National Aeronautics and
Space Administration

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EXPLORING MARS TOGETHER

DRAFT Plan for a Sustainable Future for Science at Mars

2023 – 2043

MEP Planning Team

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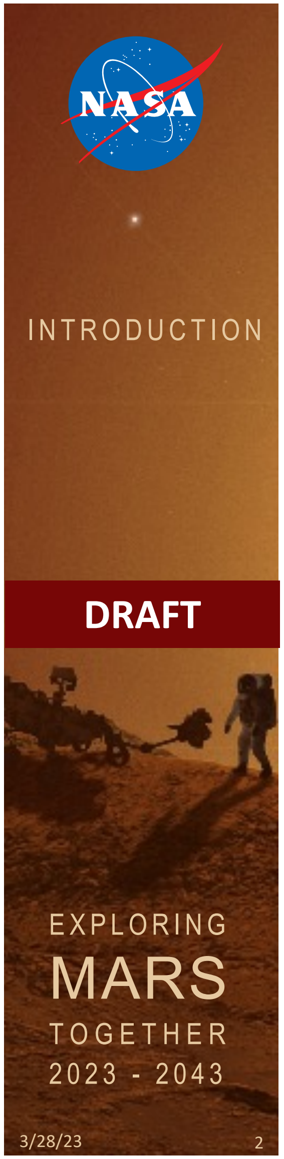
Draft for Community Feedback



PROGRAM CONTEXT

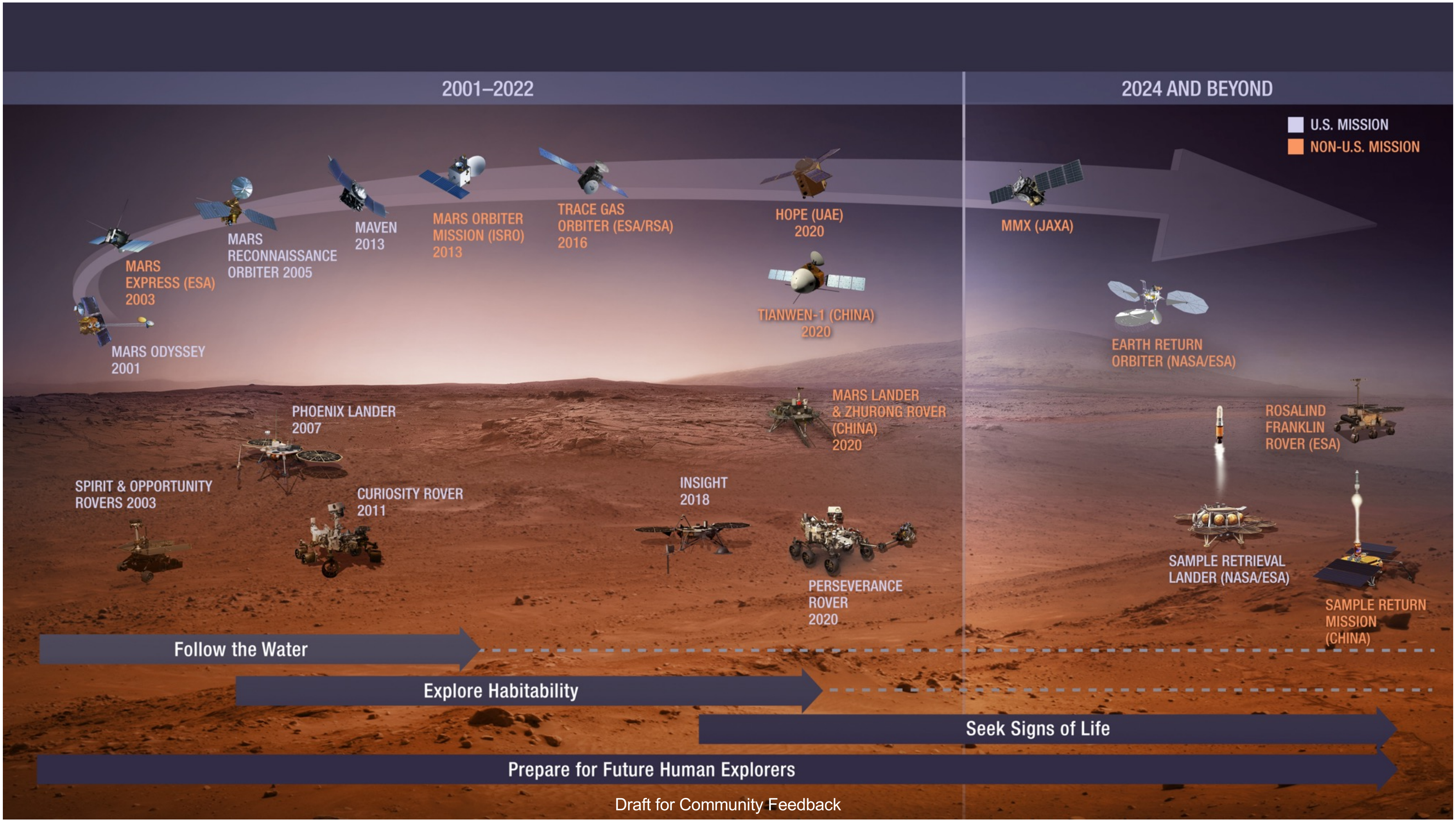
Over the past two decades NASA and the Mars Exploration Program (MEP) have been making progressive steps to better understand the planet and to search for past and present life at Mars through a series of orbiters, landers, and rovers

