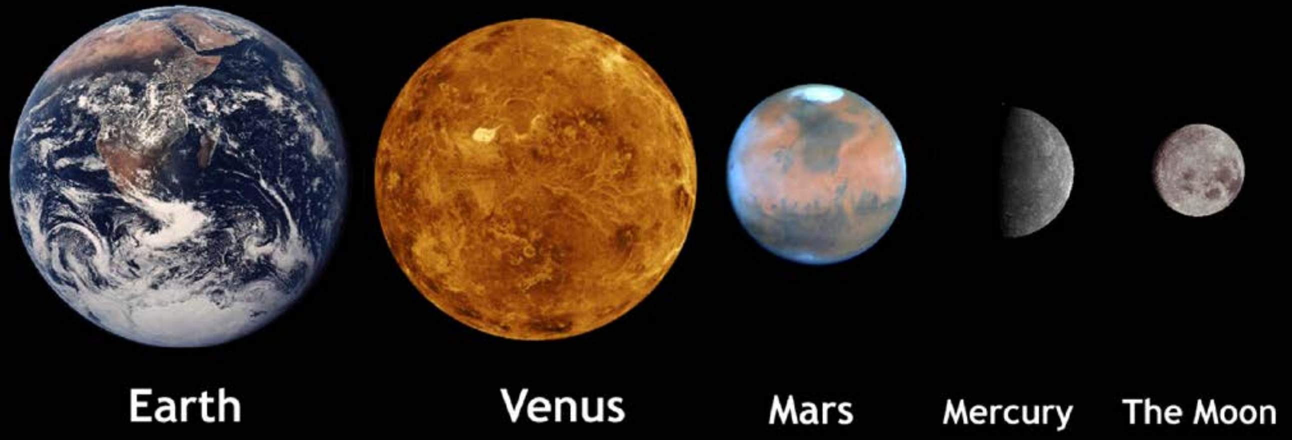
Michael Meyer
Lead Scientist
Mars Exploration & Mars Sample Return

Planetary Science Decadal Survey
Panel on Mars, Nov 2, 2020



Why Mars?

Mars is a habitable planet and has the potential to answer fundamental questions about our Solar System

- The potential for life
- A geological record of the first billion years of planetary evolution
- A drastically changing climate through time
- A compelling target for Human Exploration

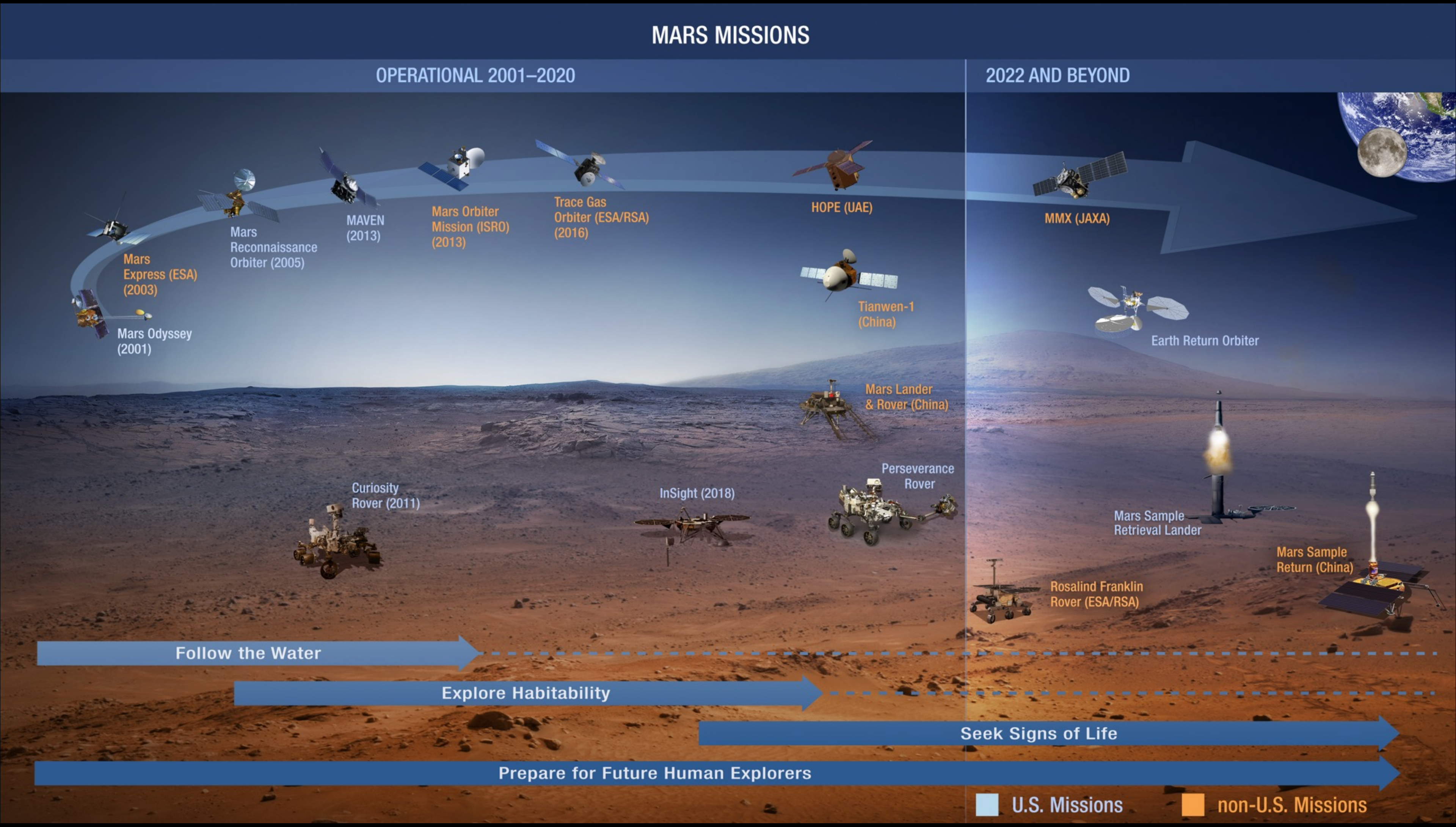
Mars Exploration Program Analysis Group Goals

