National Aeronautics and
Space Administration

EXPLORE MARS

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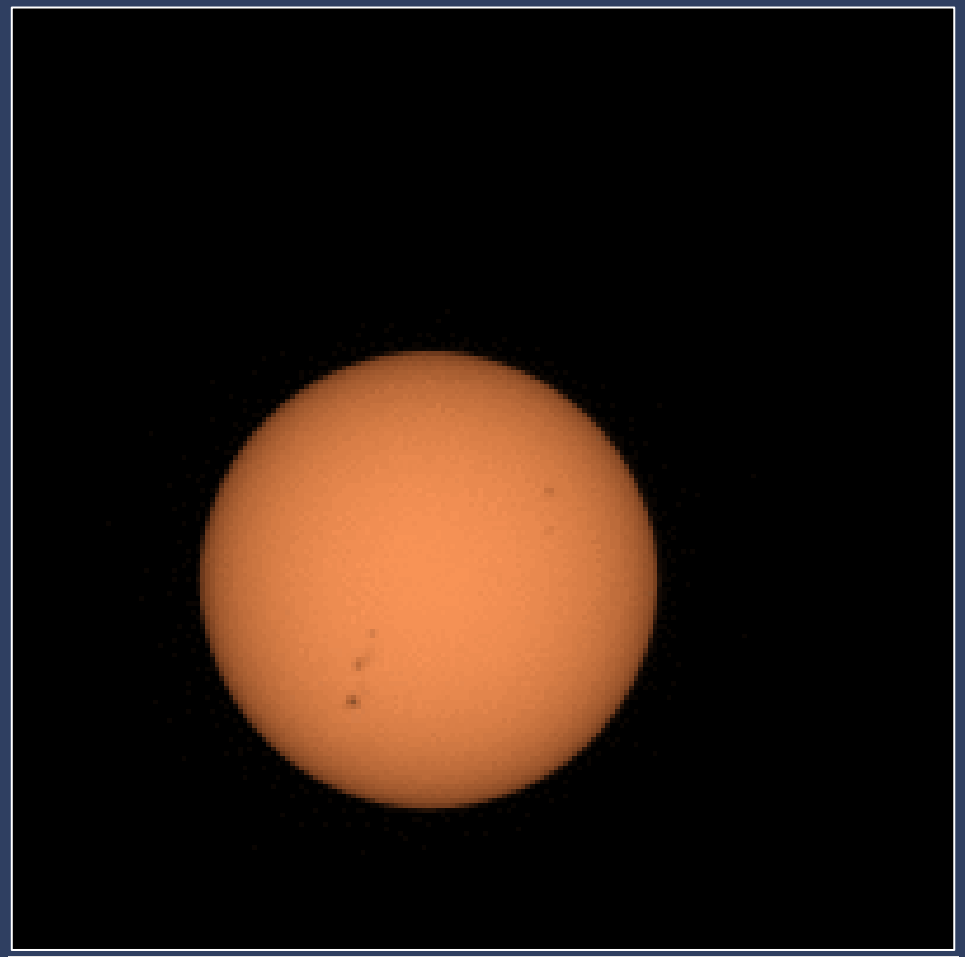
Mars Exploration Program Presentation to MEPAG
May 3, 2022

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 27 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
- 2022 Appropriation passed
- Successful MEP Program Implementation Review/KDP-III
- Planetary Science & Astrobiology Decadal Survey released
- 2023-2025 Senior Review Mission Extensions Announced: https://www.nasa.gov/feature/nasa-extends-exploration-for-8-planetary-science-missions



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

MEP Look-Ahead

Strategic Planning

- 90-day response to the Decadal
- Developing MEP Strategic Plan that considers Planetary Decadal, Mars Low-Cost workshop, MASWG report, other studies and factoring in budget expectations
- Strategic Planning Retreat (HQ/MEPO) in June

Events

- Science Objectives for Human Exploration of Mars Workshop – May 4-6, 2022
- Humans to Mars Summit – May 17-19, 2022
- Explore Mars' Achieving Mars IX Workshop – June 14-16, 2022

MEP Budget

2022 Appropriations Bill

- PSD budget more than the FY21 appropriation, but less than the FY22 PBR

2023 President's Budget Request

- Multi-year funding identified for Sample Receiving Project
  - Funding Sample Receiving Facility Assessment Studies
- International Mars Ice Mapper Mission Zeroed Out
- Funding for 4 MEP extended missions included:
  - Odyssey
  - MRO
  - MAVEN
  - MSL
- MEP will continue funding Ingenuity operations

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.

InSight (Principal Investigator: Dr. Bruce Banerdt, JPL)

Since landing on Mars in 2018, the Interior Exploration using Seismic Investigations, Geodesy and Heat Transport (InSight) mission has operated the only active seismic station beyond Earth. Its seismic monitoring of "marsquakes" has provided constraints on Mars' interior, formation, and current activity. The extended mission will continue InSight's seismic and weather monitoring if the spacecraft remains healthy. However, due to dust accumulation on its solar panels, InSight's electrical power production is low, and the mission is unlikely to continue operations for the duration of its current extended mission unless its solar panels are cleared by a passing 'dust devil' in Mars' atmosphere.

