National Aeronautics and
Space Administration

A Science Strategy for the Human Exploration of Mars
April 25, 2024
Becky McCauley Rench, NASA HQ

Mars Exploration Program
Science Mission Directorate, NASA Headquarters

EXPLORING MARS TOGETHER
DRAFT Plan for a Sustainable Future for Science at Mars
2023 – 2043

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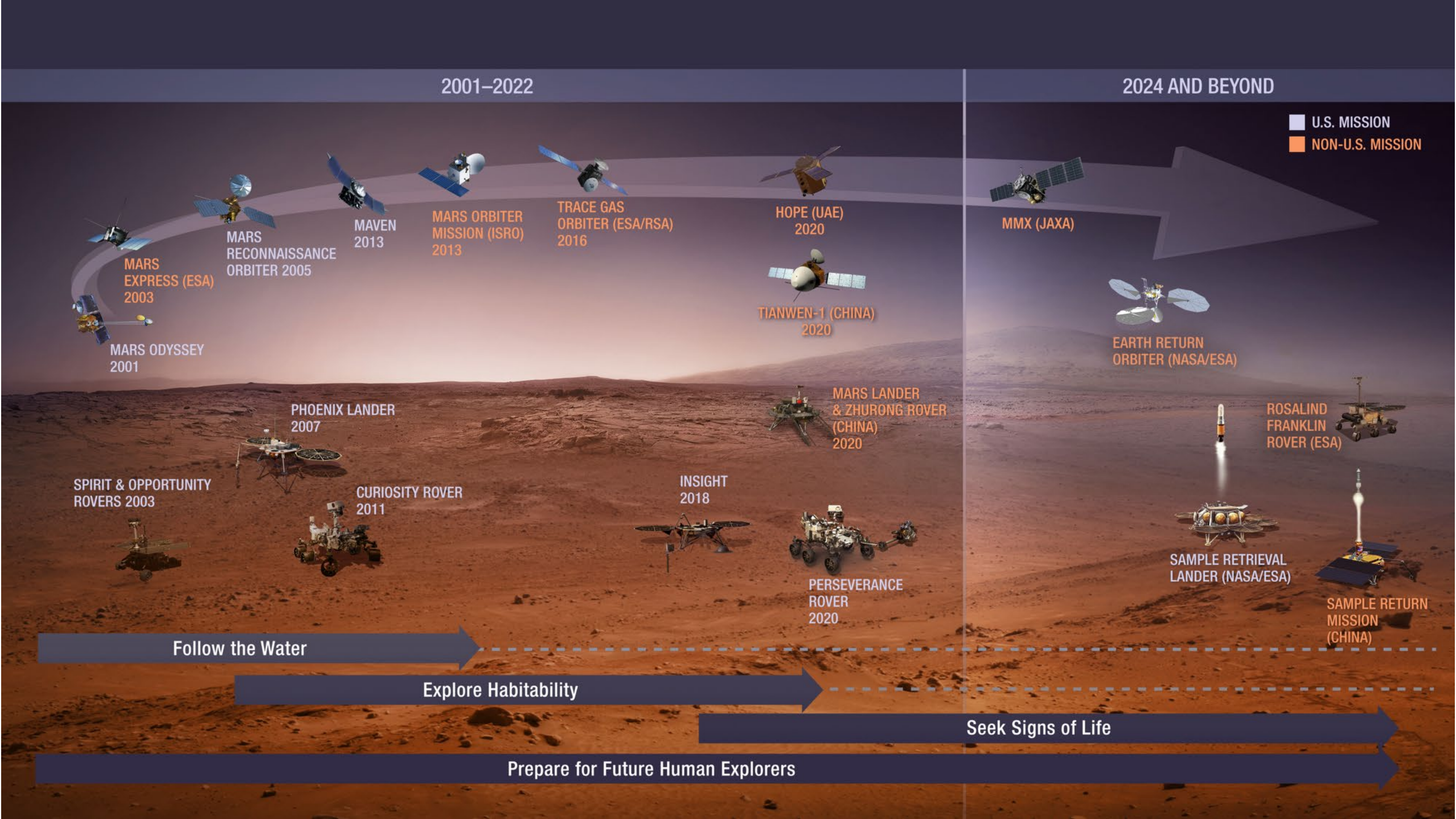
MEP Moon2Mars Interface Team – supporting ESSIO



2001–2022
2024 AND BEYOND
U.S. MISSION
NON-U.S. MISSION
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) 2020
TIANWEN-1 (CHINA) 2020
MMX (JAXA)
EARTH RETURN ORBITER (NASA/ESA)
PHOENIX LANDER 2007
SPIRIT & OPPORTUNITY ROVERS 2003
CURIOSITY ROVER 2011
INSIGHT 2018
MARS LANDER & ZHURONG ROVER (CHINA) 2020
PERSEVERANCE ROVER 2020
ROSALIND FRANKLIN ROVER (ESA)
SAMPLE RETRIEVAL LANDER (NASA/ESA)
SAMPLE RETURN MISSION (CHINA)
Follow the Water
Explore Habitability
Seek Signs of Life
Prepare for Future Human Explorers

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EXPLORING MARS TOGETHER

2023 – 2043 MEP Future Plan

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Introduction

Mars Exploration Program Context

- Over two decades of successful missions to understand Mars and to search for past and present life through a series of orbiters, landers, and rovers
- Address critical/aging infrastructure at Mars
- Prepare for a human presence at Mars
- Space business environment expanding - broadening international participation and commercial interest/capability

Mars Sample Return

- Critical chapter in Mars exploration culminates in the return of Martian samples to Earth - the community's highest Planetary Science priority over the last two decades, as cited in the past three Decadal Surveys

Future Plan Development

- MEP is planning for the next two decades of equally profound scientific investigations with a new strategic paradigm designed to send lower-cost, high-science-value missions and payloads to Mars at a higher frequency
- This Plan incorporates inputs from several sources across the planetary science community, Mars science community, engineering and technology communities, and the 2022 Planetary Science & Astrobiology Decadal Survey

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SCIENCE THEMES

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EXPLORING MARS TOGETHER 2023 - 2043