- Mars Pathfinder *
- Mars Odyssey
- Mars Spirit & Opportunity Rovers
- Mars Reconnaissance Orbiter
- Mars Phoenix
- MSL Curiosity Rover
- MAVEN
- InSight *
- Mars 2020 Perseverance Rover

* Mars Missions managed under NASA's Discovery Program

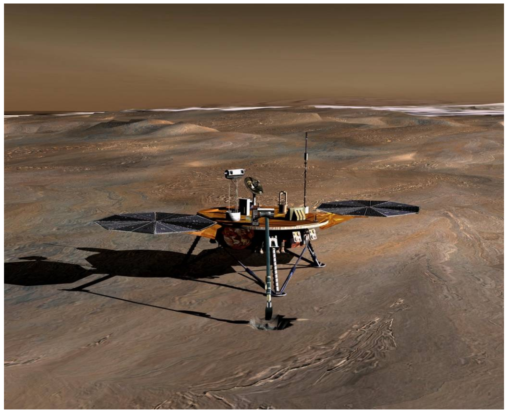
This critical chapter in Mars exploration would culminate in the return of samples to Earth through the planned Mars Sample Return campaign

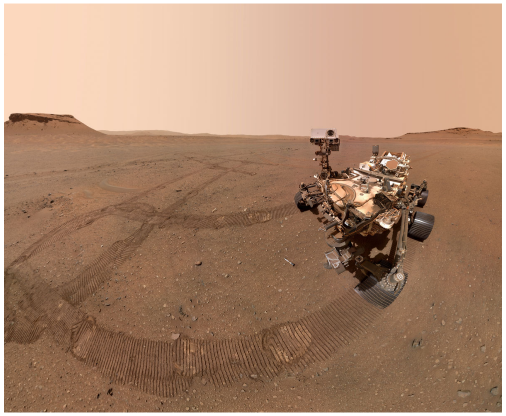
The Mars Exploration Program is now at an inflection point at which it must adapt to the changing space business environment (i.e., broadening international participation and expanding commercial interest/capability), address critical/aging infrastructure, and prepare for a human presence at Mars


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
Draft for Community Feedback