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 Propellent 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 expediting implementing All Stellar Mode (ASM) and will remain in Earth-nadir point until ASM ground testing verification completes
- Expect full recovery to nominal science and relay operations in ASM by the end of May; 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 is ending operations on May 7, 2022

Perseverance Odometer: 10789.679 meters*
Ingenuity Log: 27 flights, 6487 m, 3102.6 sec*
***April 25, 2022**

Mars2020

❖ **Power of AutoNav Perseverance set multi-sol plan record distance 528.673 m (Sol 404-405)**

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

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

Three Forks

Octavia E. Butler Landing Site

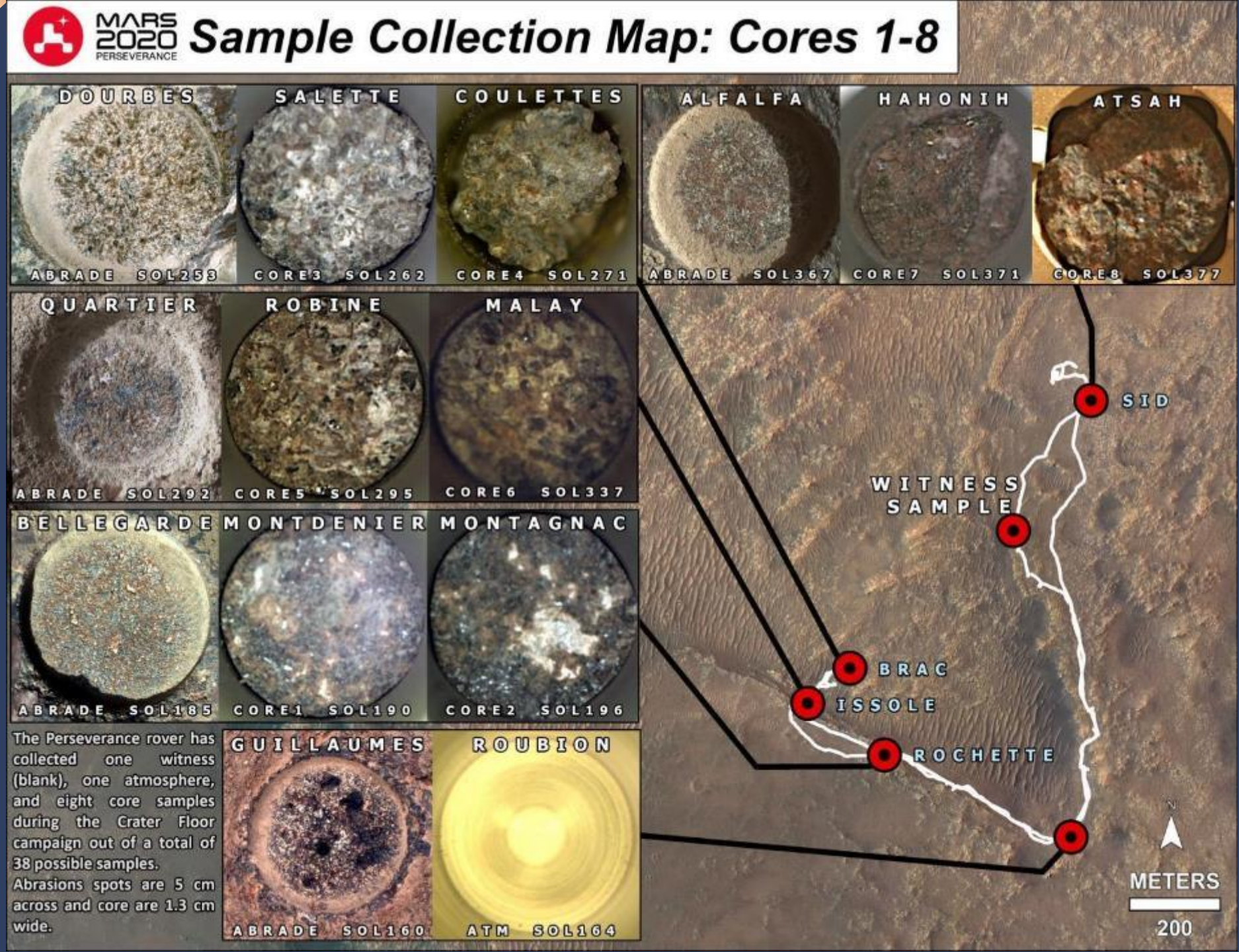
Crater Floor

Science Campaign Area

NASA's Perseverance Mars rover looks back at its wheel tracks on March 17, 2022, the 381st Martian day, or sol, of the mission. Credits: NASA/JPL-Caltech

Map Scale
0 200m 500m 1000m

Longitude, Latitude 77.47197915°, 18.45445308°



The Perseverance rover has collected one witness (blank), one atmosphere, and eight core samples during the Crater Floor campaign out of a total of 38 possible samples.
Abrasions spots are 5 cm across and core are 1.3 cm wide.