High-Level <u>Co-Equal</u> Program Science Themes, 2023 - 2043

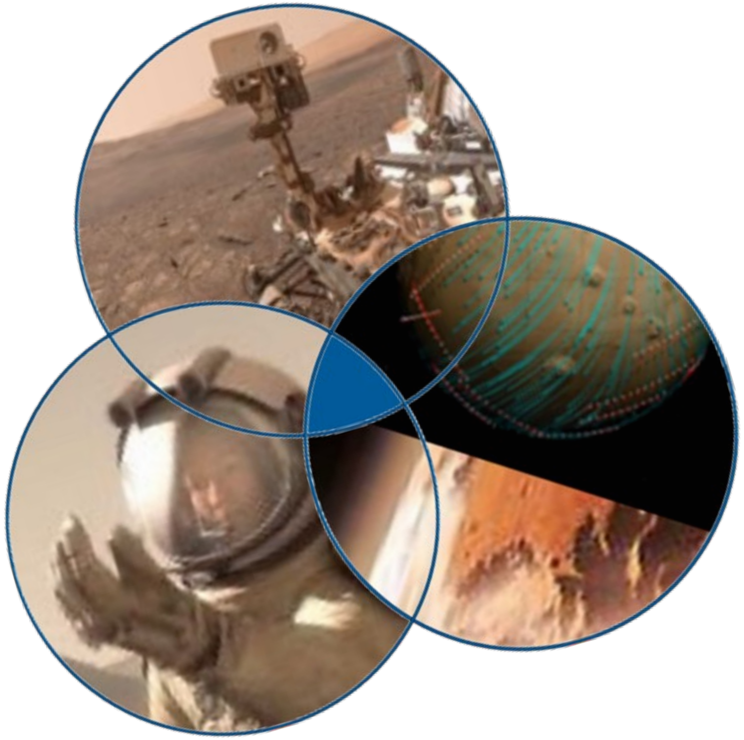
Driven by science, MEP will focus its systemic approach on the following science themes, **which draw upon the MEPAG** goals of life, climate, geology and preparation for human exploration.

Explore the Potential for Martian Life

Advance the search for past and present microbial life and habitable environments through time, while developing approaches that protect both Mars and Earth.

Support Human Exploration of Mars

Make observations that are synergistic with the objectives for human exploration of Mars and prepare for the science that humans will do once there.



Discover Dynamic Mars

Understand the dynamic geological and climatological processes on Mars to illuminate the evolution of the Martian system, our home planet Earth, our solar system, and distant planets around other stars.

SCIENCE THEME 1 — Explore the Potential for Martian Life

Search for evidence of past or present life on Mars in potentially habitable environments and establish how the Martian environment and habitability co-evolved over time.

SCIENCE THEMES

1.1 Search for Biosignatures, Past & Present

Determine whether the Martian geologic record has biosignatures and identify areas most likely to capture preserved biosignatures based on what is known about past and current habitability at Mars.

1.2 Understand Temporal and Geographic Patterns of Habitability

Leverage Mars' unique ancient geologic record to understand the extent of habitability and its temporal evolution, the existence of any present-day, subsurface habitable environments (including ice), and how habitable environments on Mars and Earth may have diverged.

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1.2.1 Physical Access to the Subsurface

Advance investigations related to subsurface and ice science and access to the ice-rich subsurface as a major programmatic focus, building on water- and habitability-related scientific discoveries of the previous two decades.

1.3 Examine Samples from MSR to Understand Martian Geological & Biological Processes

Study returned samples to understand organic chemistry processes on Mars, what the samples reveal on global, regional and temporal scales, the nature of any biosignatures, and the relationship between Mars' geological and potential biological history.

Planetary protection principles are key across our presence at Mars and upon return to Earth with samples and astronauts, especially as it relates to our search for life.

A focus on potential "special regions" (natural or spacecraft-induced) and the environmental characterization of candidate landing/exploration sites is important to mitigate risks for future human explorers and/or to their astrobiological research.

