

National Aeronautics and
Space Administration

EXPLORE MARS

Eric Ianson

Mars Exploration Program Director

Michael Meyer

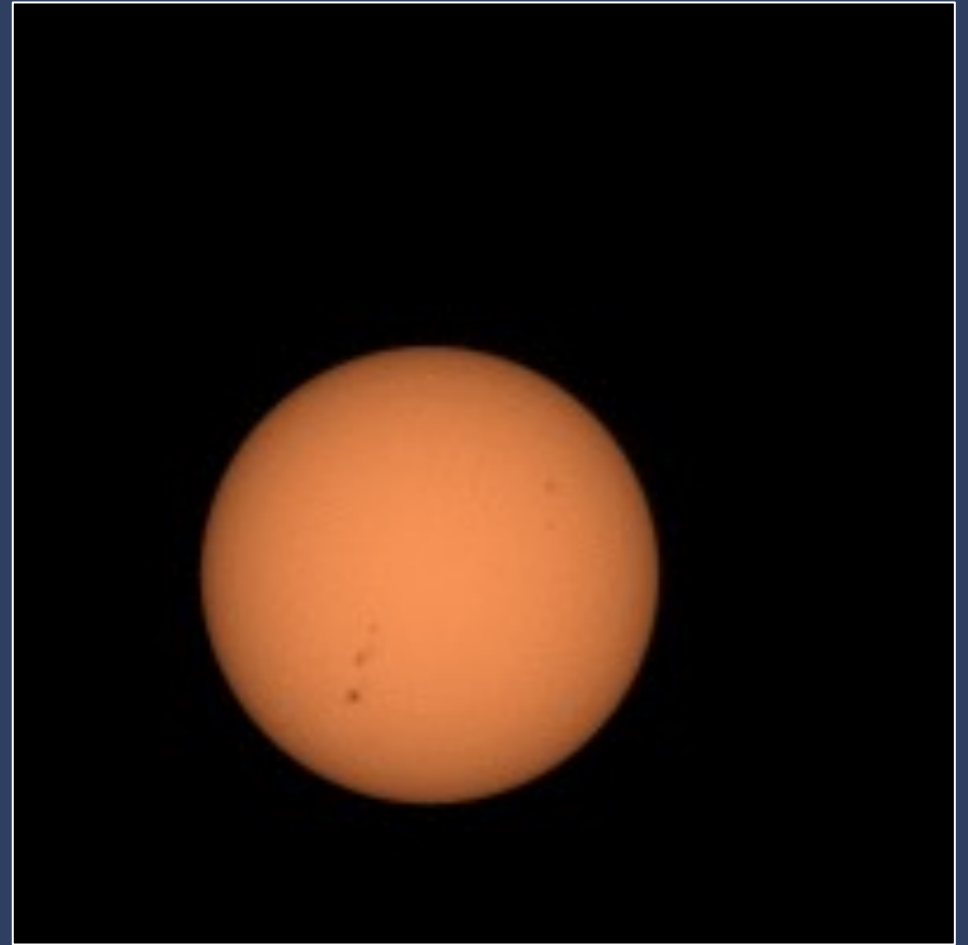
Lead Mars Scientist

NASA Planetary Science Advisory Committee (PAC) Meeting

June 2022

Mars Exploration Status Highlights

- Highly successful Low-Cost Science Mission Concepts for Mars Exploration Workshop held March 28-31, 2022
<https://www.hou.usra.edu/meetings/lowcostmars2022/>
- Perseverance sample cache has grown to 10 samples (1 witness, 1 atmospheric, 8 rock cores)
- Perseverance has arrived at the Jezero Crater delta and begun a new science campaign
- Ingenuity helicopter has successfully performed 29 flights to date
- National Aeronautic Association awarded the prestigious Robert J. Collier Trophy for achievement in flight to NASA JPL's Ingenuity Mars Helicopter team
- New IMEWG Chair Sanjay Vijendran, ESA
 - Face to Face IMEWG Sept 14-16, 2022 at ASI in Turin, Italy
- Arthur (Art) Thompson announced as new Mars2020 Project Manager
- Successful MEP Program Implementation Review/KDP-III
- 2023-2025 Senior Review Mission Extensions Announced:
<https://www.nasa.gov/feature/nasa-extends-exploration-for-8-planetary-science-missions>
- MEP Strategic Planning Retreat (HQ/MEPO) June 22-23, 2022



NASA's Perseverance Mars rover used its Mastcam-Z camera to shoot video of Phobos, one of Mars' two moons, transiting the Sun. It's the most zoomed-in, highest-frame-rate observation of a Phobos solar eclipse ever taken from the Martian surface. Credits: NASA/JPL-Caltech/ASU/MSSS/SSI

Senior Review of Extended Missions for Mars

MAVEN (Principal Investigator: Dr. Shannon Curry, University of California, Berkeley)

The Mars Atmosphere and Volatile Evolution (MAVEN) mission plans to study the interaction between Mars' atmosphere and magnetic field during the upcoming solar maximum. MAVEN's observations as the Sun's activity level increases toward the maximum of its 11-year cycle will deepen our understanding of how Mars' upper atmosphere and magnetic field interact with the Sun.

Mars Science Laboratory (MSL) (Project Scientist: Dr. Ashwin Vasavada, JPL)

The Mars Science Laboratory and its Curiosity rover have driven more than 16 miles (27 km) on the surface of Mars, exploring the history of habitability in Gale Crater. In its fourth extended mission, MSL will climb to higher elevations, exploring the critical sulfate-bearing layers which give unique insights into the history of water on Mars.

Mars Odyssey (Project Scientist: Dr. Jeffrey Plaut, JPL)

Mars Odyssey's extended mission will perform new thermal studies of rocks and ice below Mars' surface, monitor the radiation environment, and continue its long-running climate monitoring campaign. The Odyssey orbiter also continues to provide unique support for real-time data relay from other Mars spacecraft. The length of Odyssey's extended mission may be limited by the amount of propellant remaining aboard the spacecraft.

Mars Reconnaissance Orbiter (MRO) (Project Scientist: Dr. Rich Zurek, JPL)

MRO has provided a wealth of data regarding the processes on Mars' surface. In its sixth extended mission, MRO will study the evolution of Mars' surface, ices, active geology, and atmosphere and climate. In addition, MRO will continue to provide important data relay service to other Mars missions. MRO's CRISM instrument will be shut down entirely, after the loss of its cryocooler has ended the use of one of its two spectrometers.



MEP Orbiters

Mars Relay Network: MEP successfully managing network activities

Odyssey: 21 yrs since launch on April 7, 2001! Continues orbital science investigations & relay services for surface assets

- Recent Propellant Gauging System (PGS) Studies yielded estimate of approximately 3-4 kg (vs 9 kg) usable fuel remaining, reducing predicted ops life
 - Propellant investigation continues, but potential culprit is excess thrusting during safe mode activities, and the project is assessing their planning for the extended mission

MAVEN: Entered safe-mode in February 2022 due to IMU-1 issues. Science and relay operations paused

- Project successfully expedited implementation of All Stellar Mode (ASM) and resumed nominal science and relay operations on May 28th
- Operations will meter out IMU lifetime for critical events

ExoMars/TGO: Continuing to support relay operations for MEP surface assets

MRO: In nominal science and relay operations; All stellar mode in use to preserve IMU lifetime; providing valuable monitoring data for Mars community

- CRISM instrument ended operations on May 7, 2022

Belva

Mars2020

Perseverance Odometer: 12052.7 m*
Ingenuity Log: 29 flights, 7084.0 m, 3317.5 s*

*June 13, 2022



NASA's Perseverance Mars rover Navcam looking back down to the Three Forks region (Sol 464). Credits: NASA/JPL-Caltech



Delta Front Campaign Area

Three Forks

❖ 29 successful flights & over 1 yr
of ops for Ingenuity!