Life	Climate	Geology	Human Exploration
			
I. Determine if Mars ever supported, or still supports life	II. Understand the processes and history of climate on Mars	III. Understand the origin and evolution of Mars as a geological system	IV. Prepare for human exploration

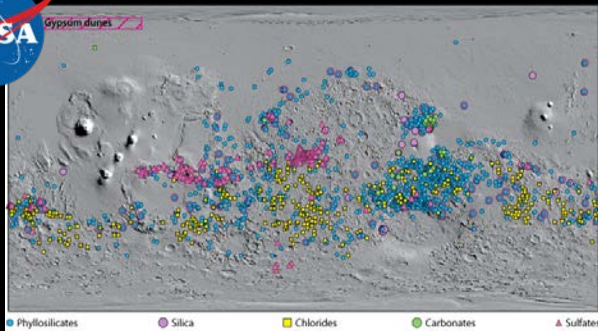
Life	**I. Determine if Mars ever supported, or still supports, life.**	A. Search for evidence of life in environments that have a high potential for habitability and preservation of biosignatures. B. Assess the extent of abiotic organic chemical evolution.
Climate	**II. Understand the processes and history of climate on Mars.**	A. Characterize the state and controlling processes of the present-day climate of Mars under the current orbital configuration. B. Characterize the history and controlling processes of Mars' climate in the recent past, under different orbital configurations. C. Characterize Mars' ancient climate and underlying processes.
Geology	**III. Understand the origin and evolution of Mars as a geological system.**	A. Document the geologic record preserved in the crust and investigate the processes that have created and modified that record. B. Determine the structure, composition, and dynamics of the interior and how it has evolved. C. Determine the origin and geologic history of Mars' moons and implications for the evolution of Mars.
Human Exploration Source: MEPAG 2020	**IV. Prepare for Human Exploration.**	A. Human landing with acceptable cost, risk and performance. B. Human surface exploration and EVA with acceptable cost, risk and performance. C. In Situ Resource Utilization (ISRU) of atmosphere and/or water with acceptable cost, risk and performance. D. Biological contamination and planetary protection protocols with acceptable cost, risk and performance. E. Human missions to Phobos or Deimos with acceptable cost, risk and performance.

Overarching questions in Planetary Science compiled by MEPAG

- How do planetary surfaces, crusts, and interiors form and evolve?
- How do climates and atmospheres change through time?
- What are the pathways that lead to habitable environments across the solar system and the origin and evolution of life?
- How is the solar system representative of planetary systems in general?
- What is needed for humans to explore the Moon and Mars?

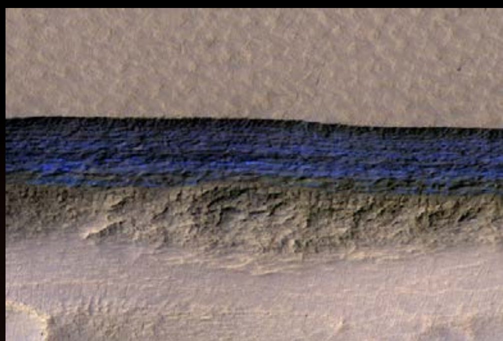

MARS MISSIONS
OPERATIONAL 2001–2020
2022 AND BEYOND
Mars Odyssey (2001)
Mars Express (ESA) (2003)
Mars Reconnaissance Orbiter (2005)
MAVEN (2013)
Mars Orbiter Mission (ISRO) (2013)
Trace Gas Orbiter (ESA/RSA) (2016)
HOPE (UAE)
Tianwen-1 (China)
MMX (JAXA)
Earth Return Orbiter
Mars Lander & Rover (China)
Curiosity Rover (2011)
InSight (2018)
Perseverance Rover
Mars Sample Retrieval Lander
Mars Sample Return (China)
Rosalind Franklin Rover (ESA/RSA)
Follow the Water
Explore Habitability
Seek Signs of Life
Prepare for Future Human Explorers
U.S. Missions
non-U.S. Missions

What Have We Learned?