SCIENCE THEMES

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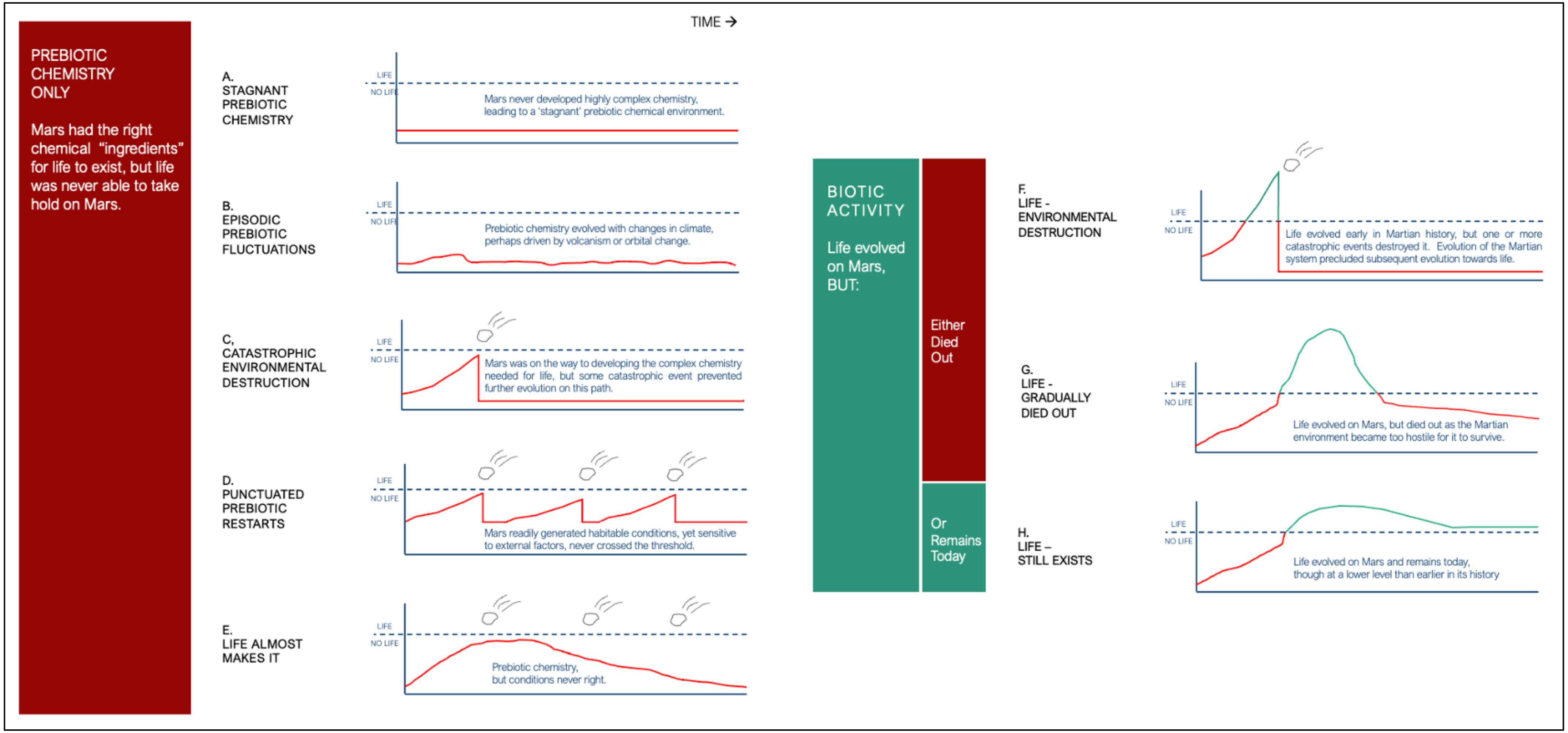
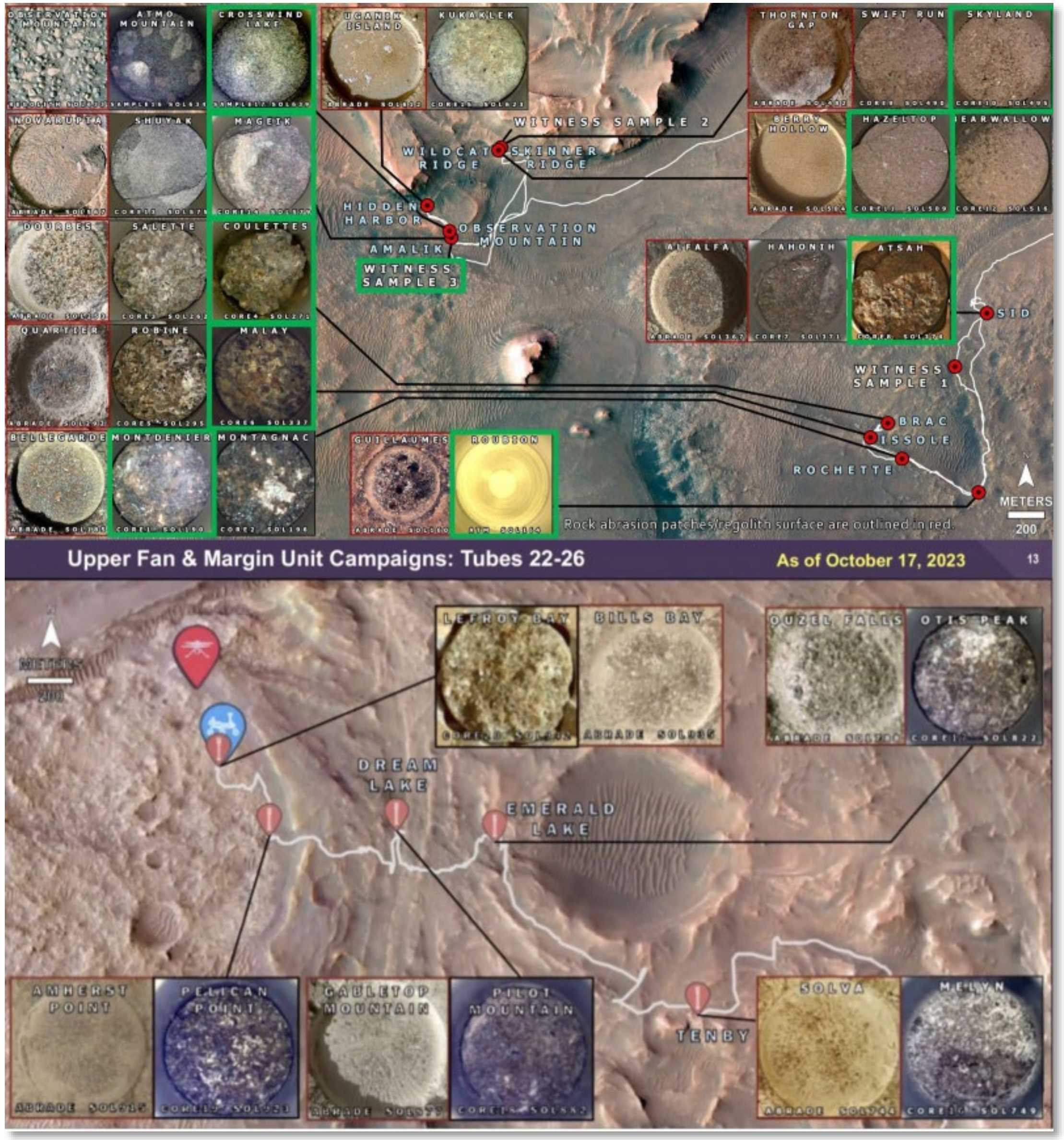
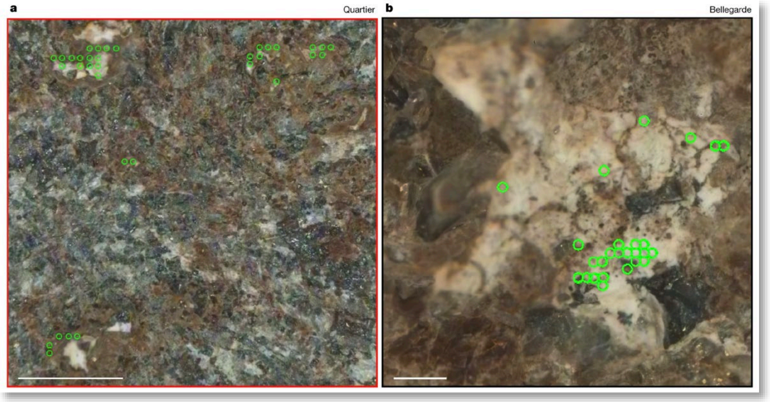
Did Life Ever Arise on Mars?



MSR Sample Family Portrait





Detection of organics in Mars surface materials

Learn more about the Mars 2020 sample collection here

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SCIENCE THEME 1 Explore the Potential for Martian Life

Search for evidence of past or present life on Mars in potentially habitable environments and establish how the Martian environment and habitability co-evolved over time.

What does this mean for science objectives of human explorers at Mars?

- **The science explorers must build on the scientific knowledge gained prior to their arrival. Science will integrate both robotic and crewed mission data to advance our decadal-level science in the search for life.**

- **Mars and astrobiology communities should gain as much information as feasible about the potential for life at Mars prior to humans arriving. Depending on our existing knowledge at the time humans arrive, maintaining the scientific integrity of Mars samples is of utmost importance.**

- **Physical access to the subsurface may be significantly easier with crewed exploration. Any access to the subsurface must consider potential contamination of subsurface samples by humans – a challenge that is surmountable with appropriate planning and technology. Human-robotic partnership is a key component of Mars exploration.**

Search for evidence of past or present life on Mars in potentially habitable environments and establish how the Martian environment and habitability co-evolved over time.

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What does this mean for science objectives of human explorers at Mars?

- **Crewed missions have the potential to cover more field sites for sample collection. Current robotic exploration of Mars has been limited by the distance of traversable landscapes for our rovers and the number of missions we have been able to land. Humans may be able to visit more numerous and diverse sites whether during one mission or over the course of a campaign.**

- **If we send trained discipline scientists, their skills in choosing the best samples for analysis are excellent in improving the science outcomes. On Earth, astrobiologists have explored the most extreme environments our planet has to offer, such as Antarctica and the Atacama, to understand how one might search for life where it is sparse and/or similar to what we might find at Mars.**

- **Crewed missions are always return missions, so backward planetary protection must be mitigated in a way that is not always a requirement of robotic exploration.**

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SCIENCE THEME 2 Support Human Exploration of Mars

Make observations that are synergistic with objectives for the human exploration of Mars and prepare for the science that humans will do once there.

2.1 Define Priority Human-Led Science at Mars

Define, with multidisciplinary community input (science, human mission planning), the highest value scientific objectives humans could uniquely advance while traveling to and from Mars and on the surface.