Octavia E. Butler Landing Site

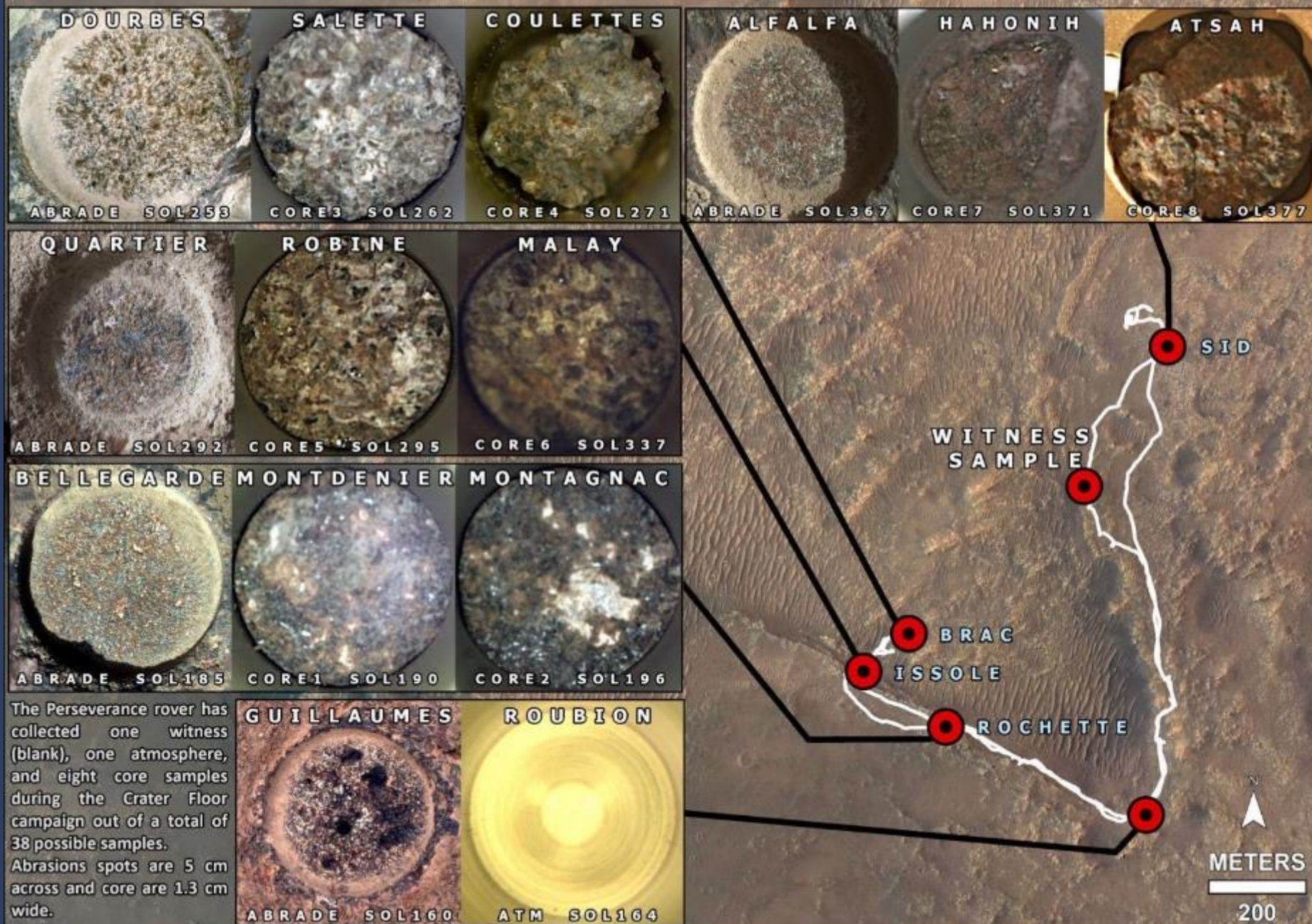
Crater Floor Science Campaign Area

❖ Perseverance set
single-sol record
319.786m (Sol 351)



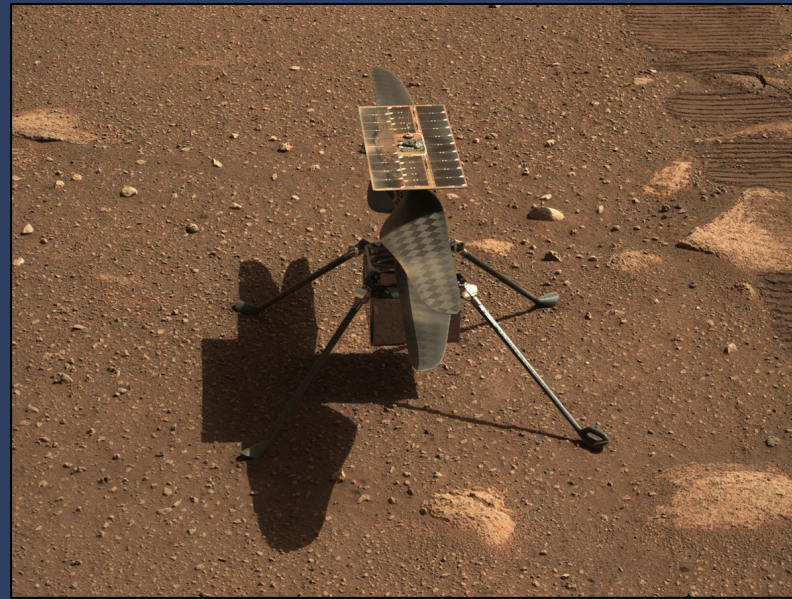
MARS
2020
PERSEVERANCE

Sample Collection Map: Cores 1-8



Ingenuity

- Over 1 year of Ops! Ingenuity intended to make 5 Martian flights, has made 29 flights as of June 14, 2022
- Ingenuity's 26th flight captured images of Perseverance's entry, descent and landing gear. The images may help ensure safer landings for future spacecraft
- This July marks the beginning of Ingenuity's 1st winter
- Ingenuity briefly lost contact with Earth in May 2022 due to a decline in battery life
- Decline in battery life was due to decreased solar energy, and increased energy demand on the heaters
- NASA will suspend use of Ingenuity's onboard heaters at night to preserve power throughout the four-month Martian winter
 - Hope to resume normal Ingenuity operations this fall when available solar energy increases



NASA's Ingenuity is seen here in a close-up taken by Mastcam-Z, a pair of zoomable cameras aboard the Perseverance rover. Credits: NASA/JPL-Caltech/ASU



This image of Perseverance's backshell and supersonic parachute was captured by NASA's Ingenuity Mars Helicopter during its 26th flight on Mars on April 19, 2022. Credit: NASA/JPL-Caltech



International Mars Ice Mapper Status

- International Mars Ice Mapper (I-MIM) funding zeroed in FY23 PBR
 - International partners notified
- I-MIM Measurement Definition Team (MDT) completing efforts
- MDT charter is to:
 - Define measurements and recommend optimizations for the primary anchor payload (SAR/SAR Sounder provided by CSA)
 - Provide options for potential high-priority, synergistic recon/science augmentation
 - Prepare a concept of operations
- MDT completed their interim report in March 2022
- MDT final report completion expected early July 2022

Sample Receiving Project (SRP) Overview

Enable safe & rapid release of samples to external laboratories



1. Safely recover samples while maintaining sample integrity
2. Receive the contained MSR samples at a secure BSL4 facility
3. Extract the samples from the returned flight hardware, complete basic characterization/preliminary examination
 - a) Protect the samples from degradation
 - b) Maintain biological high-containment until sterilized and/or deemed safe
4. Support execution of the Sample Safety Assessment
5. Facilitate worldwide scientific investigations
6. Provide curation services and enable future long-term curation

MSR Sample Receiving Project Status

- Ground Sample Recovery activities under study
- NASA Facility Assessment Study to trade priorities
 - Facility types/modalities (traditional, existing, modular, hybrid)
 - Instrumentation/capabilities
 - Time to release samples
- Assessment Study with Architecture & Engineering Firms
 - RFP released in April 2022
 - Studies to evaluate all modalities & capabilities
 - Complete by end of 2023
 - Identification of capabilities that can be achieved within each of the modalities
 - Quantitative risk/benefit trades