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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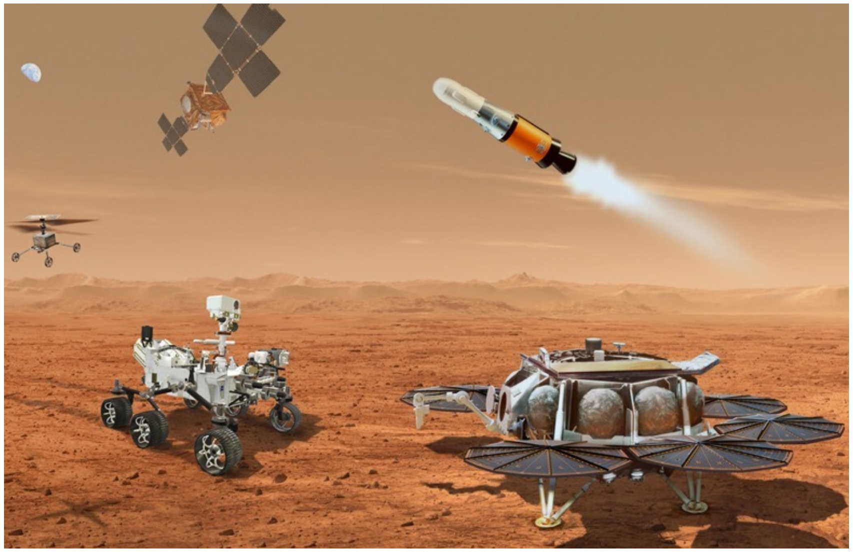
Mars Sample Return within the Context of the Mars Exploration Program

- 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 them at the future Sample Receiving facility.


Artist's Concepts

- While MSR would achieve decadal-class science enabled by the past two decades of MEP exploration, 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.

*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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"NASA should maintain the Mars Exploration Program, managed within the PSD, that is focused on the scientific exploration of Mars. The program should develop and execute a comprehensive architecture of missions, partnerships, and technology development to enable continued scientific discovery at Mars."

– 2022 Planetary Science & Astrobiology Decadal Survey

"A Program strategy should be developed before the end of 2022 following the release of the Decadal Survey. The strategy should provide a clear plan of action that includes the overarching science goal for the decade, mission cadence, opportunities for a mix of small, medium, and large missions that increase opportunities for competition and broad community participation including the commercial sector, and that includes a strategy to replenish the communication infrastructure."

– MEP Program Implementation Review, Standing Review Board Recommendation

INTRODUCTION

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The following presentation provides a <u>draft</u> plan for the future of the Mars Exploration Program (MEP).

The MEP is seeking input to this plan from key stakeholders before finalizing it.

While this is a plan for an SMD program, it requires close coordination with many organizations, including ESDMD, SOMD, and STMD.

The Mars Sample Return program remains the top priority for SMD Mars exploration. MSR is a foundational science mission that would inform future Mars activities.

It is important to note that implementation of this plan is <u>NOT</u> included in the current MEP budget.

<u>Any budget and schedule information presented herein should be considered notional.</u>

EXECUTIVE SUMMARY

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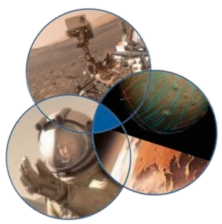
EXPLORING MARS TOGETHER 2023 - 2043

EXPLORING MARS TOGETHER: MEP FUTURE PLAN, 2023 - 2043

KEY TAKEAWAYS

Mars continues to pose key questions that call for a coordinated program of scientific exploration – three community-responsive science themes for 2023-2043 will guide MEP activities:



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

Emerging capabilities enable a new era of competitive missions, strengthened infrastructure, transportation opportunities, advanced technologies, and inclusive exploration – MEP will:

- Expand opportunities through frequent, small, low-cost missions to produce impactful science
- Build, strengthen, and maintain critical infrastructure
- Reduce the cost of access to Mars through partnerships, low-cost launch vehicle providers, and new delivery systems
- Develop technologies to enable new capabilities for exploring Mars
- Make exploration more accessible and inclusive to the broader community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This Plan incorporates inputs from several sources across the planetary science community, Mars science community, and engineering and technology communities.