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 in May 2022

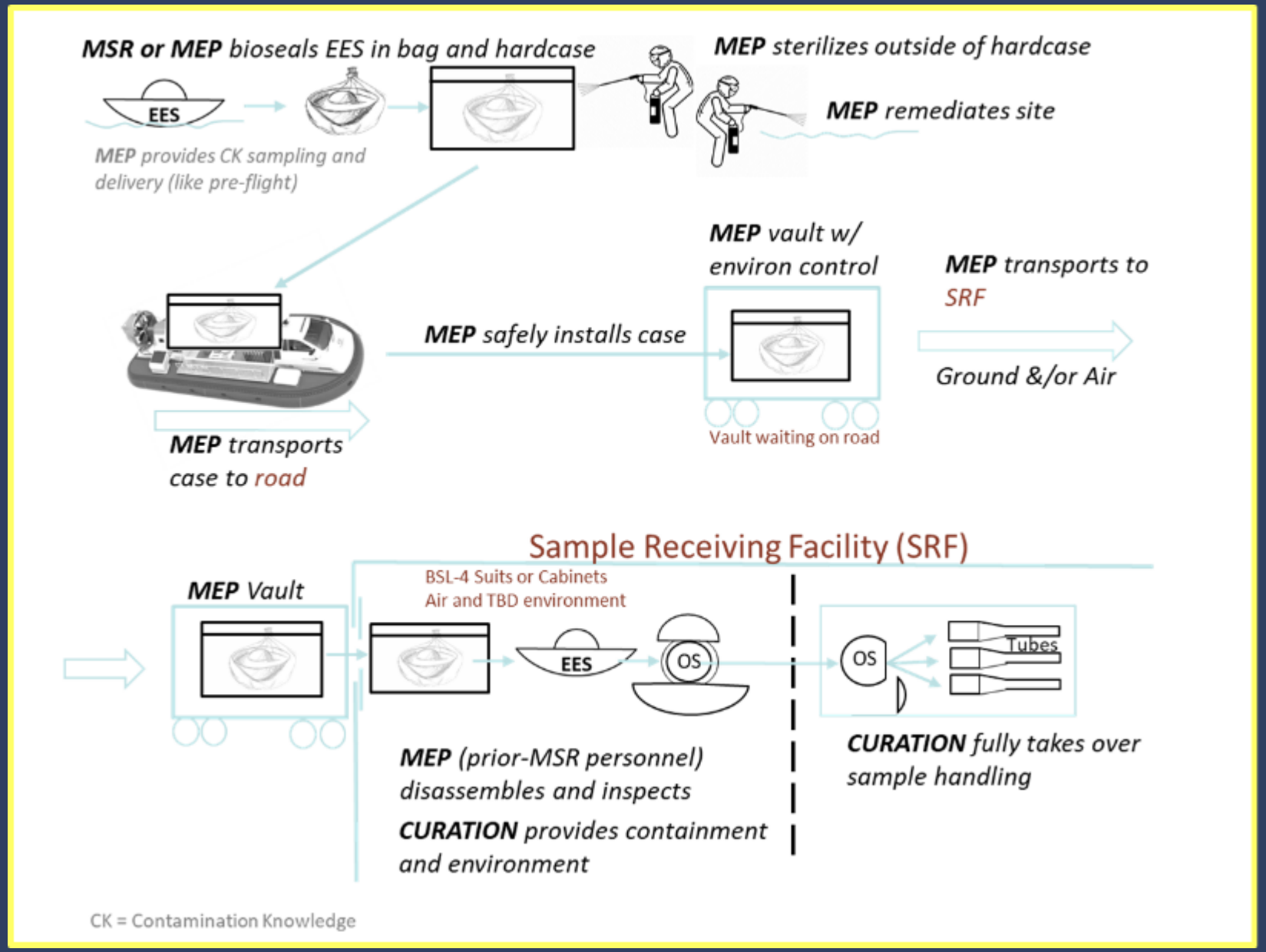
*Reconnaissance: "What we need to know before humans go"