2.2 Characterize Potential Ice-rich Sites for Human Exploration

Scientifically study the environment of candidate ice-rich sites to determine optimal locations for high-priority human-led science, resource potential, and operational feasibility/safety.

2.3 Study Atmospheric Science and Weather for Human Needs

Target investigations of the Martian atmosphere/exosphere sufficient to support prediction of extreme events (e.g., dust storms), human-class landing/launch operations, and a better understanding of how terrestrial microbes released during human operations could propagate in the Martian atmosphere.

2.4 Understand Potential Health and Safety Hazards for Humans (Supporting)

Coordinate with ESDMD to understand mechanical properties (e.g., abrasiveness for suit and hatch seal designs) and breathing hazards to humans (e.g., particle size and potential biological exposures). Supporting biological and physical science objectives in the Moon-to-Mars initiative, develop remote-sensing technologies and obtain data on the Martian environment relevant to human-mission planners in assessing ways to protect and strengthen human health and performance.

2.5 Construct Analogue Missions to Prepare for Expeditions on Mars (Collaborative)

Coordinate with ESDMD to simulate science-driven, robot-assisted expeditions to prepare astronauts and the wide Mars science community on Earth for future interplanetary collaboration in making discoveries “in the Martian field” and in transit. Draw on human lunar activities to feed forward into Mars operational strategies where relevant.

MEP will partner with ESDMD and STMD to collaborate on this theme

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SCIENCE THEME 2 — Support Human Exploration of Mars

Make observations that are synergistic with objectives for the human exploration of Mars and prepare for the science that humans will do once there.

What does this mean for science objectives of human explorers at Mars?

- **SMD is responsible for identifying the high-priority science objectives of human explorers. SMD accomplishes this through community feedback mechanisms, competitive proposal processes, and cultivating a partnership with ESDMD in establishing an enabling mission architecture.**

- **Planning and testing synergistic field campaigns that demonstrate achieving both scientific goals and crew needs are important pre-work for maximizing the benefit of crewed exploration at Mars.**

- **Creating useful, accurate, and data-informed weather and climate models will position NASA to successfully implement crewed exploration at Mars.**

- **Science data on Mars chemical and physical environment can inform crew safety.**

SCIENCE THEMES

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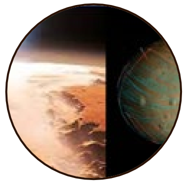


SCIENCE THEME 3 Discover Dynamic Mars

Reveal geological and climatological changes through Martian history to understand the evolution of Mars and its potential support of life; conduct interdisciplinary systems-science investigations of Mars and its moons in relation to other planets in our solar system and around other stars.

3.1 Investigate Ancient and Modern Drivers of Change on an Active Planet

- **S3.1.1** Characterize Geologic Planetary Evolution from Early Mars through the Present
- **S3.1.2** Understand Early Environmental Change through the Stratigraphic Record
- **S3.1.3** Determine Recent Climate Evolution through the Study of Volatile Cycles
- **S3.1.4** Study Dynamic Modern Environments and their Processes
- **S3.1.5** Characterize Modern Habitability

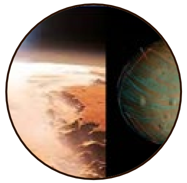
3.2 Understand Mars as a System through Investigations of the Global Environment

Conduct investigations through orbital, aerial, and landed spacecraft to illuminate the ways in which individual components of the Martian global environment – the atmosphere, hydrosphere, cryosphere, and geosphere – are integrated to make up the Martian system.

3.3 Study the Uniquely Available Geological Conditions on Mars to Conduct Comparative Planetology and Understand "Goldilocks Worlds"

Provide research opportunities that link the uniquely available geological conditions on Mars to fundamental understanding of comparative planetology.

These elements are directly responsive to the primary MEPAG goals of life, climate and geology



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SCIENCE THEMES

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What does this mean for science objectives of human explorers at Mars?

- **Crewed exploration at Mars has the potential for dynamic, yet persistent monitoring campaigns to further our understanding of Mars as a system, with rich, informative comparisons to other dynamic planetary systems, including Earth.**
- **Similar to Science Theme 1, drilling is likely to be an important component in collecting information on climatological history of Mars. Human-robotic partnership has the potential to greatly improve our ability to successfully drill and collect cores.**
- **Crew will be able to rapidly analyze collected samples, if provided appropriate tools, thereby improving the quality of data gained as compared to the potential degradation of samples during sample return to Earth. This is also useful in mission contingency planning in case samples do not complete their return to Earth.**

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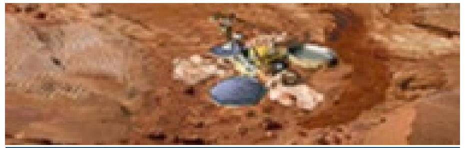
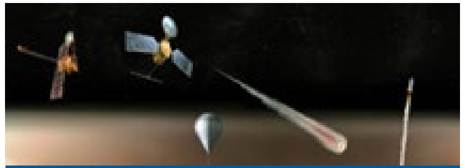
Program Initiatives for the Future of MEP



INITIATIVE 1

EXPAND OPPORTUNITIES TO EXPLORE MARS THROUGH COMPETED, LOWER-COST, MORE FREQUENT FLIGHT OPPORTUNITIES



INITIATIVE 2

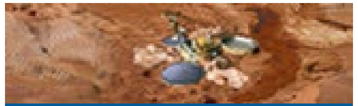
STRENGTHEN AND BROADEN INFRASTRUCTURE AT MARS TO ENABLE A DIVERSE SET OF MISSIONS & NEW OPPORTUNITIES FOR PARTNERSHIPS

INITIATIVE 3

INVEST IN KEY TECHNOLOGIES TO ENABLE EXPANDED ACCESS TO, AND SCIENTIFIC UNDERSTANDING OF, MARS

INITIATIVE 4

ENABLE PARTICIPATION IN MARS EXPLORATION FOR ALL COMMUNITIES



INITIATIVE 1

Expand Opportunities to Explore Mars through Competed, Lower Cost, and More Frequent Flight Opportunities

Establish a regular cadence of science-driven, lower-cost mission opportunities as a new element of the MEP portfolio to provide rapid and flexible response to discoveries, to address the breadth of outstanding Mars questions, and to enable increased participation by the diverse Mars science community.

