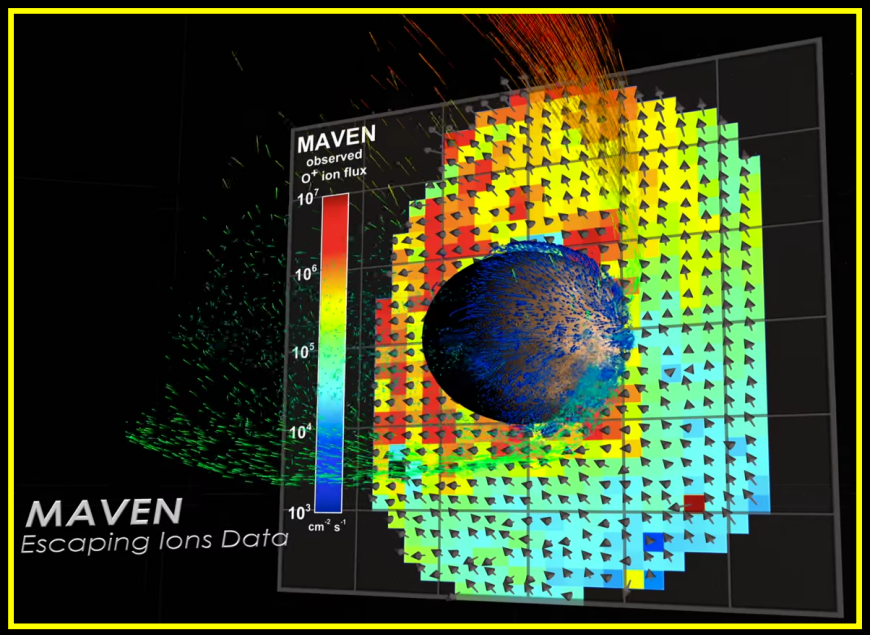


[4]Low-thermal inertia (TI) areas due to secondary impacts

[1]*Dundas et al., 2017, Nature Geoscience,* **10**
[2]*Dundas et al. 2018, Science,* 359
[3]*Cannon et al., 2017, Nature* **552**
[4]*Hill & Christensen, 2017, JGR-Planets*
[5]*Heavens et al., Nature Astronomy, in press*

Mission Status Highlights: Mars Atmosphere and Volatile EvolutioN (MAVEN)

- MAVEN began extended mission after completing 2nd year in orbital operations

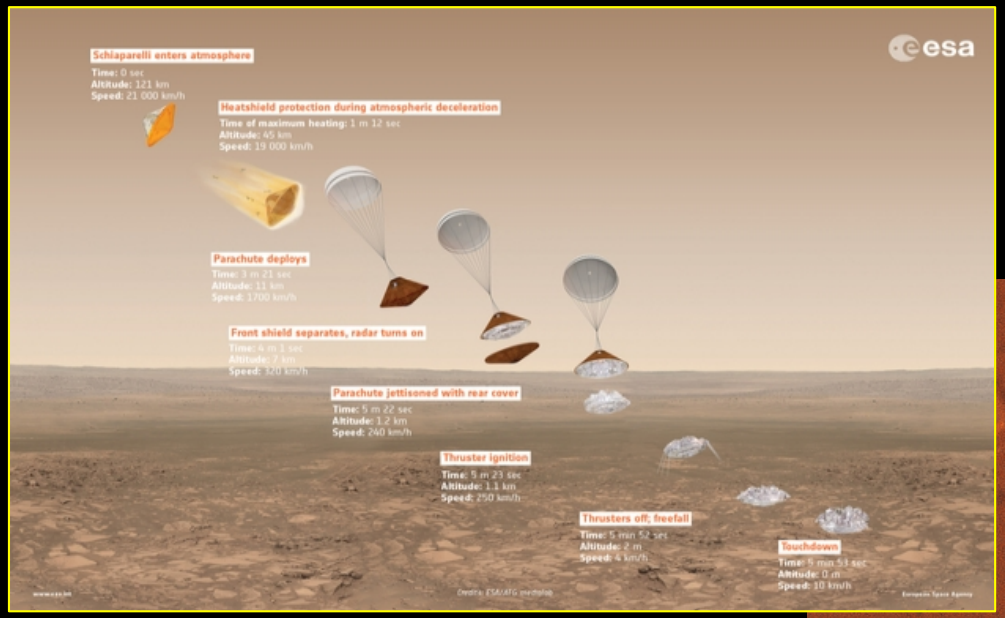


- A 3-D animation created by NASA's Scientific Visualization Studio using data from the MAVEN mission to Mars is the corporate winner of the inaugural Data Stories video contest sponsored by Science magazine
  - The video explains how the solar wind is driving atmospheric gases from Mars into space.
  - Estimates of atmospheric loss constrained by Argon isotope measurements indicate that most of an early massive atmosphere has been lost to space over the last 4 billion years.
- A major solar event last September is helping constrain the contribution of solar storms to this loss
- Providing data relays to Curiosity rover

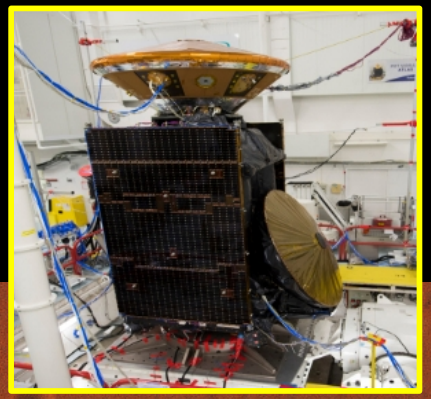
http://lasp.colorado.edu/home/maven/2016/05/13/maven-data-used-for-award-winning-nasa-scientific-visualization-studio-video/

Mission Status Highlights: ESA

- NASA participates in ESA Mars Express and ExoMars MOMA; augments 2020 ExoMars Rover site imaging



ESA EDL Demonstration Module (EDM/Schiaparelli)



MRO HiRISE Image of Schiaparelli Impact Point

TGO completes aerobraking next week; achieves final science/relay orbit propulsively in March

Executive Committee

Jeff Johnson, Chair, JHU-APL

Lisa Pratt, Past Chair, IU/NASA HQ

Wendy Calvin, UNR

Don Banfield, Goals Committee Chair, Cornell

Scott Hubbard, Stanford

Jen Eigenbrode, GSFC

Dave Beaty, JPL

Michael Meyer, NASA HQ

Ben Bussey, NASA HQ

Rich Zurek, JPL

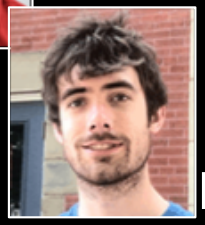
Goals Committee

Jen Stern
NASA GSFC, Goal 1

Sarah Stewart Johnson
Georgetown, Goal 1

Paul Withers,
Boston University, Goal 2

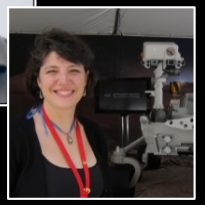
David Brain
Univ. Colorado, Boulder
Goal 2



Robin Wordsworth
Harvard University, Goal 2

Don Banfield, Goals Committee Chair, Cornell

Steve Ruff, ASU, Goal 3



R. Aileen Yingst, PSI, Goal 3

Ryan Whitley,
NASA JSC, Goal 4

Jacob Bleacher,
NASA GSFC, Goal 4