INPUT	AREAS OF FINDINGS
2023-2032 Decadal Survey	Mars Sample Return, Mars Life Explorer, International Mars Ice Mapper (I-MIM), Human Exploration, Research and Analysis, Technology, Infrastructure, State of the Profession
Mars Architecture Strategy Working Group (MASWG) & Mars Concurrent Exploration Science Analysis Group (MCE-SAG)	Interconnected network of low-cost missions working together to address major outstanding Mars questions, Dynamic Mars, imaging needs, mission classes, competed and low-cost missions
Keck Institute for Space Studies (KISS) Workshop: *Revolutionizing Access to the Martian Surface*	Recommended sustainable architecture to reduce landed Mars costs through efficient operation of multiple assets, leveraging lunar capabilities and partnerships
Low-Cost Science Mission Concepts for Mars Exploration Workshop	Viability of small missions, mission concepts, industry partnering
Industry Day	Partnerships to enable access to Mars, including spacecraft/low-cost mission delivery systems and payload hosting; telecom relay, imaging, and weather monitoring
Industry Partnering Opportunities - Site Visits	Industry capabilities and partnering interest
International Mars Ice Mapper Measurement Definition Team (I-MIM MDT)	Ice science and ice record, reconnaissance, and the need for high-res imaging
Human Exploration	Decadal Survey, Science Objectives for Human Exploration of Mars Workshop, ties to lunar program
Moon-to-Mars Objectives/Recurring Tenets	LPS-3: Volatiles; LPS-4: Life; SE-3: Core samples of frozen volatiles; SE-5 Remote sensing for human mission planning; RT-1: International Partners; RT-2/RT-9: Industry Partners/Commerce and Space Development; etc.
Building on Agency Initiatives	Incorporate lessons learned from Moon2Mars, COTS/CLPS, etc.


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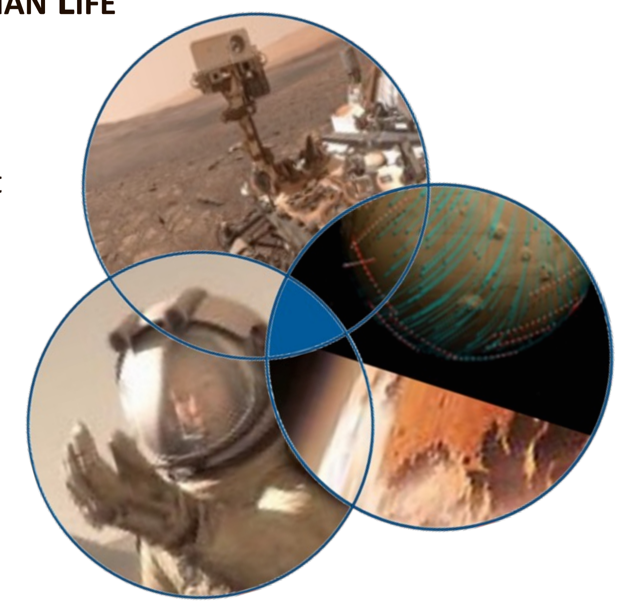
High-Level Co-Equal Program Science Themes, 2023 - 2043

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.



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.

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.

SECTION 2

SCIENCE THEMES

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EXPLORING MARS TOGETHER 2023 - 2043

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.

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.

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.

SECTION 2

SCIENCE THEMES

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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

SECTION 2
SCIENCE THEMES

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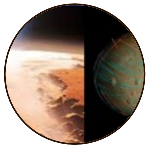
EXPLORING MARS TOGETHER 2023 - 2043



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

- **S 3.1.1** Characterize Geologic Planetary Evolution from Early Mars through the Present
- **S 3.1.2** Understand Early Environmental Change through the Stratigraphic Record
- **S 3.1.3** Determine Recent Climate Evolution through the Study of Volatile Cycles
- **S 3.1.4** Study Dynamic Modern Environments and their Processes
- **S 3.1.5** 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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INITIATIVES FOR THE NEXT TWO DECADES

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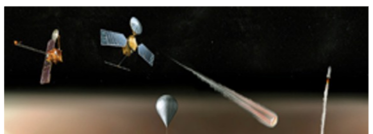
Program Initiatives for the Future of MEP

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

NASA

SECTION 3
INITIATIVES FOR THE NEXT TWO DECADES

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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.