INITIATIVES FOR THE NEXT TWO DECADES

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I 1.1

LOW-COST MISSIONS

Targeted or Discovery-Responsive Science

- Competed small missions at the $100M, $200M, or $300M levels
- Intent: select missions for every Mars launch opportunity
- Considering one-step or two-step processes
- May select multiple smaller missions per launch opportunity
- Draws on experience from COTS/CLPS programs

I 1.2

MEDIUM-CLASS MISSIONS

Broad Science

- Strategic Decadal-class science
- More complex instrument suites
- New technologies in sample acquisition, mobility, autonomy
- Considering competing either at the mission or instrument level
- Scalable to significant discoveries

I 1.3

COMPETED PAYLOADS

Leveraging Commercial & International Opportunities

- Missions of Opportunity
- Potentially competed or directed
- Could be science or infra-structure focused
- Flown on international or com-mercial missions

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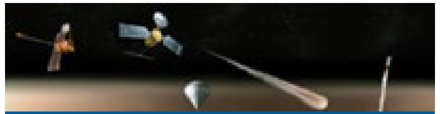


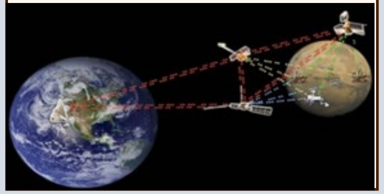
INITIATIVE 2

Strengthen and Broaden Infrastructure at Mars to Enable a Diverse Set of Missions & Opportunities for Partnerships

Enable infrastructure advancements that no one mission could likely achieve alone and that lower the costs and risks of, and increase benefits for, all Mars missions.

SCIENCE AND MISSION ENABLING

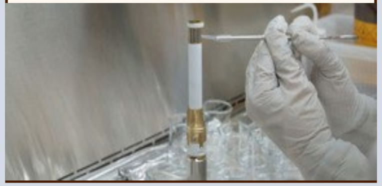
I 2.1 Mars Telecom Network



I 2.2 High-resolution Imaging

I 2.3 Global Meteorological Monitoring

I 2.4 Sample Handling and Receiving



Actively consider opportunities to buy commercial services to address infrastructure

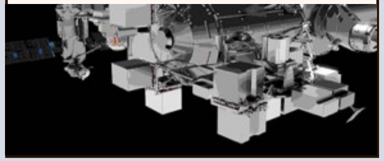
I 2.5 Ground Receiving Networks

I 2.6 Data Infrastructure, Visualization, & Analysis

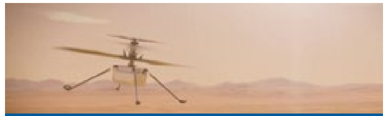
ACCESS TO MARS

I 2.7 Spacecraft Delivery (including Rideshares)

I 2.8 Payload Hosting Opportunities



Requirements/implementation approaches coordinated with ESDMD, STMD, and SOMD, as appropriate.



INITIATIVE 3

Invest in Key Technologies to Enable Expanded Access to, and Scientific Understanding of, Mars

Provide continuing improvement in the capabilities of robotic science- and human-enabling missions that collectively enhance US leadership in Mars exploration, lower the costs of all Mars missions, and build upon the developments and experience of Earth and the Moon-to-Mars initiative.

INITIATIVES FOR THE NEXT TWO DECADES

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I 3.1

Entry/Deorbit, Descent, & Landing Systems and Surface Access

I 3.2

Aerial Mobility, In Situ Surface Mobility, & Autonomy

I 3..3

Revolutionary Subsurface Access up to Hundreds of Meters

I 3.4

In Situ Sample Handling, Pre-Processing, and Analysis & Returned Sample Handling

I 3.5

In Situ Remote Sensing and Search for Evidence of Life Measurements

I 3.6

Direct to Orbit, Direct to Earth, and Proximity Link Telecommunications

Activities to be planned in coordination with STMD

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INITIATIVE 4

Enable Participation in Mars Exploration for All Communities

Develop MEP initiatives that support NASA's goals to train, sustain, and retain a qualified and diverse workforce, to develop scientific and technical literacy, and to foster a more inspired and informed society.

INITIATIVES FOR THE NEXT TWO DECADES

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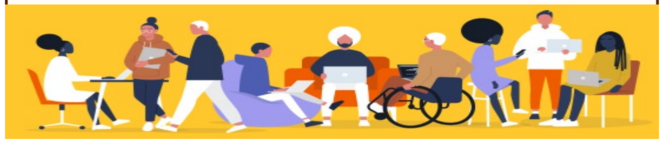
I 4.0 Establish Inclusive DEIA Leadership

Ensure Involvement of Under-Represented Communities in Development of Data-Driven Methods to Measure Progress



I 4.1 Ensure Inclusivity in MEP

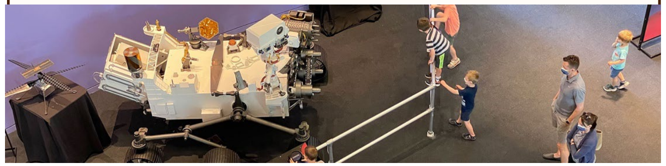
Involve and Support Under-Represented Communities in MEP Internships, Mission Teams, & Leadership Training Opportunities

I 4.2 Enhance the State of the Profession

Assess MEP Demographics, Provide Career Opportunities, and Build a Culture of Inclusivity

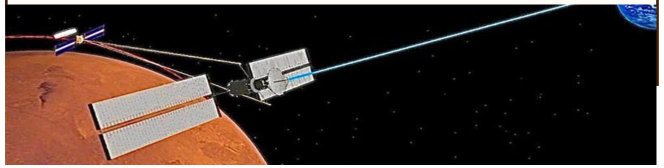
I 4.3 Create Opportunities for Public Participation in Mars Exploration

Enable Direct Participation in Exploration through Immersive Technologies



I 4.4 Create New Models for Community Collaboration

Build upon Emerging Synergistic Capabilities with New Public/Private Partnerships



I 4.5 Respect Role in the Stewardship of Mars for Humanity

Be Mindful of Responsibilities in Exploring Mars "For All Humanity"

INITIATIVES FOR THE NEXT TWO DECADES

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Near-term Activities

As implementation of this plan is not funded, the program may begin precursor activities within existing program resources:

- Initiate career and project opportunities to enable broader participation in the Mars community
- Explore opportunities for commercial services to address infrastructure needs
  - Award study contracts to industry to better define potential public-private partnerships
  - Industry Study RFP released in Q1CY24; proposals are currently under review
- Engage the international community on potential partnerships and hosting opportunities
- Invest in technologies to expand access to Mars and improve scientific understanding of the planet
- Commissioned a National Academies study to identify science objectives for human campaigns to Mars: “A Science Strategy for the Human Exploration of Mars”
- Develop a draft Announcement of Opportunity for the first Low-Cost Mission opportunity
- Planning underway for virtual workshop on Science and Planetary Protection in Advance of Human Exploration


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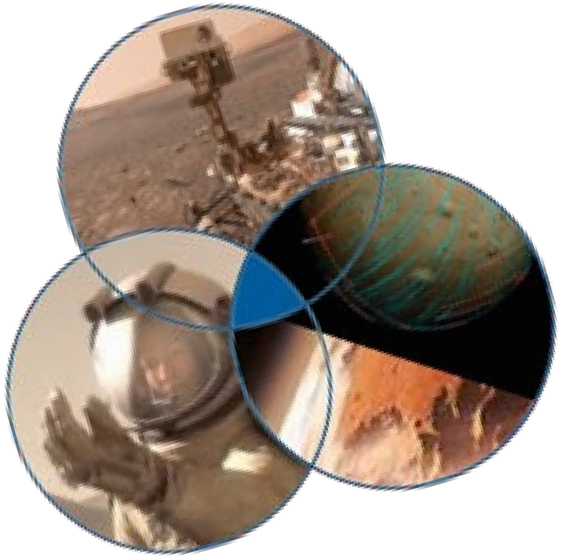
Where are we in the process?