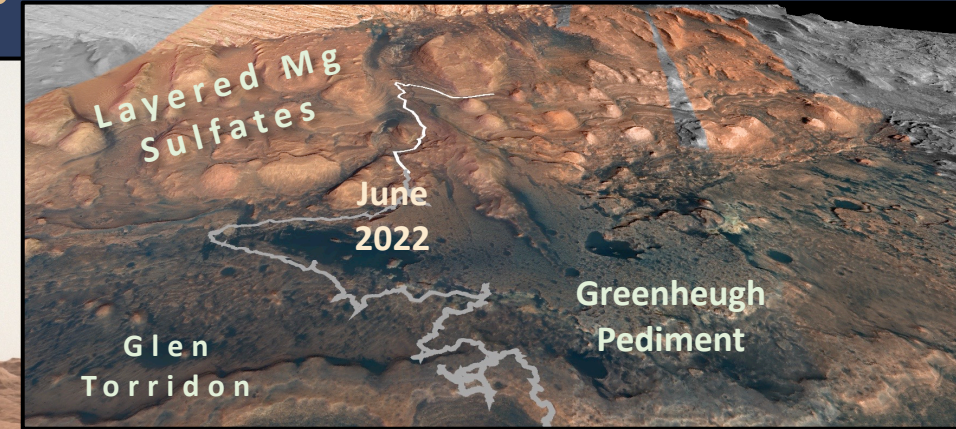
Science Update from Curiosity

NASA.JPL-Caltech/MSSS

Layered Sulfate Unit

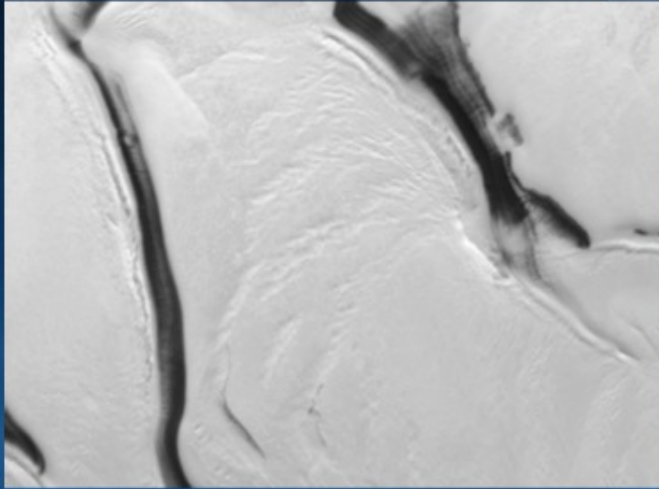
Lenses

Cross-Bedded Deposits

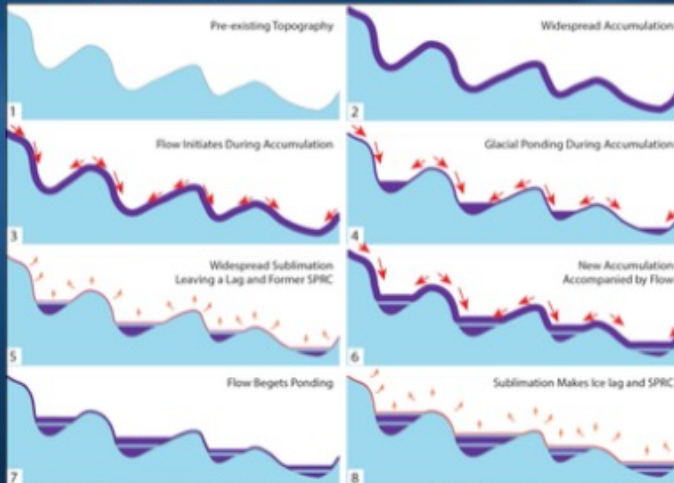


The upper portion of this region is characterized by large cross-bedded deposits and erosion-resistant lenses. These are interpreted to have formed in an aeolian dune field punctuated by small ponds and/or streams. Clay minerals have decreased in abundance, and amorphous Mg-sulfates along with other salts are detected. Combined, these observations suggest a decline in the availability of surface water at Gale crater during the time period recorded in this interval, relative to the continuous record of lakes at lower elevations.

Glacier flow in the South Polar Cap



The surface of Wolf Glacier, showing crevasses and topography associated with flowing ice



Alternating periods of atmospheric deposition and sublimation, with continuous flow, explains the distribution of ice

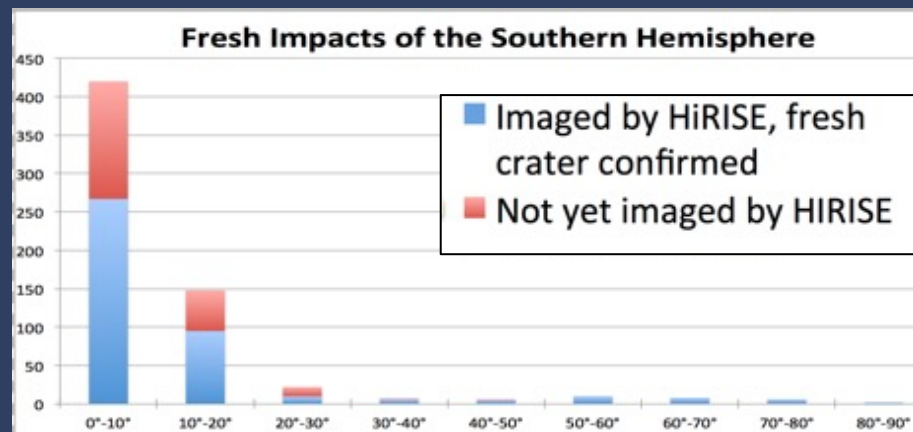
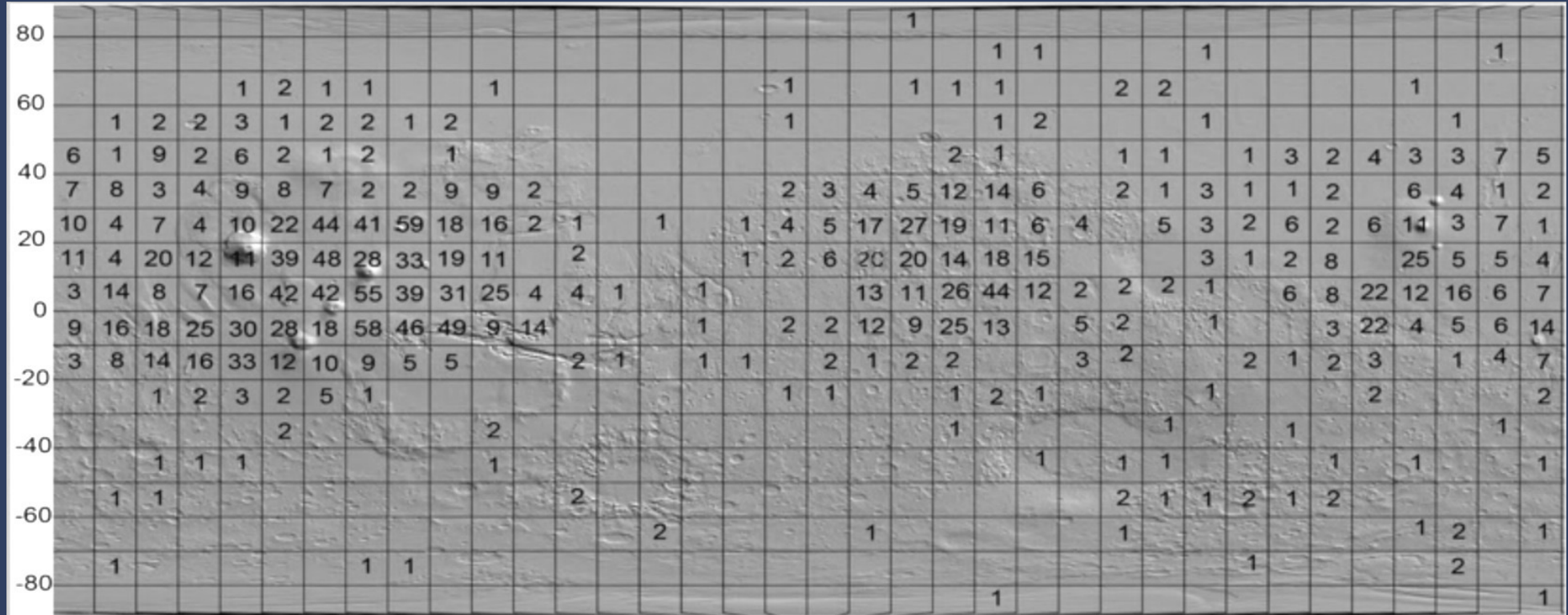
Thick deposits of CO₂ ice at the south pole of Mars began depositing ~600 kyr in the past and flow as glaciers into their present state, which is in topographic basins.