Observed Outcrops of Minerals Formed in Liquid Water *Ehlmann & Edwards (2014)*

- *Mars had a variety of environments that could be habitable, intermittently.*
- *If there is life on Mars today? Associated with the ice or the subsurface.*



Exposed Mid-latitude Ice Cliff
C. Dundas USGS / *U. Arizona / JPL / NASA*

- *Mars had an early, more Earth-like climate that changed dramatically over time*
- *The evidence of that early change was recorded in a physical rock record that is accessible at/near the surface today*
- *Mars preserves in its ice deposits a record of geologically recent ice ages*

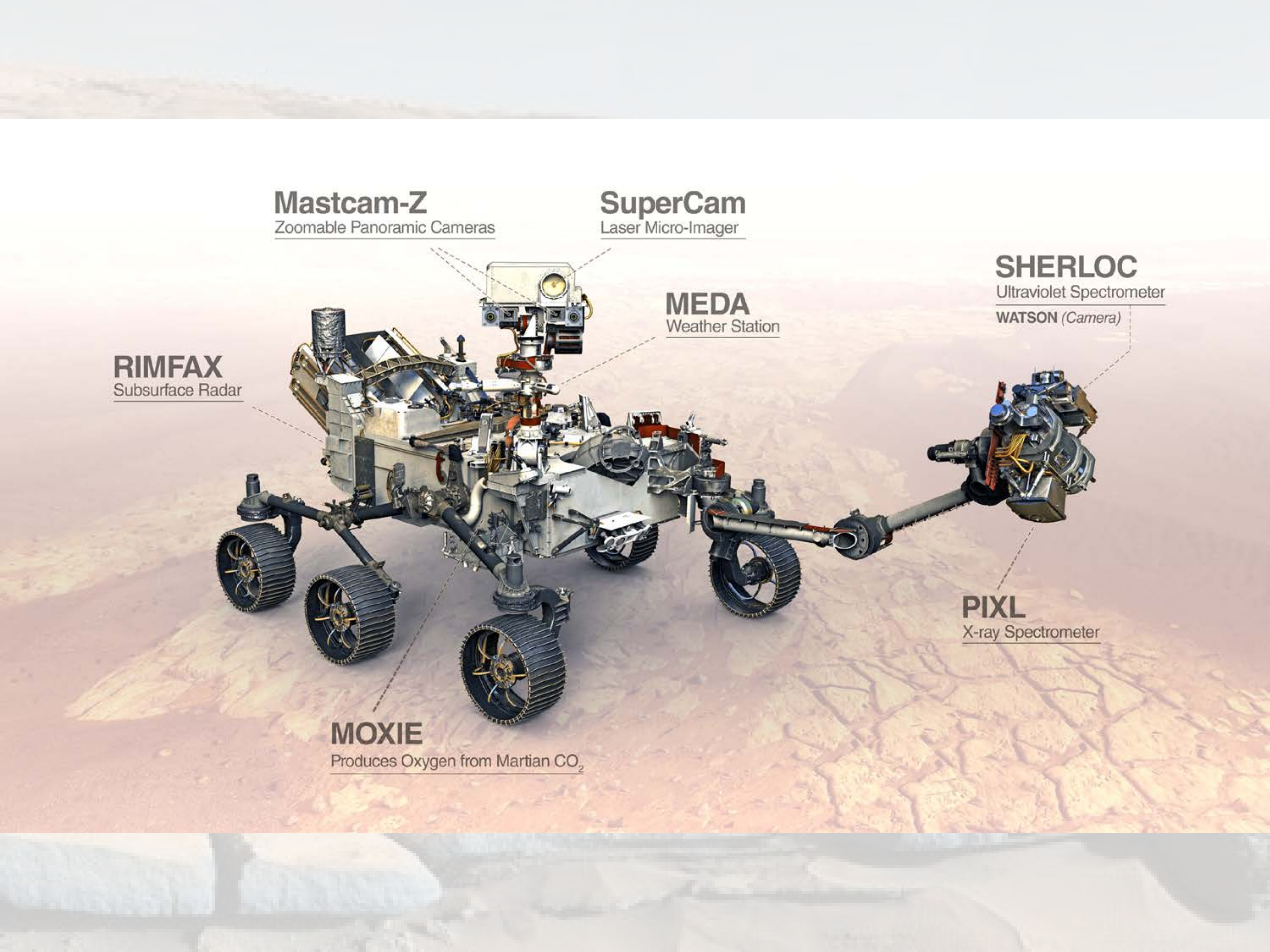
- *Mars is a dynamic planet that still changes today*
  - *Sand dunes move, volatile ice and aeolian processes shape the surface*
  - *Dust storms can cover the planet in some, but not all years. A complicated interplay of dust, water and carbon dioxide dominate atmospheric transport, including loss to space*