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

Sample Receiving Project (SRP) Elements

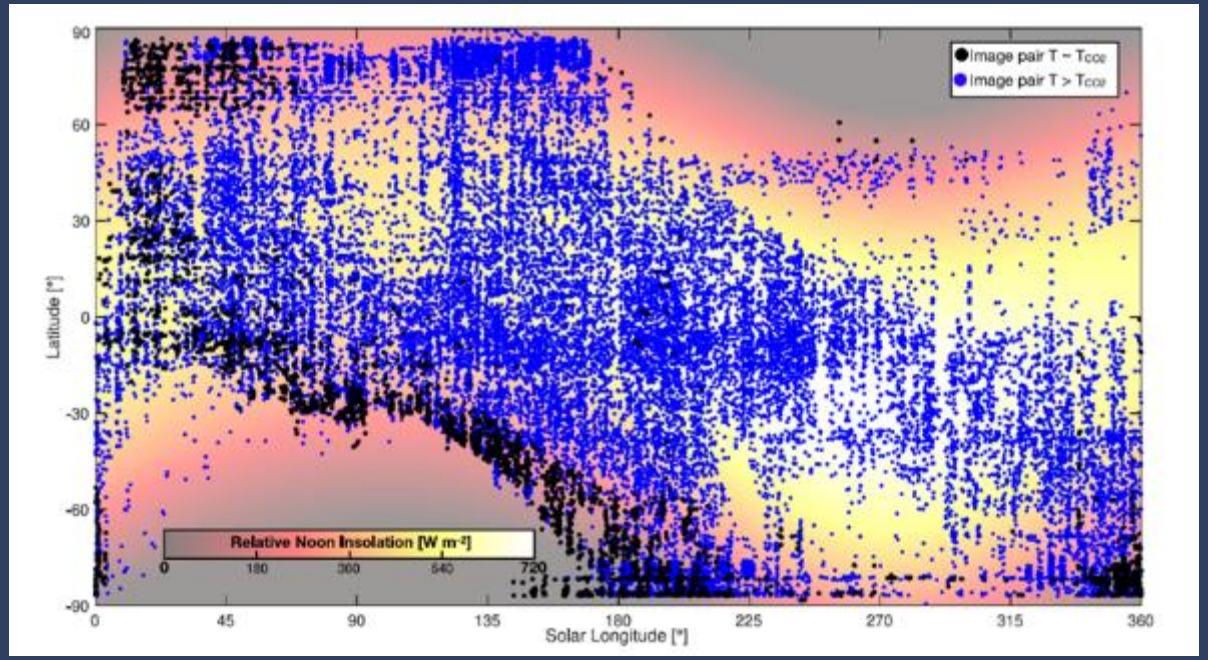


MSR Sample Receiving Project Status

- 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 Updates

- MAVEN mission and the United Arab Emirates' Emirates Mars Mission (EMM) Hope Probe established scientific collaboration to exchange data between the two orbiters
  - MAVEN & EMM explore different aspects of Mars atmosphere; combining data adds significant value to both missions and scientists performing analysis
- Solar Cycle 25 began 6 months earlier than predicted and is expected to peak in 2025. MAVEN observations during this period are important to understanding solar cycle impacts on the Martian atmosphere
- Lange et al., 2022 (JGR) searched thousands of dawn THEMIS VIS and IR pairs, discovering places where the surface was at the CO_2 frost point but no frost was visible. They concluded that frost mixes in with dust in these areas.
- Mars Data Analysis Program ROSES 2021
  - Announcement of selections in May



This figure shows places where there are overlapping THEMIS IR and VIS images taken near dawn.