- Models based exclusively on atmospheric deposition cannot explain the volumetric distribution of CO₂ ice: thickness, or location
- We present geomorphic and modeling evidence that the CO₂ deposits flow as glaciers into basins to reach their observed volumetric distribution
- This improves our understanding of past climatic periods and demonstrates that the Martian landscape is evolving today. It also adds one type of ice that we know to be flowing in the Solar System

Smith, I. B., Schlegel, N.-J., Larour, E., Isola, I., Buhler, P. B., Putzig, N. E., & Greve, R. (2022). JGRP

Global Distribution of Fresh Impact Craters

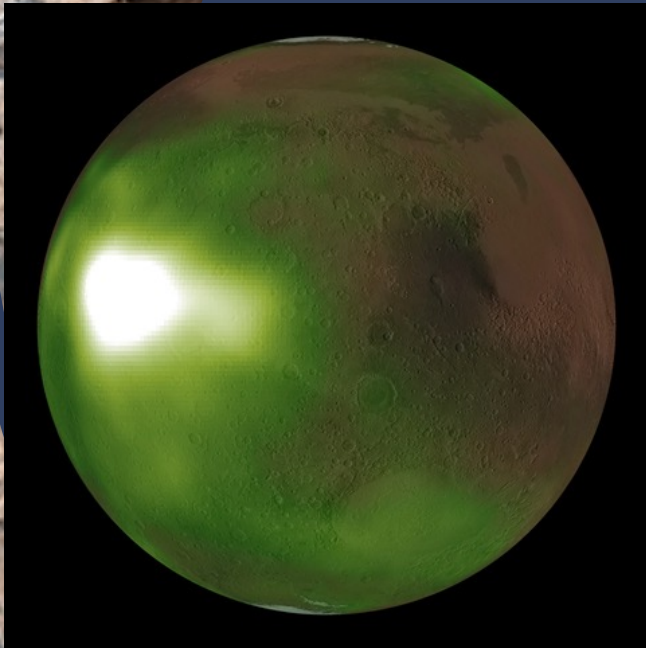
Detected by MRO



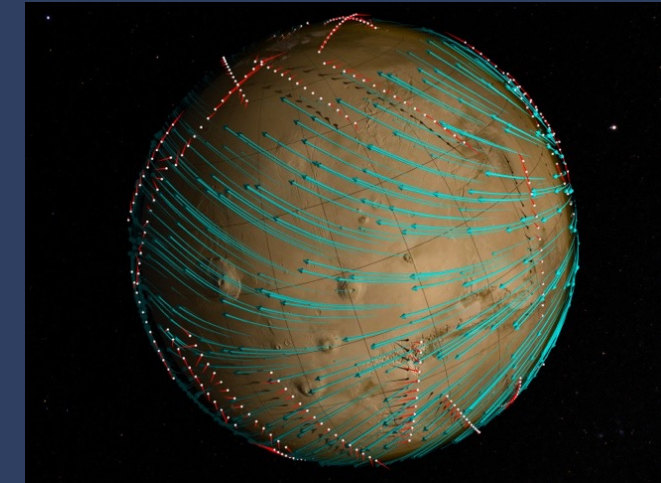
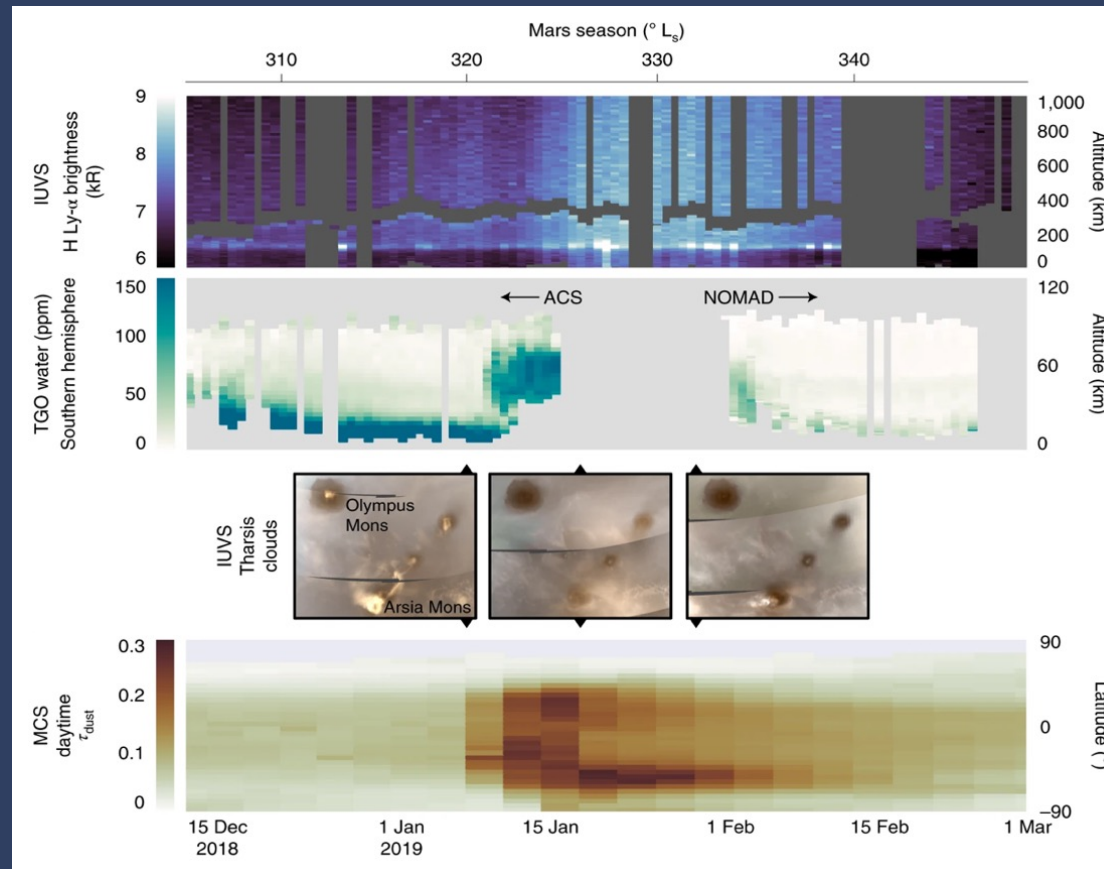
- 2160+ candidate impacts discovered since the beginning of the MRO mission
- Heavily concentrated in Tharsis, Arabia, and Elysium (bias: dark splotches in bright areas)
- About 629 candidate impacts (409 confirmed), or ~29%, were located in the southern hemisphere and ~ 2/3rds of those were within 10° of the equator

MAVEN – upper atmosphere interactions

During a period of increased dust opacity (bottom panel), the atmosphere warms, which inhibits cloud formation (3rd panel) and allows water to be transported to high altitude (2nd panel). Hydrogen, from the dissociation of water, is greatly enhanced in the corona (top panel), where it can escape to space. From Chaffin et al., [2021].



MAVEN IUVS observations of nitric oxide nightglow emission (false color). Localized peaks in intensity are repeatable and show downward winds cause chemical reactions that result in UV light.



MAVEN NGIMS observations of thermospheric neutral winds (red) were the first to constrain wind circulation patterns (green) in the upper atmosphere of a planet other than Earth.



<https://www.nasa.gov/feature/jpl/nasa-s-perseverance-studies-the-wild-winds-of-jezero-crater>