- Fall 2022 – Spring 2023: Internal MEP development of the draft plan in PPT form
- Spring 2023 – Fall 2023: Briefed community stakeholders and solicited feedback
- **Winter 2023/2024 – Spring 2024: Developing a narrative version of the plan based on feedback**
- Summer 2024: Targeting release of a written baseline plan
- Future: Implementing the plan, pending availability of funding



- **Explore the Potential for Martian Life**
- **Support Human Exploration of Mars**
- **Discover Dynamic Mars**

Summary of the Plan

Four Core Initiatives

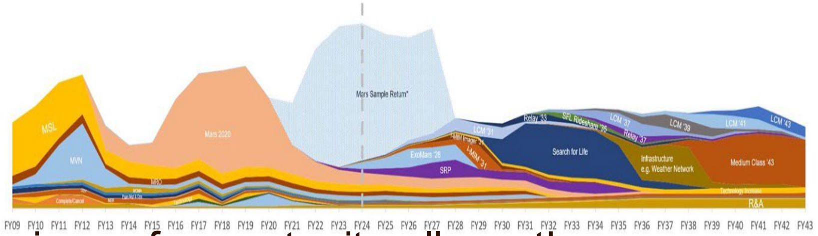
- Shifts focus to more frequent, lower-cost science missions
- Emphasizes the importance of replenishing/growing the Mars infrastructure
- Prioritizes re-establishing a solid foundation of technology investments
- Recognizes the value of expanded participation in the Mars Exploration Program

Exploring Mars Together

- Embraces international partnership
- Seeks to engage with industry on public/private partnerships
- One of the four initiatives seeks to grow participation in the Mars community

Key Attributes for implementation

- Content and schedule are variables to be managed against a sustained budget level and maximizing science return



- Focus on smaller, lower-cost missions, partnerships, and missions of opportunity allows the program to be more agile and responsive to discoveries
- Implement science that is supportive of, and synergistic with, humans at Mars

SECTION 4
Aspirational Program Timeline

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Questions?

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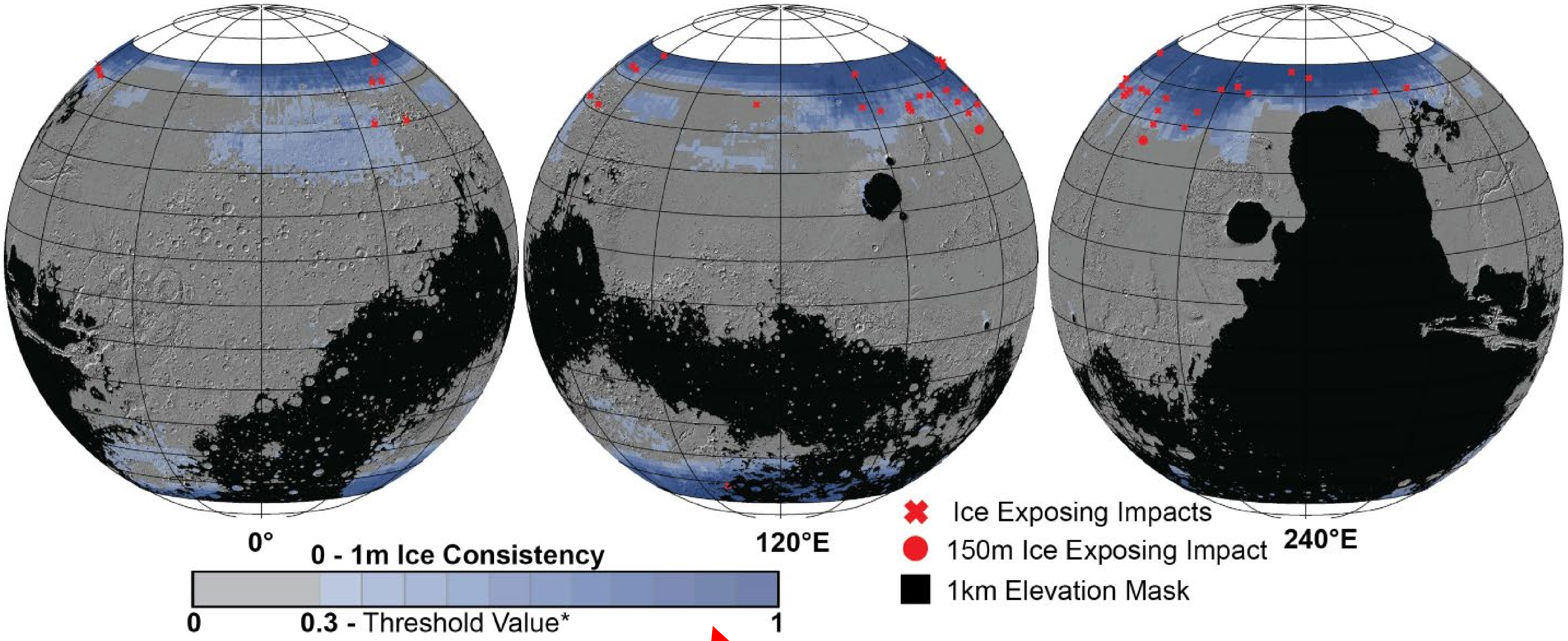
Distribution of Buried Ice on Mars



Blue regions represent areas with near-surface ice,
potential targets for human missions

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SUBSURFACE WATER ICE MAPPING
RED PLANET