2018 Planet-Encircling Dust Event
Cantor & Malin, MSSS / JPL / NASA

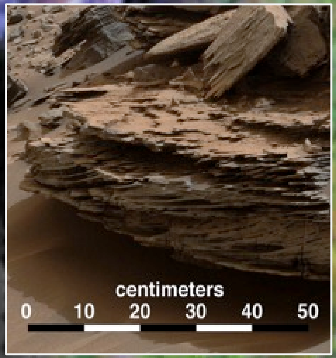
- *Mars is a compelling destination for exploration by humans*

Mars Science Activities

- Mars Architecture Strategy Working Group – what could and should be done in addition to or after Mars Sample Return
  - Preliminary report presented at HQ, MEPAG virtual meeting, and a draft formally reviewed by senior members of the Mars community
  - White paper containing key findings/recommendations submitted to decadal process *Mars, The Nearest Habitable World – A Comprehensive Program For Future Mars Exploration*
  - Penultimate version presented to HQ Oct. 28, release expected in the near future.
- NASA/ESA Mars Sample Return Sample Planning Group – Phase 2 (MSPG2) will address science and curation planning questions for analyzing samples brought from Mars.
- COSPAR's Sample Safety Assessment Protocol Working Group (SSAP) is developing a recommendation for determining when extraterrestrial samples are safe for distribution outside of containment, aiming to report out at the 43rd COSPAR Assembly in Jan/Feb 2021.


Mastcam-Z
Zoomable Panoramic Cameras
SuperCam
Laser Micro-Imager
SHERLOC
Ultraviolet Spectrometer
WATSON (Camera)
MEDA
Weather Station
RIMFAX
Subsurface Radar
PIXL
X-ray Spectrometer
MOXIE
Produces Oxygen from Martian CO_2

Mars 2020 Mission Objectives



HABITABILITY AND BIOSIGNATURES

- Assess habitability of ancient environment
- Seek evidence of past life
- Select sampling locations with high biosignature preservation

GEOLOGIC EXPLORATION

- Explore an ancient environment on Mars
- Understand processes of formation and alteration