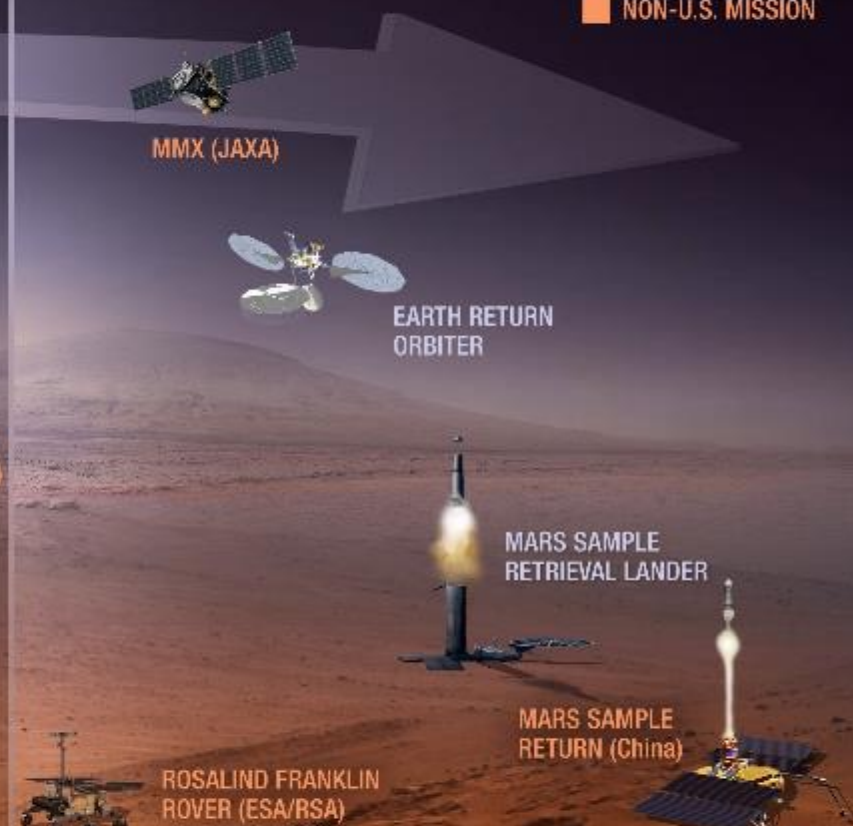
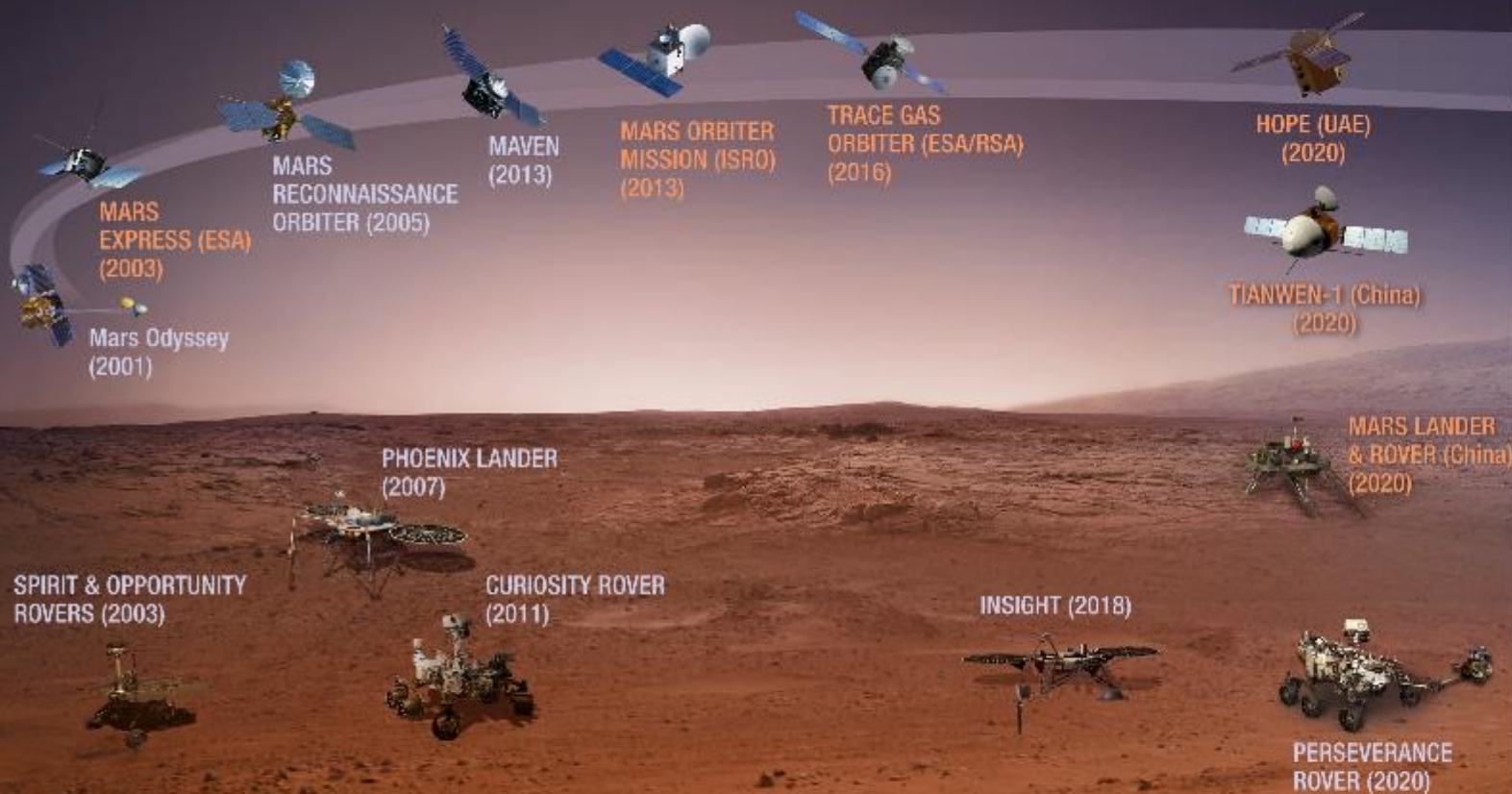


EXPLORE
with us

2001–2020

2022 AND BEYOND

■ U.S. MISSION
■ NON-U.S. MISSION




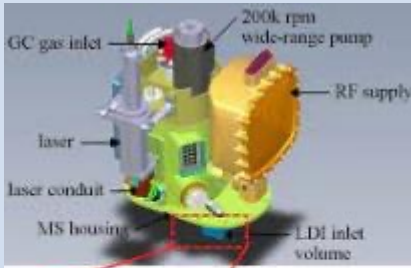

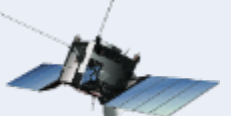
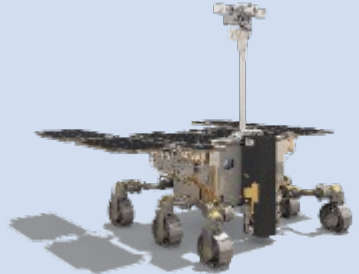

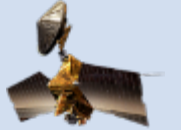
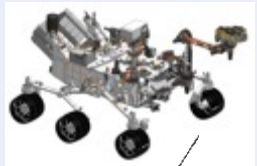



Follow the Water

Explore Habitability






Seek Signs of Life

Prepare for Future Human Explorers






Missions in Operation, Development, & Pre-Formulation

Operations	Development	Pre-Formulation
Odyssey 	MOMA-MS 	International Mars Ice Mapper 
Mars Express 		Sample Receiving Project 
Mars Reconnaissance Orbiter 		
Mars Science Laboratory Curiosity 		
MAVEN 		
Trace Gas Orbiter 		
Mars 2020 Perseverance & Ingenuity 		

Summary of Mars Relay Network (MRN) Assets

Mission	Agency	Launch Year	Orbit	UHF Relay Payload	Max Return-Link Data Rate
ODY 	NASA	2001	385 km x 450 km 93 deg incl	CE-505 redundant units, quadrifilar helix antenna, 12 W transmit power	256 kb/s
MEX 	ESA	2003	298 km x 10,100 km 86 deg incl	Melacom single unit, patch antennas, 8.5 W transmit power	128 kb/s
MRO 	NASA	2005	255 km x 320 km 93 deg incl	Electra redundant units, quadrifilar helix antenna, 5 W transmit power	2048 kb/s adaptive data rate enabled
MAVEN 	NASA	2013	~200 km x 4500 km 75 deg incl	Electra single unit, quadrifilar helix antenna, 5 W transmit power	2048 kb/s adaptive data rate enabled
TGO 	ESA	2016	400 km x 400 km 74 deg incl	Electra redundant units, quadrifilar helix antenna, 5 W transmit power	2048 kb/s adaptive data rate enabled

Status of Aging Mars Relay Network Assets

Mission	Mission Status
ODY 	<p>Fuel usage is ~1 kg/yr, with <4 kg remaining. “All-stellar mode” in use to preserve IMU lifetime. No remaining redundancy in reaction wheel assembly.</p>
MEX 	<p>Some onboard memory issues persist. Fuel load extremely low and uncertain. Available for emergency relay services for NASA’s landed assets.</p>
MRO 	<p>Fuel usage ~10 kg/yr, with ~150 kg remaining. “All-stellar mode” in use to preserve IMU lifetime. X-band TWTA is effectively single-string due to waveguide transfer switch (WTS) anomaly. Relay services expected to remain viable into the 2030s.</p>
MAVEN 	<p>Fuel usage ~5 kg/yr, with ~70 kg remaining. Fuel usage planned to allow science and relay operations through 2031. “Minimum All-stellar mode” in use since 04/19. IMU powered off to preserve lifetime. MAVEN will remain in Earth-nadir point until ASM ground testing verifies other pointing. Expected return to science and relay service at the end of May.</p>
TGO 	<p>Relay services expected to remain viable well beyond 2030. Presently returning >50% of relay data from NASA’s landed assets.</p>



National Aeronautics and
Space Administration

EXPLORE MARS SAMPLE RETURN

Jeff Gramling

Director, Mars Sample Return Program

Dr. Michael Meyer

Mars Lead Scientist

Planetary Science Advisory Committee

June 21, 2022





GOAL — First Sample Return From Another Planet

A priority since 1980 and of three 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***

Perseverance Odometer: 12052.7 meters*
Ingenuity Log: 29 flights, 7084 m, 3317.5 sec*
*June 16, 2022, Sol 470

Mars2020



NASA's Perseverance rover at Hogwallow Flats on June 10, 2022, the 464th Martian day, or sol, of the mission. Credit: NASA/JPL-Caltech/USGS/UofA (PH)



Longitude, Latitude 77.38228798°, 18.44272865°

Samples Collected by Perseverance

Perseverance has arrived at the delta front.
Has 8 rock samples collected during Crater Floor Science Campaign.