MSR Sample Caching

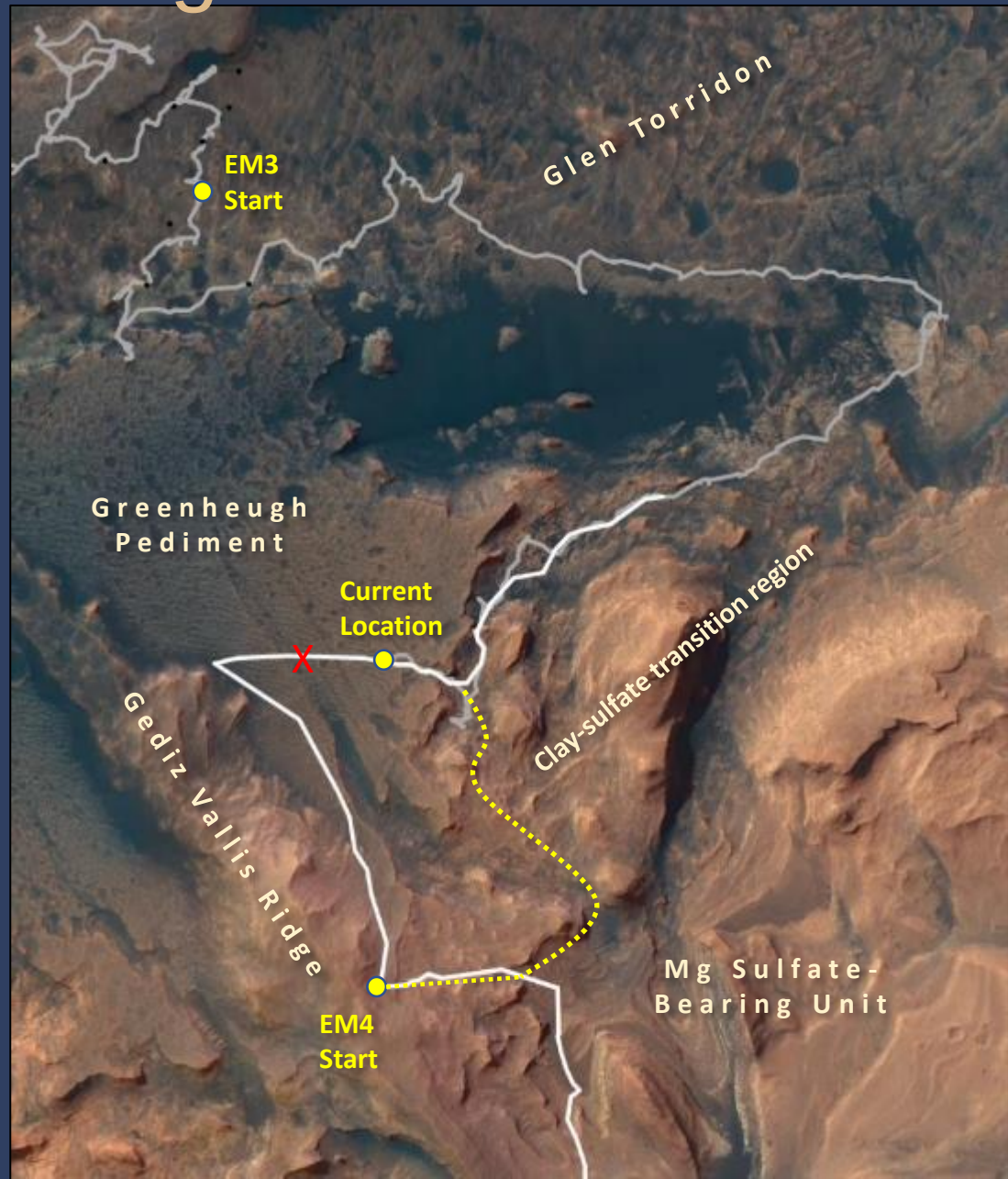
- MSR Campaign considering initial depot at Three Forks (Landing Strip)
  - Initial depot should be placed prior to reaching Perseverance design lifetime
  - Initial depot must be Scientifically Return-Worthy (SRW)

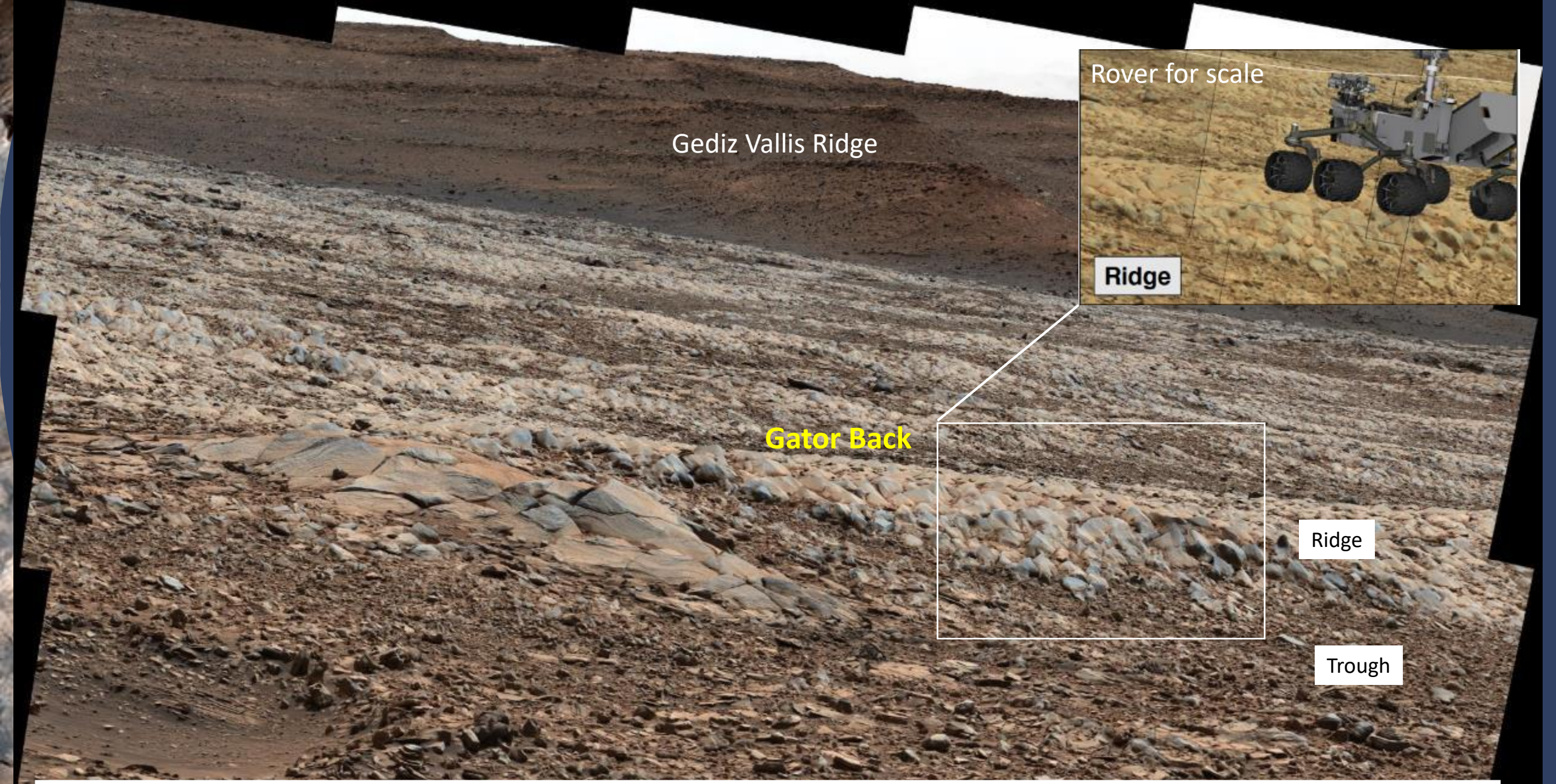
- The Three Forks area has the most benign terrain in the entire Jezero crater region
  - SRL landing site(s) and depot can be placed in close proximity
  - Reduces technical and programmatic risk
- Early placement of initial depot will have fewer samples than a depot near Belva Crater (tightly constrained landing sites)
- Sample Caching Workshop September 2022 to consider SRW sample cache