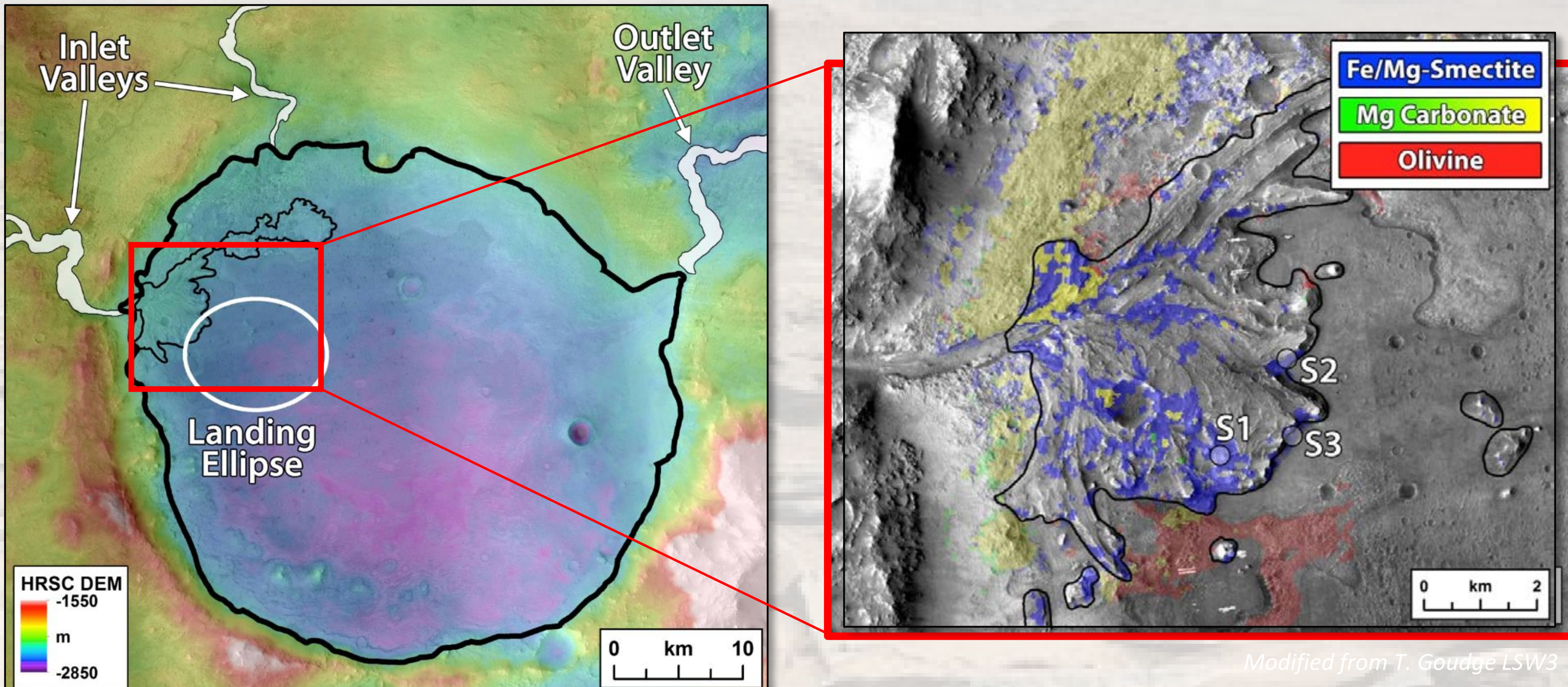
PREPARE A RETURNABLE CACHE

- Capability to collect ~40 samples and blanks
- Include geologic diversity
- Deposit samples on the surface for possible return

PREPARE FOR HUMAN EXPLORATION

- Measure temperature, humidity, wind, and dust environment
- Demonstrate In Situ Resource Utilization converting atmospheric CO_2 to O_2

Delta Deposit Inside Jezero Crater



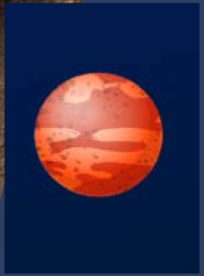
HRSC topography overlain on CTX mosaic

Modified from T. Goudge LSW3

MARS *Ice Mapper*

SCIENCE & RECONNAISSANCE QUESTIONS ADDRESSED

SCIENCE



MARTIAN HYDROSPHERE/ENVIRONMENT

FOLLOW THE WATER: What does subsurface water-ice reveal about the possibility of life and the identification of potential “special regions”?

What geologic features lie under all of the dust and dirt on Mars?

What do they reveal about the volcanic, fluvial, impact, & other processes in Mars’ history?

What can we learn about Mars’s climate from seasonal water ice/atmospheric exchanges?

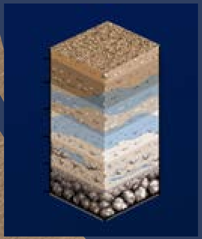
RECON

WATER ICE RESOURCES

How much near-surface water-ice exists?

How thick/deep are the deposits?

Can robot-assisted human explorers core and sample ice for high-value surface science investigations?



TERRAIN

How much regolith is on top of water-ice resources?

What is the distribution of materials (e.g. bedrock vs. regolith)?

How porous is the soil at prospective landing sites?

How rough is the terrain?