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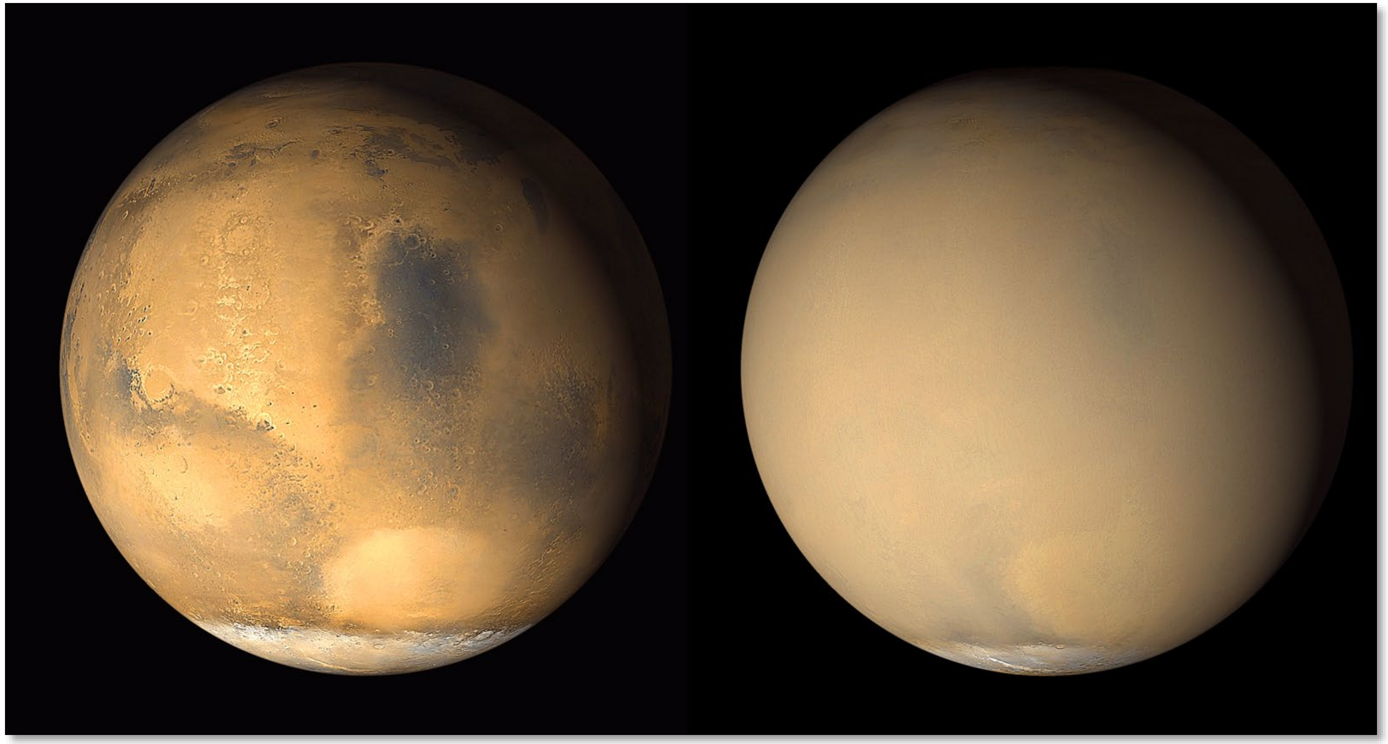
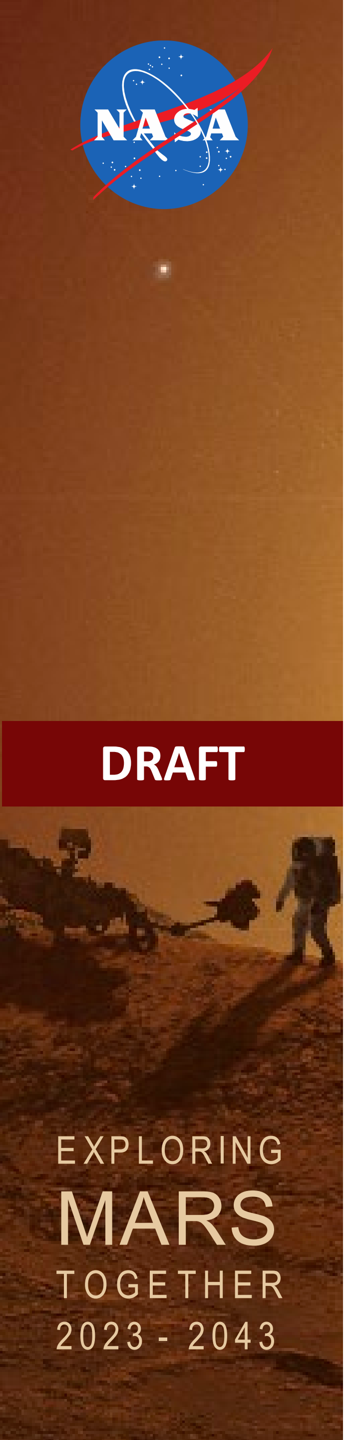
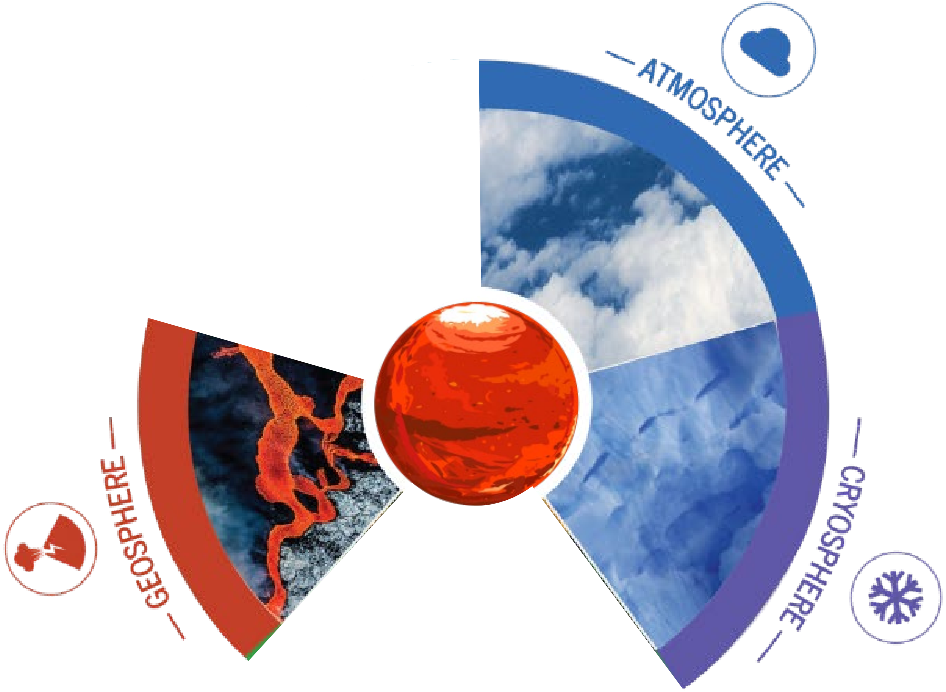


Atmospheric events can impact human surface operations, health and safety



Mars as a System



- Analogous to Earth System Science
- How do the different 'spheres' of Mars play together?
- Mars is a simpler system than Earth—learn about Earth by removing complexities at Mars

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Comparative Planetology

- What processes led to the vastly different conditions on the terrestrial planets?
- Mars has uniquely preserved surface from 4 billion years ago—the same time life began to take hold on Earth.