View of the Landing Strip from the NavCam April 14, 2022. Credits: NASA/JPL-Caltech

MSL Strategic Route Change

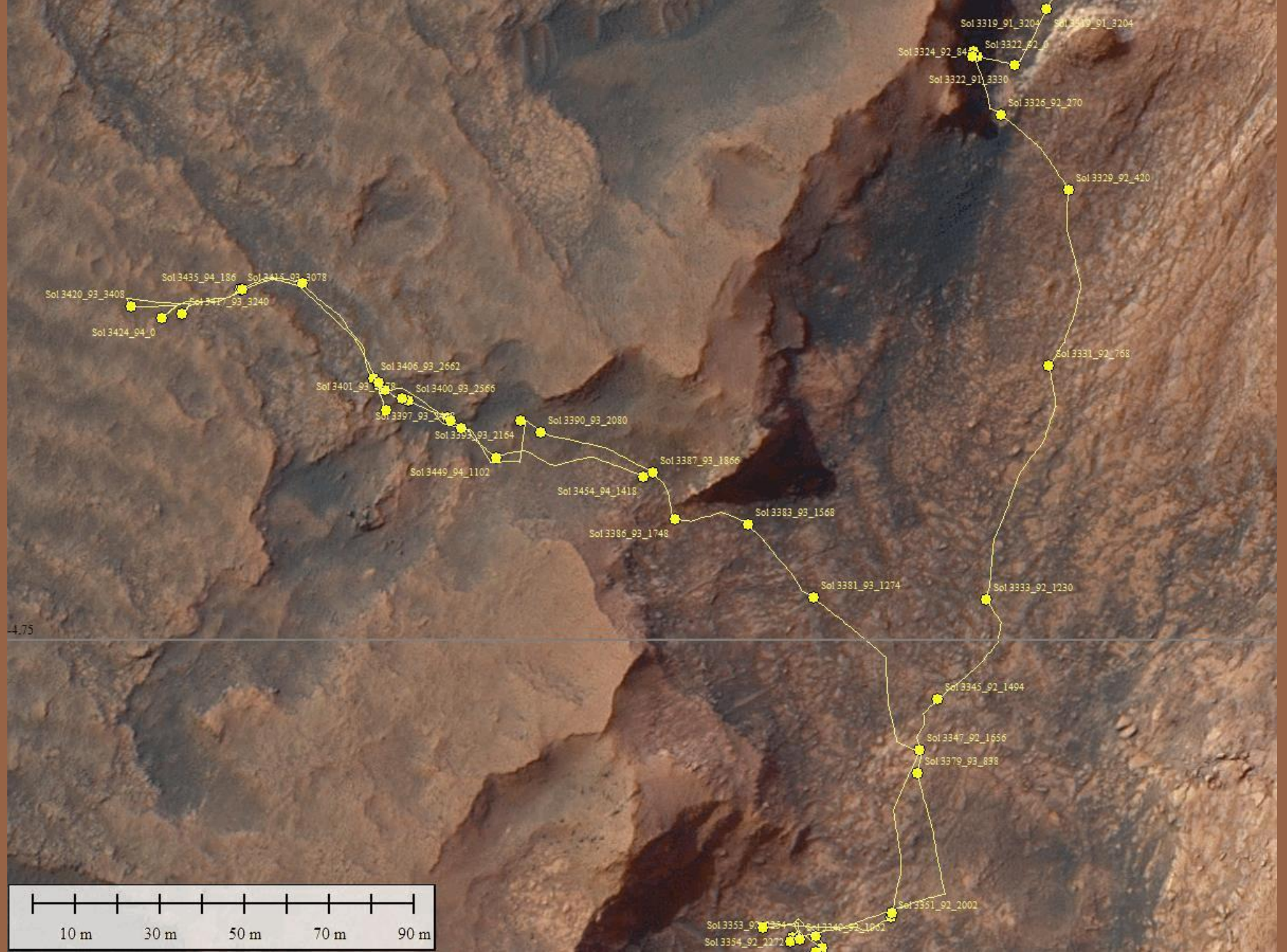
- Recent rover-based imaging of the surface of the Greenheugh pediment shows the terrain to be considerably rougher than anticipated from orbiter images
- Assessment by mobility and wheel wear experts determined that continuing onward would significantly increase rates of wheel wear and add risk to the mission due to challenges in steering, navigation, and faulting
- The Gediz Vallis (GV) ridge may contain the youngest evidence for fluid-driven deposition accessible to Curiosity (along solid white line)
- The route change prevents the highest-resolution images of the northern GV ridge but allows longer-range imaging from the current location.
- The alternative route (yellow dotted) allows the team to extend the investigation of the clay-sulfate transition region for ~80 vertical meters