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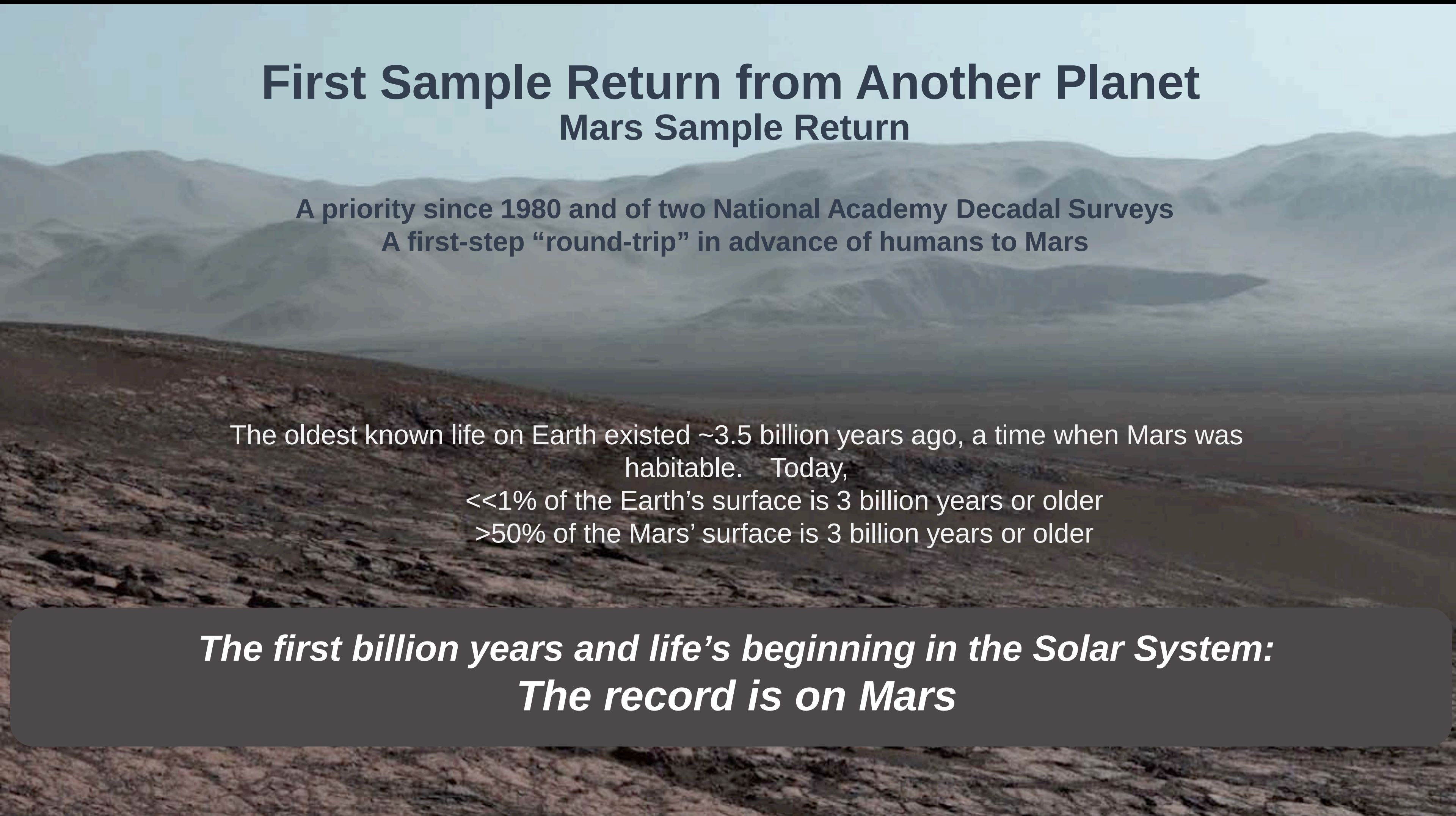