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

SECTION 3

INITIATIVES FOR THE NEXT TWO DECADES

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EXPLORING

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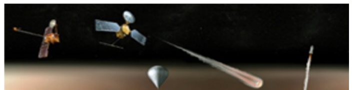


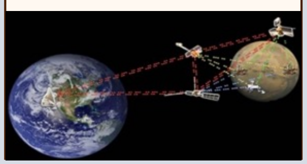
INITIATIVE 2

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.

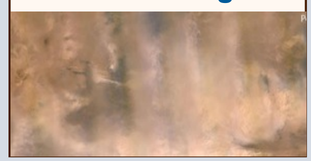
SCIENCE AND MISSION ENABLING

2.1 Mars Telecom Network

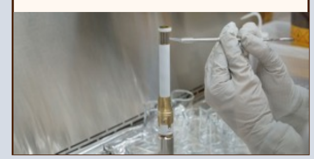


2.2 High-resolution Imaging

2.3 Global Meteorological Monitoring

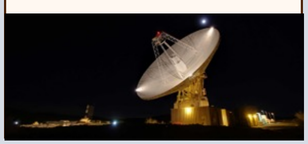


2.4 Sample Handling and Receiving



Actively consider opportunities to buy commercial services to address infrastructure

2.5 Ground Receiving Networks

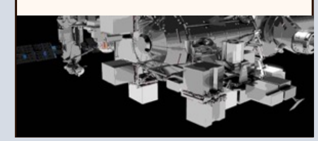


2.6 Data Infrastructure, Visualization, & Analysis

ACCESS TO MARS

2.7 Spacecraft Delivery (including Rideshares)

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.

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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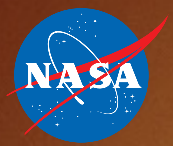

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INITIATIVE 4

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.

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"

SECTION 3
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:

- Explore opportunities for commercial services to address infrastructure needs
- Award study contracts to industry to better define potential public-private partnerships
- Engage the international community on potential partnerships and hosting opportunities
- Commission a National Academies study to identify science objectives for human campaigns to Mars
- Invest in technologies to expand access to Mars and improve scientific understanding of the planet
- Develop a draft Announcement of Opportunity for the first Low-Cost Mission opportunity
- Initiate work to enable broader participation in the Mars community


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SECTION 4
Aspirational Program Timeline