The upper pediment surface, particularly the ridges that form the washboard-like pattern visible from orbit, is covered by cemented sandstone blocks sharpened by abrasion from wind-blown sand, presenting a significant risk to traversability, including wheel wear and steering. There is no way to reach Gediz Vallis Ridge (~500 m away) without crossing dozens of these ridges.

sol03415_ML_101646_workspace_extension_7x2_L0_PM.png


Sol 3319_91_3204
Sol 3324_92_84
Sol 3322_91_3330
Sol 3326_92_270
Sol 3329_92_420
Sol 3331_92_768
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Sol 3345_92_1494
Sol 3347_92_1656
Sol 3379_93_838
Sol 3351_92_2002
Sol 3435_94_186
Sol 3420_93_3408
Sol 3424_94_0
Sol 3406_93_2662
Sol 3400_93_2566
Sol 3390_93_2080
Sol 3387_93_1866
Sol 3449_94_1102
Sol 3454_94_1418
Sol 3383_93_1568
Sol 3386_93_1748
Sol 3381_93_1274
10 m
30 m
50 m
70 m
90 m

Curiosity: Working through Challenging Terrain of Rocks and Sand

This image was taken by Right Navigation Camera onboard NASA's Mars rover Curiosity on Sol 3447. Credits: NASA/JPL-Caltech.

NASA's Mars rover Curiosity acquired this image using its Mars Hand Lens Imager (MAHLI), located on the turret at the end of the rover's robotic arm, on April 17, 2022, Sol 3447 of the Mars Science Laboratory Mission, at 23:50:10 UTC.

NASA's Mars rover Curiosity acquired this image using its Mars Hand Lens Imager (MAHLI), located on the turret at the end of the rover's robotic arm, on April 17, 2022, Sol 3447 of the Mars Science Laboratory Mission, at 23:48:42 UTC.

https://mars.nasa.gov/msl/mission-updates/9171/sols-3449-3450-comin-down-the-mountain/