First Sample Return from Another Planet

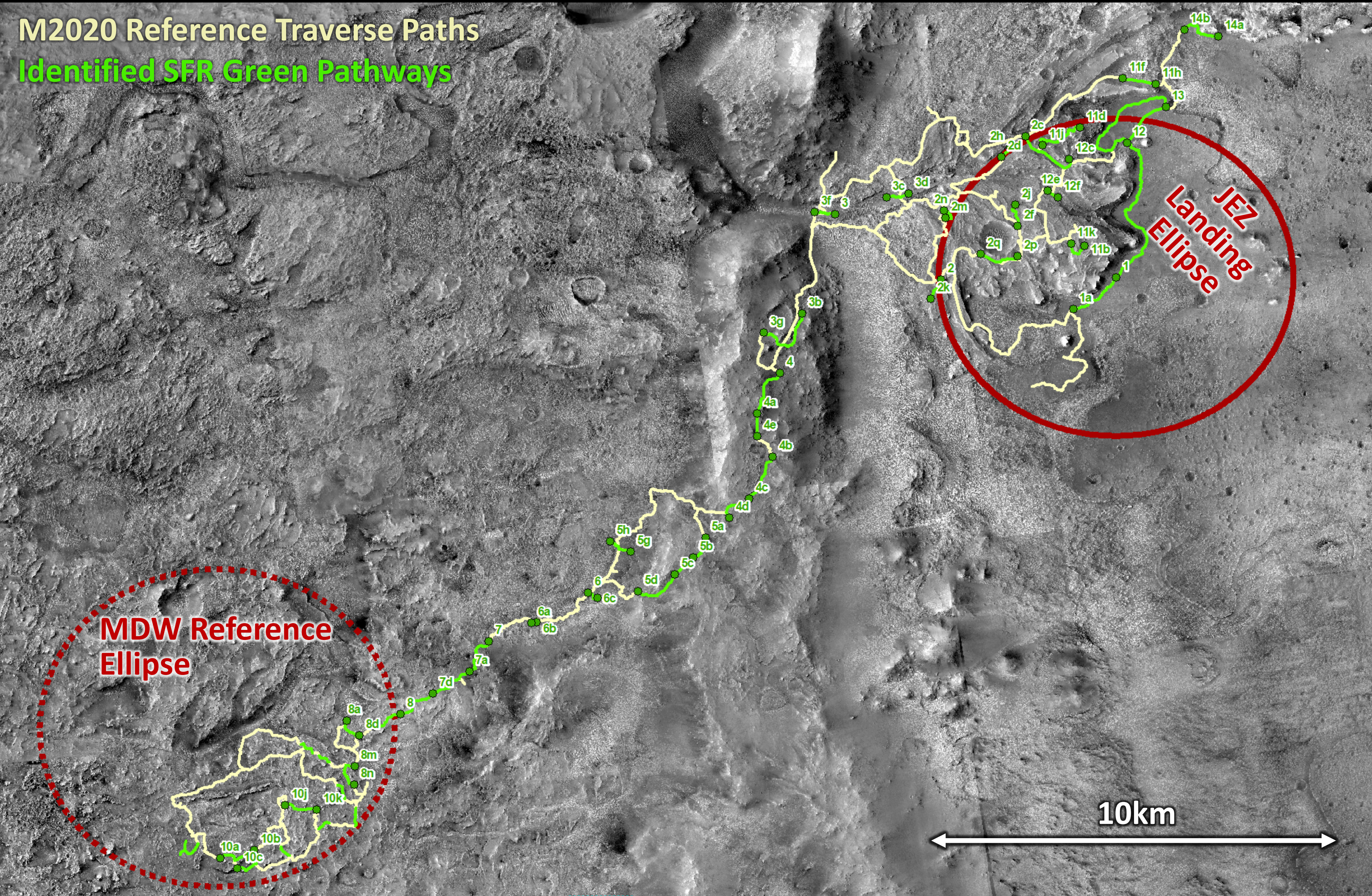
Mars Sample Return

A priority since 1980 and of two National Academy Decadal Surveys
A first-step “round-trip” in advance of humans to Mars

The oldest known life on Earth existed ~3.5 billion years ago, a time when Mars was habitable. Today,
<<1% of the Earth’s surface is 3 billion years or older
>50% of the Mars’ surface is 3 billion years or older

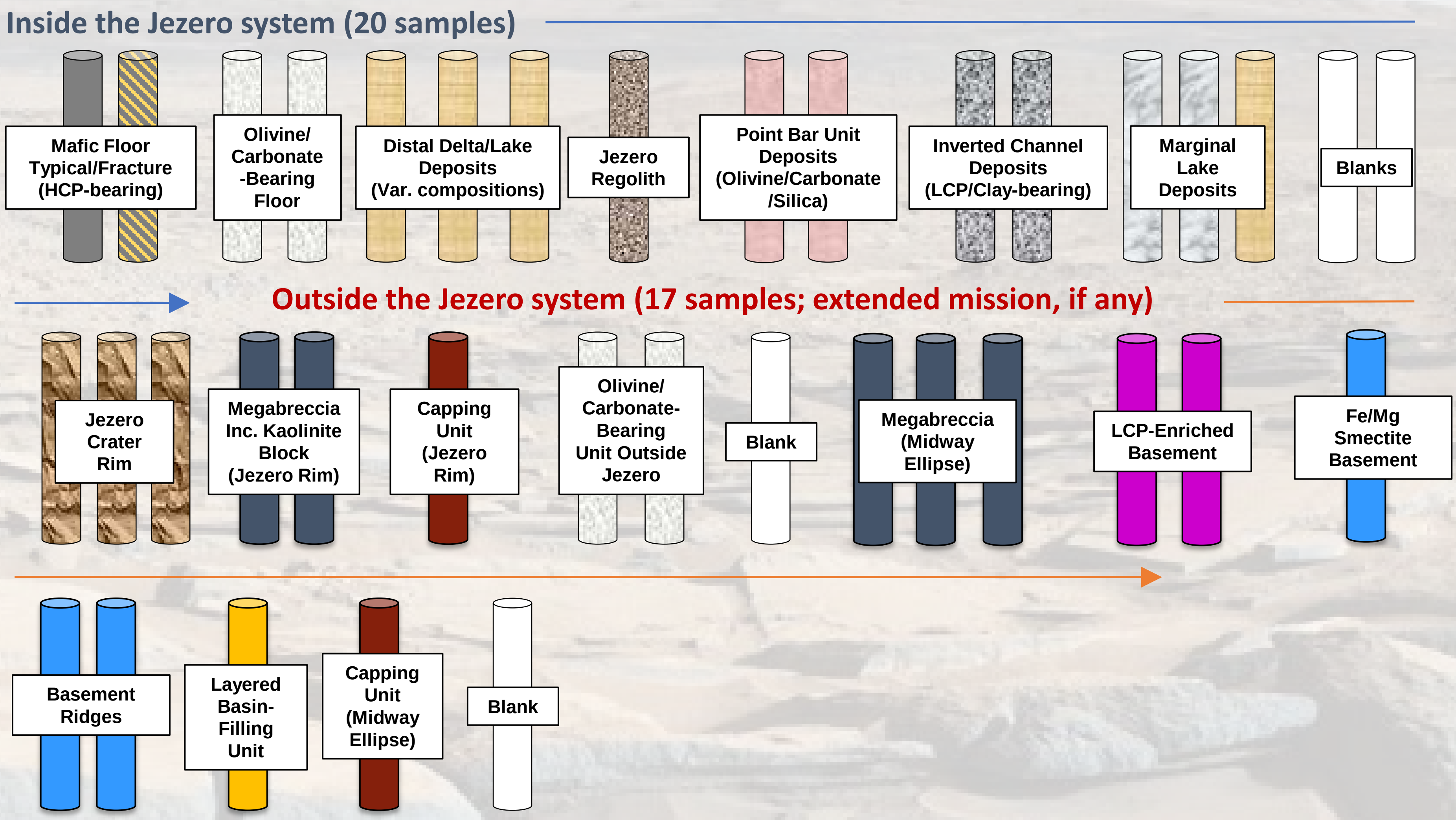
The first billion years and life’s beginning in the Solar System:
The record is on Mars