Total 10 tubes sealed:

1 Witness blank

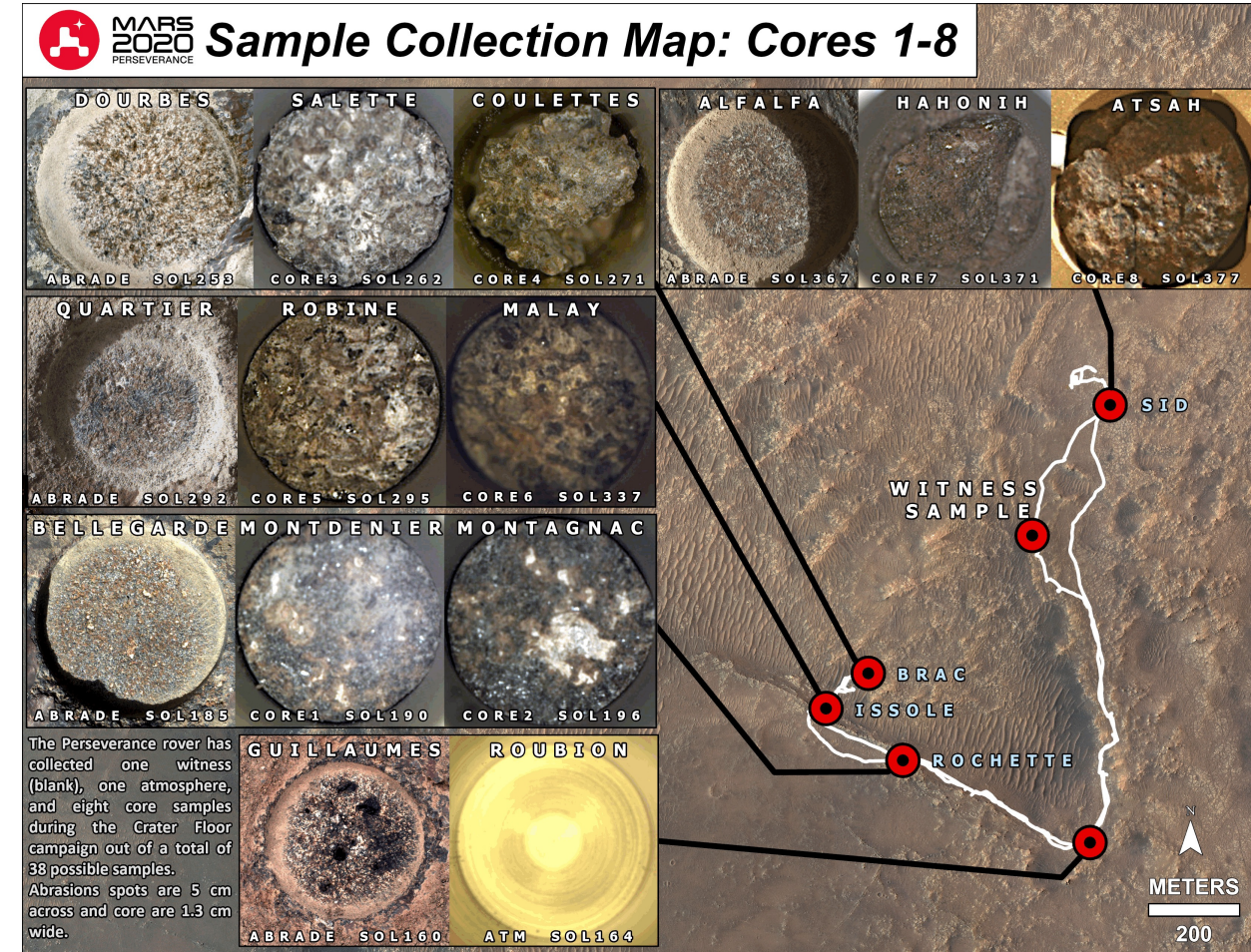
1 Atmospheric sample

4 pairs of rock core samples

An initial 30-day report is prepared for each sample that will provide contextual information on the returned samples.

Landing site characterization for the first depot at the “Landing Strip” are underway.

Science Community Workshop for depot of the first sample set is being planned for last week in September 2022



Sampling Sites

The background of the slide is a composite image. The top left shows a satellite with solar panels in orbit. The bottom left shows a Mars rover on the reddish, rocky surface of Mars. A large, dark blue curved shape covers the right side of the slide, serving as a background for the text.

MSR:

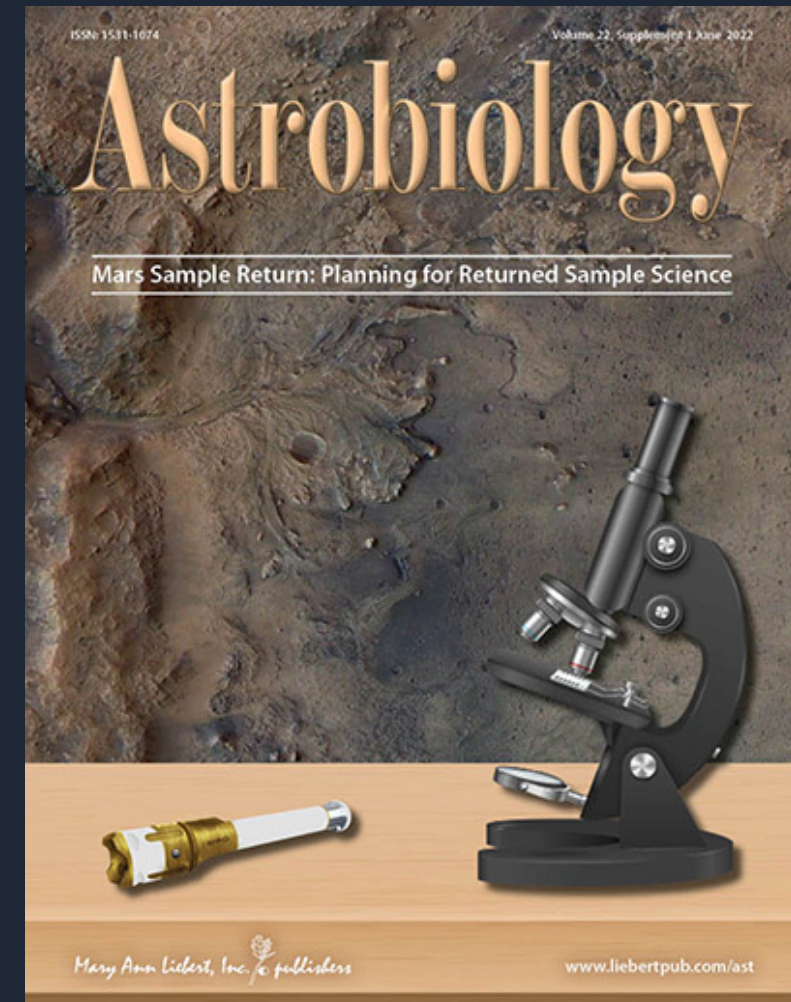
Potential benefits from samples already cached

- Igneous rocks will provide absolute age of the Jezero crater region and anchor the ages of martian epochs
- Salts and other products of aqueous alteration will provide insights into the history of water in this region on Mars
- Organic compounds already detected in some samples – will be able to determine the specific compound(s) and potentially deduce their origin (biogenic vs abiogenic)
- The samples will help address major gaps in our knowledge for future human exploration

SPECIAL SUPPLEMENT

Mars Sample Return: Planning for Returned Sample Science

"Mars Sample Return (MSR) has been a high priority for the planetary science community for more than four decades. Analyzing martian samples in terrestrial laboratories would advance our understanding of Mars in multiple ways that are impossible using *in situ* missions alone," state special supplement authors in the forward. "The purpose of this special issue of ***Astrobiology*** is to collate and publish these scientific and planning reports for MSR in a single location and make them available to the community of scientists interested in MSR."