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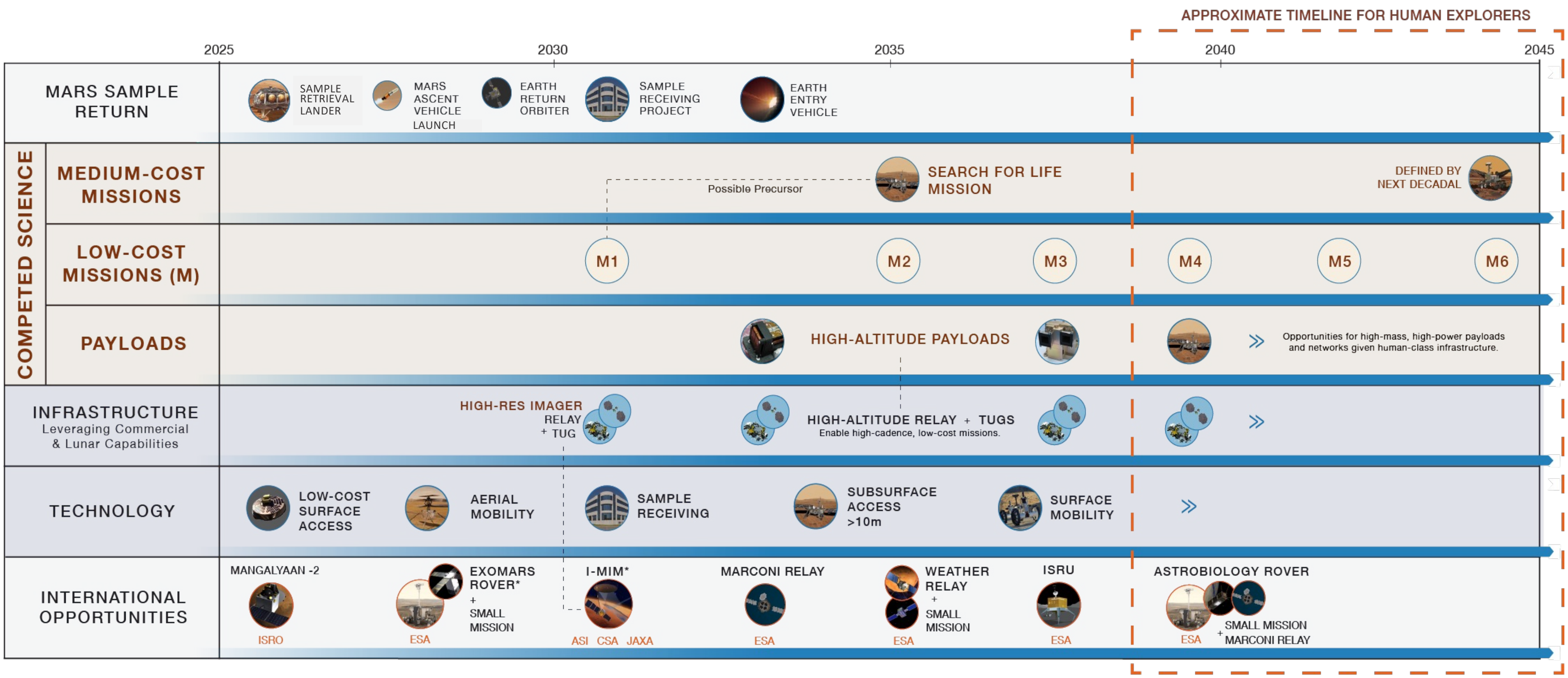
Aspirational MEP Timeline



* Launch Dates Fixed

This timeline should be considered hypothetical.

There is flexibility to adjust the phasing of activities if and when funding becomes available to begin implementation and to respond to discovery.