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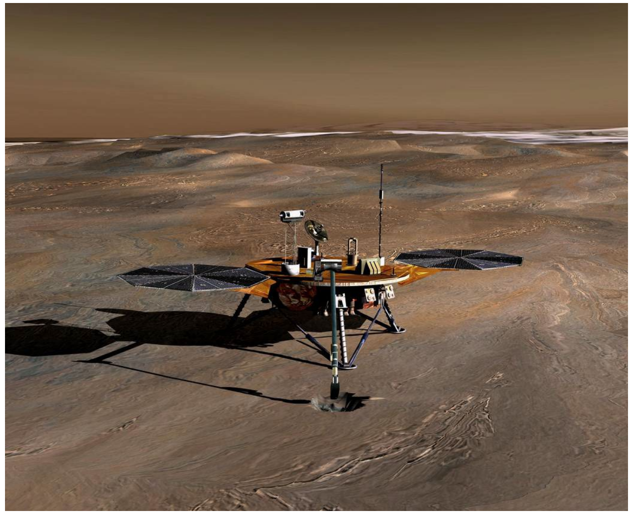
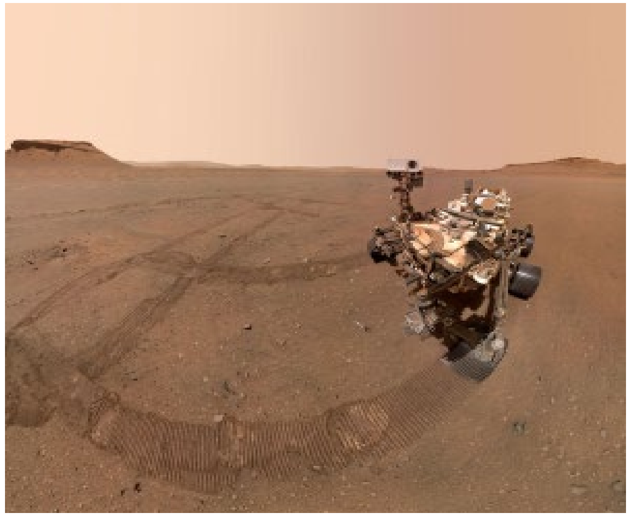
Highlights of Accomplishments at Mars

- **Odyssey** revealed large subsurface water ice at the poles.
- **Phoenix** lander sampled water directly, as ice and snow, and identified surface chemistry that can permit liquid water brine at modern-day Mars temperatures.
- **Spirit and Opportunity** rovers demonstrated that Mars once had a warmer, watery past. Used air bags for rover landing.
- **Curiosity** has demonstrated that Mars was once a habitable environment, with liquid water, organic materials, and a chemical environment necessary to sustain life as we know it. Used sky crane for rover landing.
- **MRO** has detected active gullies, ice-revealing impacts, and other key geologic features and has significantly enabled subsequent rover landing-site characterizations (e.g., Gale Crater, an ancient crater lake, and Jezero Crater, site of an ancient delta)
- **MAVEN** has provided clues to the loss of water from the Martian atmosphere to space, important to understanding the history of climate and the planet's habitability through time
- **InSight*** has shown us that Mars continues to be a planet that is dynamic, including Marsquakes.
- **Perseverance** is collecting samples from a location that was once water rich for Mars Sample Return, greatly improving the analysis that will be possible to perform on the samples.





*A Mars mission under NASA's Discovery Program

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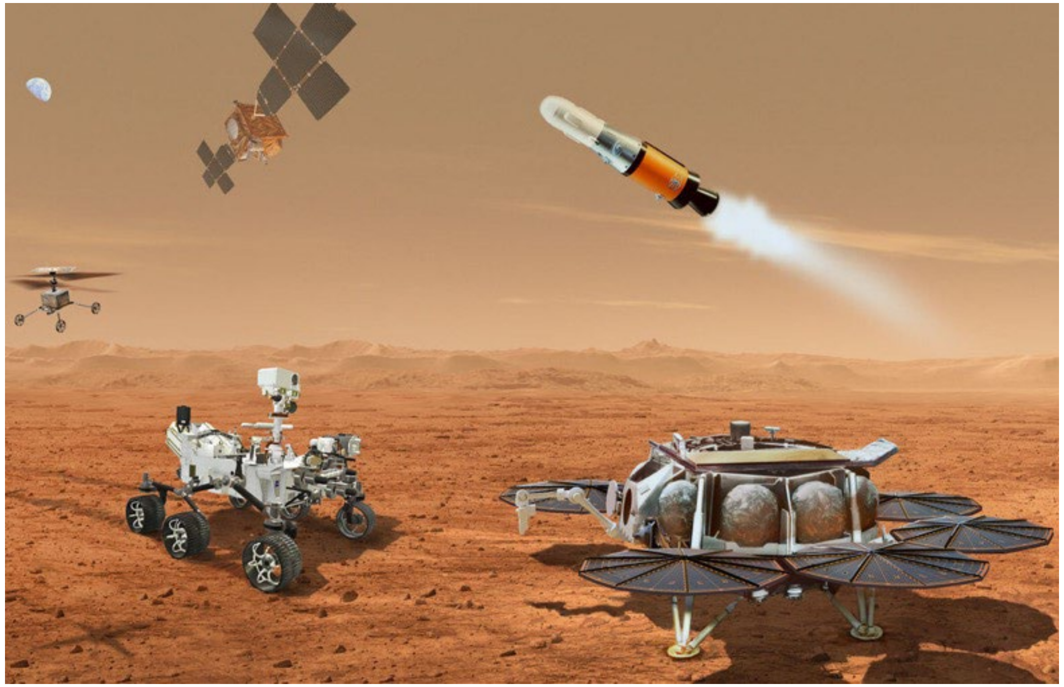
Mars Sample Return within the Context of the Mars Exploration Program

- Mars Sample Return (MSR)* represents the culmination of the community's highest Mars Exploration priority over the last two decades, as cited in the past three Decadal Surveys.
- MEP has responsibilities on both ends of the MSR campaign:
  - Collecting samples with Mars rover *Perseverance*
  - Curating and studying them as part of the future Sample Receiving Project



Artist's Concepts

- While MSR would achieve decadal-class science enabled by the past two decades of MEP exploration, MEP is also planning for the next two decades of equally profound scientific investigations with a new strategic paradigm designed to send lower-cost, high-science-value missions and payloads to Mars at a higher frequency.

*The decision to implement Mars Sample Return will not be finalized until NASA's completion of the National Environmental Policy Act (NEPA) process. This presentation is being made available for information purposes only.

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THE FUTURE OF MARS

Scientifically-selected, returned samples from Mars will…

- Address key Decadal science questions
  - Search for life elsewhere: Collecting samples in/around Jezero Crater; site selected for its likelihood in finding signs of ancient life
  - Dynamic Habitability: Mars was once like Earth, what transformed Mars? Mars holds the records lost on Earth from geologic activity
- Enable key discoveries by utilizing the most sensitive, state-of-the-art laboratories, for <u>decades</u> to come
  - Sophisticated sample prep, high sensitivity, high precision & discovery responsive investigations
  - Test hundreds of published scientific predictions utilizing analyses of the returned samples
  - Result in new research, hypotheses, and theories that will revolutionize our understanding of the solar system
- Inform NASA's Moon to Mars Strategy
  - Characterize Mars environmental conditions
  - Address Knowledge Gaps in backward planetary protection and retire risks for human exploration
  - First-ever demonstration of launch from the surface of another planet