Volume 22 Supplement 1 June 2022



NASA ESA MSR Science MoU

in review at State Department – soon to ESA

- "NASA and ESA, through a dedicated joint body to be established, shall have and provide, equitable access to returned samples for scientific research, and shall establish procedures for open competition for access by the international scientific community. Use and curation of samples shall be governed by a future agreement between the Parties, and be based on ***the principles of transparency, scientific maximization, accessibility, return of investment, and recognizing the samples as a single collection.***" – NASA ESA MoU signed October 2020
- The scope of the **MSR Science MoU** covers the science management of the Mars samples from the caching of M2020 samples, through the MSR program flight elements, to the sample handling, curation and scientific analyses on ground until completion of the first round of objective-driven science.
 - Does not intend to cover *any agreements* on the ground-based infrastructure to be used once the samples landed on Earth but permits the needed planning activities to prepare for handling the samples upon return to Earth.



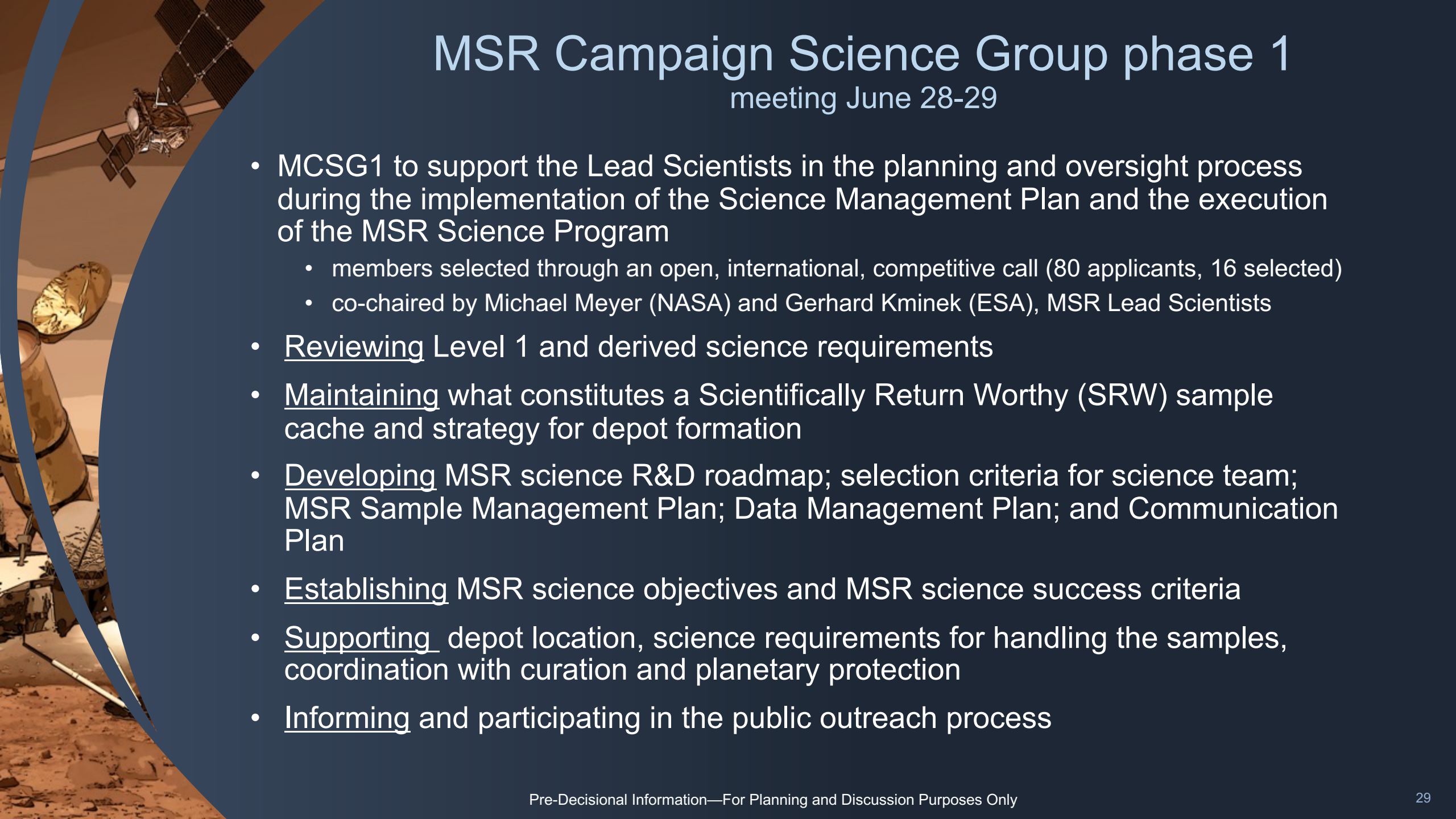
Science Management Plan*

under internal review; signatures anticipated by Sept. 2022

Plans for management, oversight, and resources are established for engineering elements of MSR but remain undefined for scientific elements

- Science functionalities required to carry out MSR include science leadership, science investigations, and involvement of the broader science community
- These functionalities are outside the scope of existing scientific bodies/activities
 - Some scientific functions covered by M2020, but most are not yet assigned
- New science bodies are needed for functionalities not yet assigned; this requires the establishment of an overarching MSR science management structure that should be initiated as soon as possible → MSR Campaign Science Group

* Science Management Plan based on: Rationale and Proposed Design for a Mars Sample Return (MSR) Science Program *Astrobiology*, Haltigin *et al.*, in press, doi: 10.1089/ast.2021.0122.



MSR Campaign Science Group phase 1

meeting June 28-29

- MCSG1 to support the Lead Scientists in the planning and oversight process during the implementation of the Science Management Plan and the execution of the MSR Science Program
 - members selected through an open, international, competitive call (80 applicants, 16 selected)
 - co-chaired by Michael Meyer (NASA) and Gerhard Kminek (ESA), MSR Lead Scientists
- Reviewing Level 1 and derived science requirements
- Maintaining what constitutes a Scientifically Return Worthy (SRW) sample cache and strategy for depot formation
- Developing MSR science R&D roadmap; selection criteria for science team; MSR Sample Management Plan; Data Management Plan; and Communication Plan
- Establishing MSR science objectives and MSR science success criteria
- Supporting depot location, science requirements for handling the samples, coordination with curation and planetary protection
- Informing and participating in the public outreach process

MCSG1 Members

Audrey Bovier	Universität Bayreuth, Bayerisches Geoinstitut	Suzanne Schwenzer	Open University, School of Earth, Environment and Ecosystem Sci.
Andrew Czaja	University of Cincinnati, Dept. of Geology	Andrew Steele	Carnegie Institution of Washington, Earth and Planetary Laboratory
Nicolas Dauphas	The University of Chicago, Dept. Geophys. Science & Fermi Inst.	Kimberly Tait	Royal Ontario Museum (ROM), Department of Natural History
Katherine French	U.S. Geological Survey (USGS), Central Energy Resources Science Center	Michael Thorpe	Texas State University, JSC
Lydia Hallis	University of Glasgow, School of Geographical and Earth Sci.	Tomoshiro Usui	Japan Aerospace Exploration Agency (JAXA), Institute of Space and Astronautical Science (ISAS)
Rachel Harris	Harvard University, Dept. of Organismic and Evolutionary Biology	Jessica Vanhomwegen	Institut Pasteur, Laboratory for Urgent Response to Biological Threats
Ernst Hauber	German Aerospace Center (DLR), Institute of Planetary Research	Michael Velbel	Michigan State Un. Dept. Earth & Environmental Sci; Dept. Mineral Sci. National Museum of Natural History
Laura Rodriguez	NASA Jet Propulsion Laboratory (LPI beginning Oct 2022)	Maria-Paz Zorzano	Center of Astrobiology (CAB), National Inst. for Aerospace Tech.