Potential Green Pathways Across Jezero-Midway Region



Sample Diversity is Key to Valued Cache

What Mars 2020 *might* cache



Adapted from Ken Farley (CAPS, 2019)

Mars Returned Sample Science - Background

- Mars Exploration Program has established the intellectual foundation and the engineering capability to characterize a region on Mars and to scientifically select samples worthy of sample return.
- Perseverance launched, capable of selecting and caching 43 samples & blanks, from which a large scientifically-invaluable subset will be brought to Earth.
  - Fifteen Returned Sample Scientists have been competitively selected, by both NASA and ESA, to be Participating Scientists on the Perseverance Science Team for selection of samples to be cached.
- NASA/ESA established Mars Sample Return Sample Planning Group (MSPG) that developed a stable foundation for international scientific cooperation for returning and analyzing samples from Mars. Report was completed and posted* online November 2019, which contains:
  - Workshop report - Science in Containment
  - Workshop report - Contamination Control
  - Science Management Framework
- A team (JPL & JSC) has visited 8 facilities (BSL-4 and contamination-controlled) in the US and abroad, to scope the containment challenges of conducting science with returned Mars samples. The report will be completed soon.

* https://mepag.jpl.nasa.gov/reports.cfm?expand=mspg

Mars Returned Sample Science - Status

- Science is working closely with system engineers on requirements and essential trade-offs.
- NASA/ESA Mars Sample Return Sample Planning Group – Phase 2 (MSPG2) will address science and curation planning questions for analyzing samples brought from Mars.
  - NASA/ESA signed the Terms of Reference in April 2020 with four tasks:
    - Develop a Science Management Plan,
    - Address technical issues related to the science and how the implementation impacts the potential scientific usefulness of the samples
    - Propose a working list of high-level requirements for the Sample Return Facility that can be used in cost estimation and budgeting, and
    - Develop a timeline key decision points with inputs from science, curation, and planetary protection
  - Jointly, the agencies openly-competed membership, selecting 29 members across a wide-range of disciplines, experience, and countries
  - Beginning in June 2020, the Team has been meeting every week, split between either Focus Groups or as a whole team.
  - Reports expected in Spring 2021
- COSPAR Sample Safety Assessment Protocol Working Group (SSAP) is developing a recommendation for determining when extraterrestrial samples are safe for distribution outside of containment.
  - The group has met 12 times, aiming for the 43rd COSPAR Assembly, Jan/Feb 2021
  - NASA interests are represented through Planetary Protection, Mars Science and US scientists
- A Perseverance/MSR Sample Caching Strategy Workshop is being planned for Jan. 2021

Mars Sample Return Science Planning Group 2

Coordination Team


Michael Meyer


Gerhard Kminek


Dave Beaty


Tim Haltigin


Brandi Carrier

Tactical Team


Carl Agee


Henner Busemann


Barbara Calavazzi


Charles Cockell


Vinciane Debaille


Danny Glavin


Ernst Hauber


Bernard Marty


Francis McCubbin


Lisa Pratt


Aaron Regberg


Alvin Smith


Caroline Smith


Kim Tait


Nick Tosca


Arya Udry


Tomo Usui


Michael Velbel


Mini Wadhwa


Maria-Paz Zorzano

Strategic Team


Monica Grady


Roger Summons


Tim Swindle


Frances Westall

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Guiding Principles for Handling Returned Samples

Transparency:

- Access to samples must be fair and the processes as transparent as possible.

Science maximization:

- It is imperative that the science management and sample-related processes optimize the scientific productivity of the samples.

Accessibility:

- International scientists must have multiple opportunities to participate in MSR.

Return on investment:

- Agencies funding the MSR campaign should benefit for enabling the samples’ return.

One Return Canister : One Collection

- Samples must be treated as a single collection, regardless of whether or not there is more than one curation facility

Mars Sample Return Challenge

- Protect the Samples from Earth
- Protect the Earth from the Samples

. . . To achieve a quantum jump in our understanding of Mars


Sunset on Mars
MSSS / JPL / NASA