SECTION 4
Aspirational Program Timeline

FY09 – FY43

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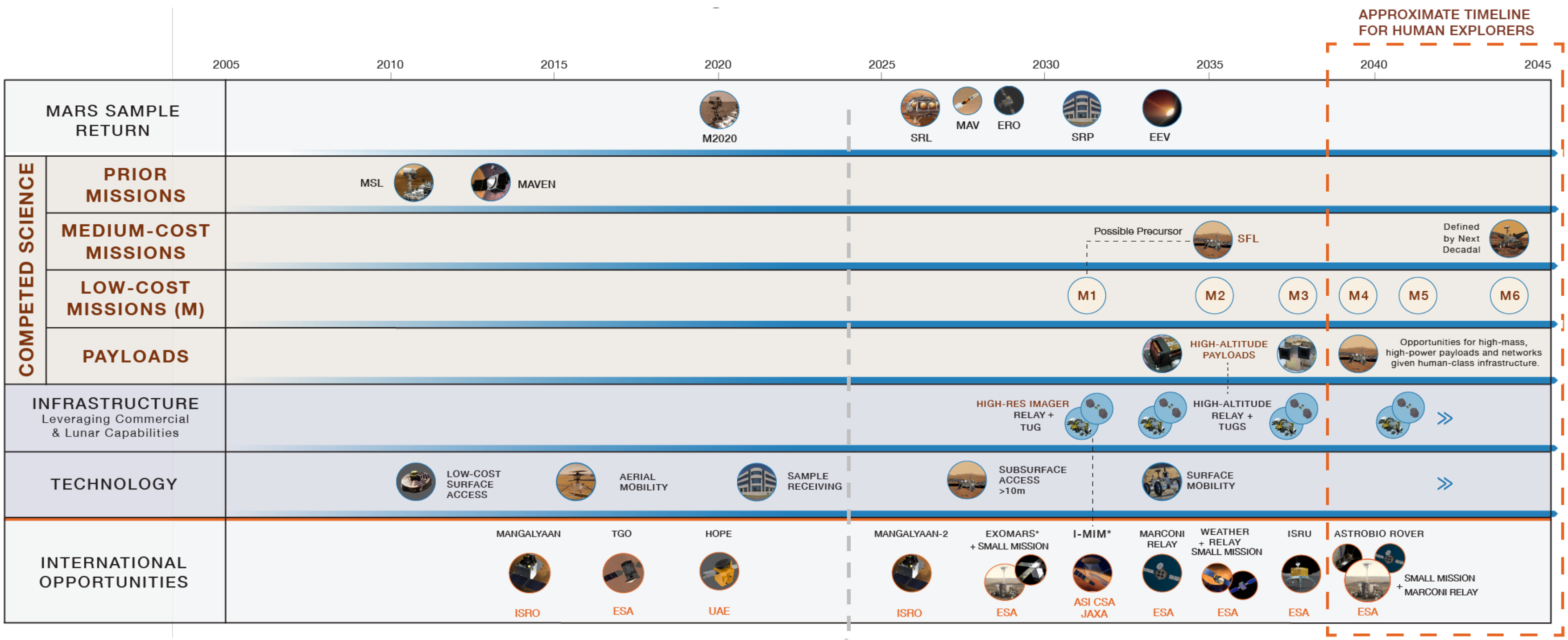
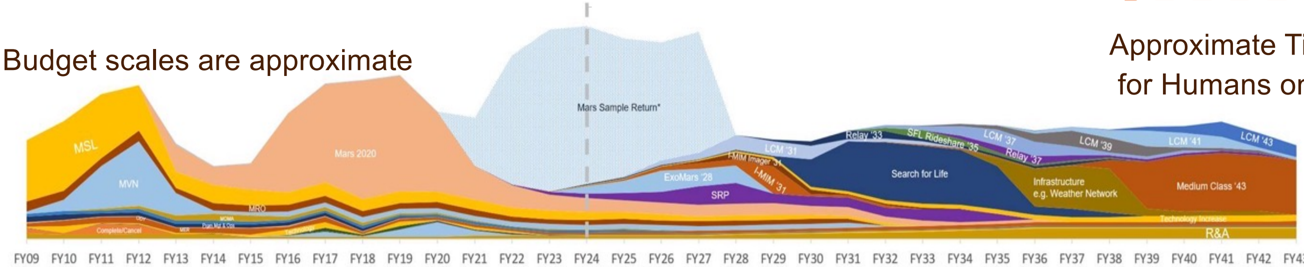
A Sustainable Budget Following MSR



Budget scales are approximate

Approximate Timeline for Humans on Mars



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Aspirational Program Timeline

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Summary of Plans

Priorities prior to the launch of MSR

- Achieve the objectives of the MEP Program of Record, including development of the Sample Receiving Project
- Collaborate with ESA on the ExoMars Rosalind Franklin Mission
- Seek low-cost opportunities to address critical infrastructure needs (particularly communications relay and high-resolution imaging)
- Continue investments in key mission-enabling technologies, especially those enabling the search for life and subsurface access
- Develop public/private partnership arrangements, reinforce existing international partnerships, and explore new opportunities with established and emerging space organizations

Priorities following the launch of MSR

- Implement a sustainable portfolio of low-cost competed missions, medium-class missions, infrastructure and technology investments, and missions of opportunity
    - 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


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We welcome your feedback!
Send comments/questions to:
HQ-MEP@mail.nasa.gov
Feedback requested by April 30, 2023
Eric E. Ianson
Director, Mars Exploration Program
EXPLORING MARS TOGETHER
DRAFT Plan for a Sustainable Future for Science at Mars
2023 – 2043
Draft for Community Feedback
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