MSR Campaign

Mars Sample Return Program

1



Sample Caching

- *Collect samples of rock and sediment*
- *Cache samples on the surface for retrieval*

2



Sample Retrieval

- *Retrieve samples cached by Mars 2020 rover*
- *Launch samples into orbit around Mars*

3



Earth Return

- *Capture and contain samples in Mars orbit*
- *Safely return samples to Earth for recovery at landing site*

4



Sample Receiving

- *Transport contained samples to receiving facility*
- *Safety assessment and sample containment*
- *Initial sample science and curation*

**Long-term
Curation &
Science
Investigations
NASA/ESA**

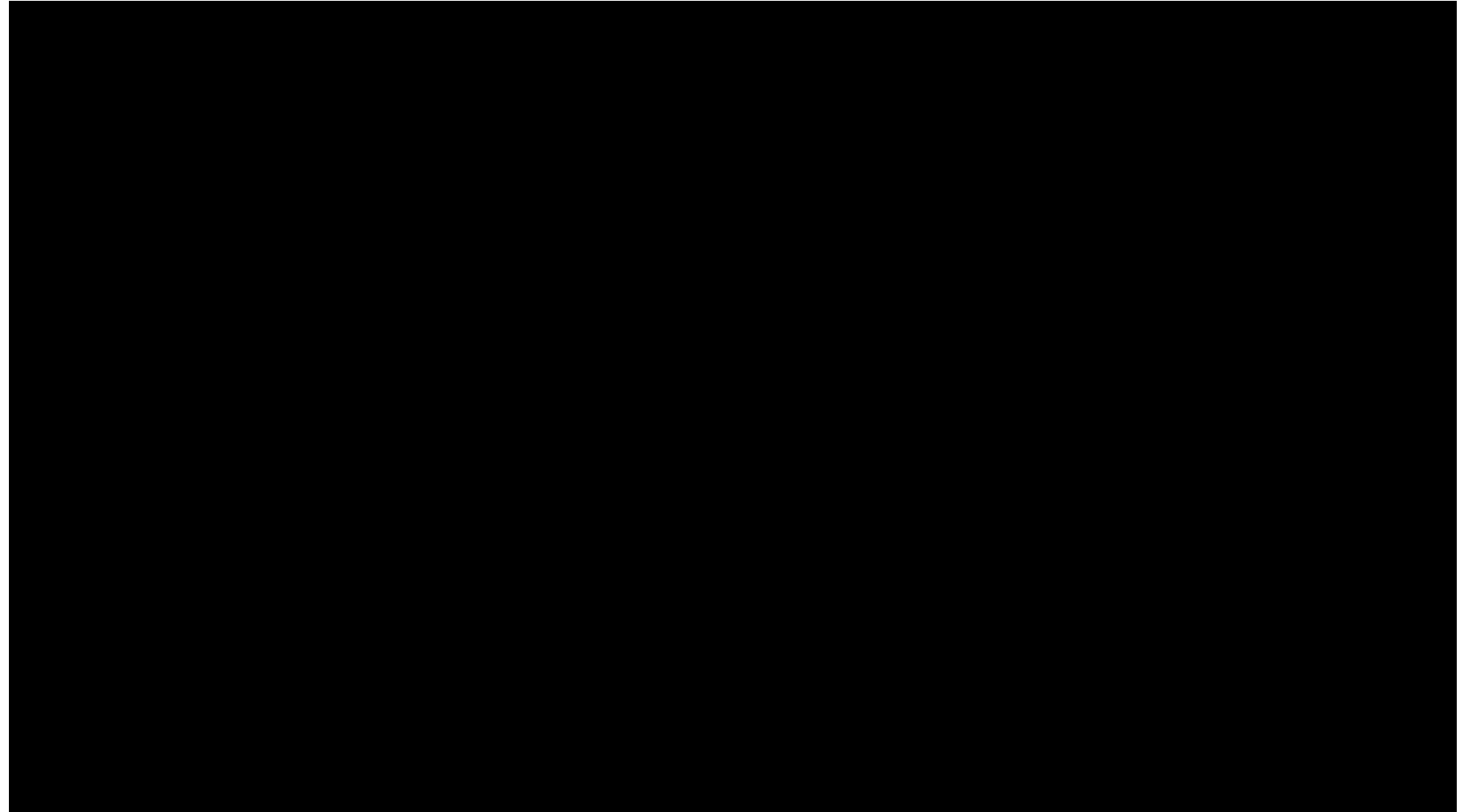
- The MSR Campaign spans flight elements and one ground element
- The MSR Program manages development and operations of Sample Retrieval and Earth Return and interfaces to Sample Caching and Sample Receiving; program concludes upon safe return at the landing site
- The MEP Program manages M2020 Phase E operations and is the home of the future Sample Receiving Project



Vertically Ejected Controlled Tip-Off Release (VECTOR)



- VECTOR is a pre-ignition separation mechanism for the Mars Ascent System (MAS)
- VECTOR provides a MAS separation state with a vertical velocity and pitch rate
- MAS ignition occurs a set time after separation within an established window that allows for successful flyaway





Earth Entry Vehicle

Manufacturing Demonstration Unit #1

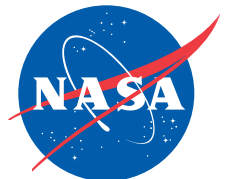
Drop Altitude: ~ 1000 ft

Terminal Velocity at impact: ~ 33 m/s / ~ 74 mph

Utah Test and Training Range – March 1, 2022

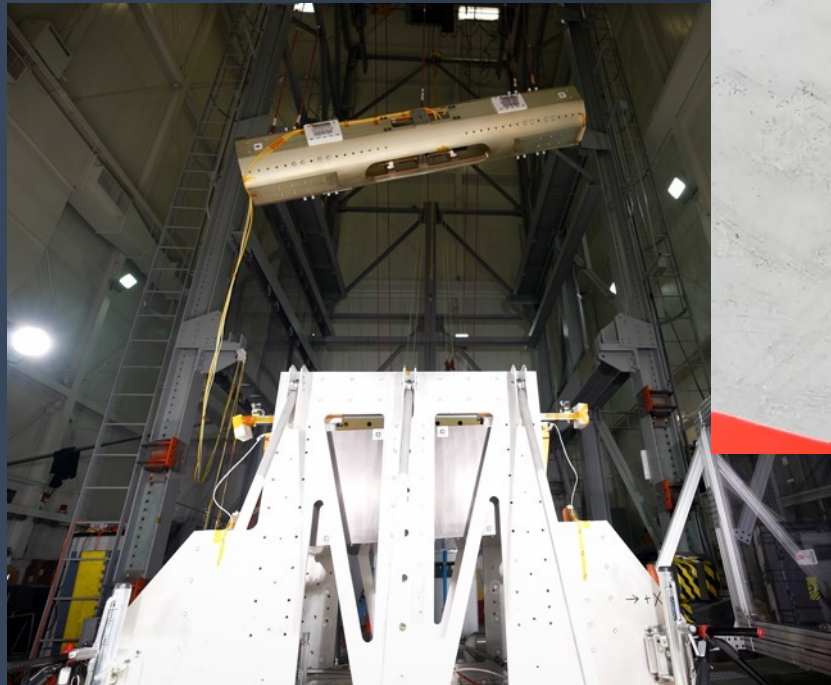


NASA / USAF Team Photo



Technology and Engineering Development Progress

Technology and engineering developments continue with progress on several prototypes



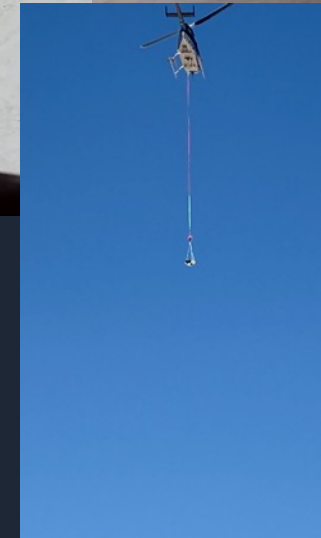
MAV VECTOR launch system



Earth Entry System Drop Test



Landing Legs





Phase A Accomplishments

- Primary trades: Single vs. Dual Lander architecture, need for MMRTG, launch dates
- Addressed pre-formulation architecture issues
 - CCRS rearchitected to establish viable on-orbit assembly approach
 - Established assurance case architecture for Back Planetary Protection to const
- Matured Key Technology/Engineering Development
 - Orbiting Sample transfer and containment assembly system
 - Aseptic sealing process via heated shrink fit
- Addressed Acquisition Risks
 - Simplified and consolidated NASA Center assignments
 - Established system level “buy” plans for MAV & EES Aeroshell
- Performed updated Perseverance Reliability Assessment
 - Reaffirms confidence in ability to support MSR surface mission operations
- Systems Requirement Review/Mission Design Review July 12th
 - Expect to enter Phase B early in FY’23



Summary

- This is the most significant planetary science undertaking in a generation
- Now is the time
 - Perseverance on surface of Mars collecting samples
 - Orbital Relay assets in place around Mars
 - European Partnership in place with substantial mission contributions
- Over the past three years, the NASA-ESA team has considered a broad set of implementation options and developed a feasible baseline concept
 - Key technologies and engineering developments have been matured
- Significant work remains, but the team is on track to launch the remaining flight elements in this decade



EXPLORE
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