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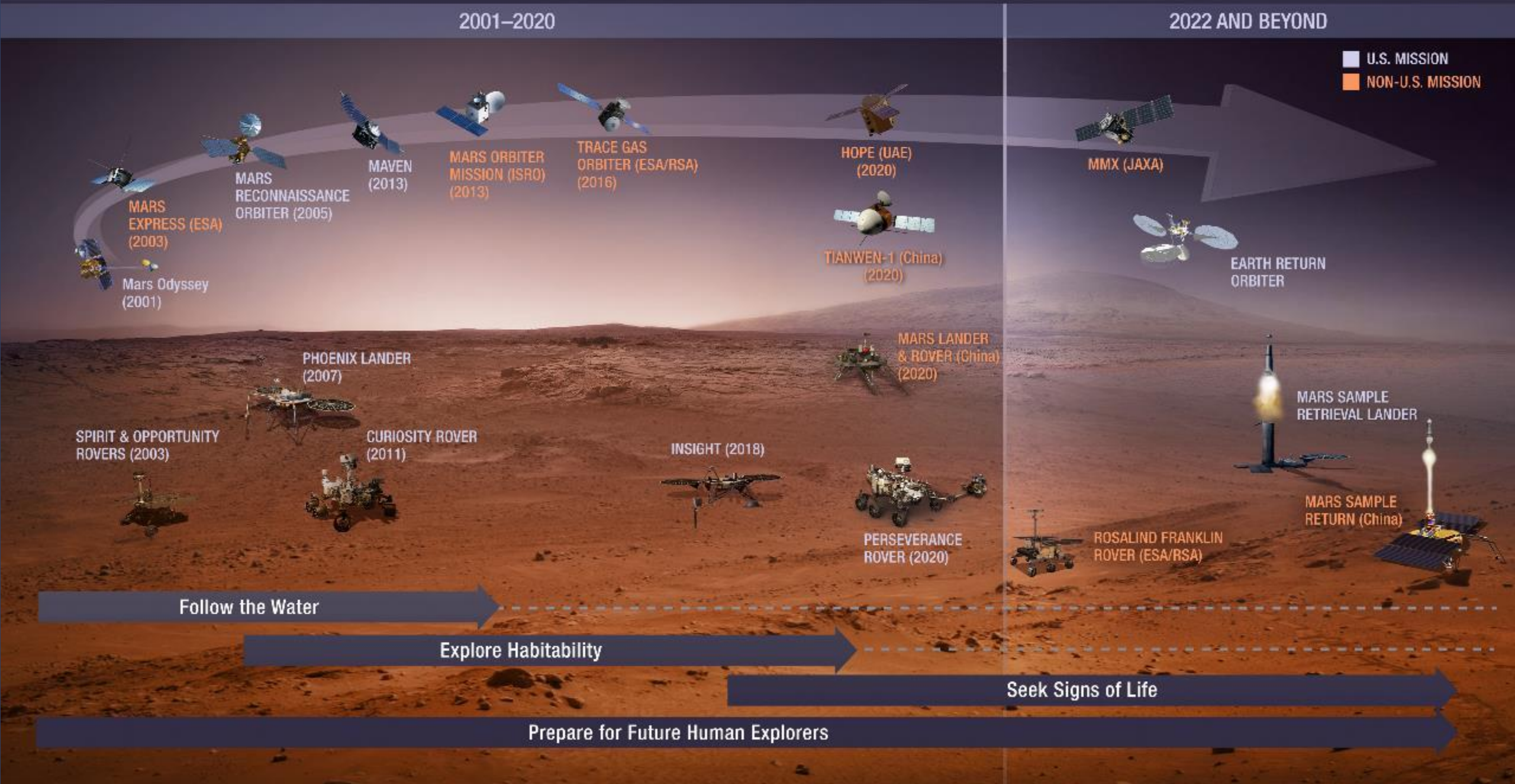
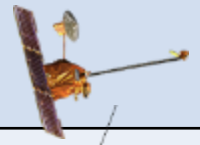
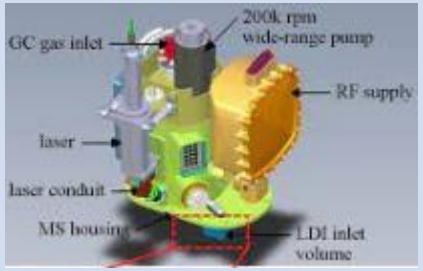
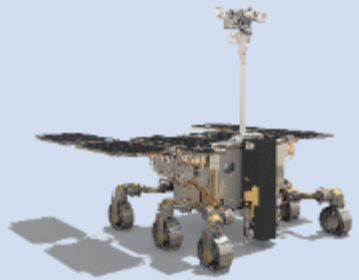
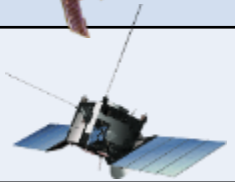
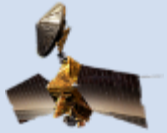
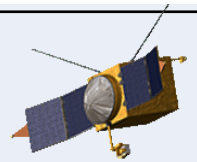
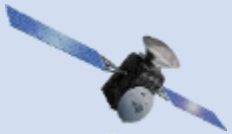
with us


2001–2020
2022 AND BEYOND
U.S. MISSION
NON-U.S. MISSION
MARS EXPRESS (ESA) (2003)
MARS RECONNAISSANCE ORBITER (2005)
MAVEN (2013)
MARS ORBITER MISSION (ISRO) (2013)
TRACE GAS ORBITER (ESA/RSA) (2016)
HOPE (UAE) (2020)
MMX (JAXA)
Mars Odyssey (2001)
TIANWEN-1 (China) (2020)
EARTH RETURN ORBITER
MARS LANDER & ROVER (China) (2020)
PHOENIX LANDER (2007)
MARS SAMPLE RETRIEVAL LANDER
SPIRIT & OPPORTUNITY ROVERS (2003)
CURIOSITY ROVER (2011)
INSIGHT (2018)
MARS SAMPLE RETURN (China)
PERSEVERANCE ROVER (2020)
ROSALIND FRANKLIN ROVER (ESA/RSA)
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 		
Mars Reconnaissance Orbiter 		
Mars Science Laboratory Curiosity 		Sample Receiving Project 
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 	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.
MEX 	Some onboard memory issues persist. Fuel load extremely low and uncertain. Available for emergency relay services for NASA’s landed assets.
MRO 	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.
MAVEN 	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
TGO 	Relay services expected to remain viable well beyond 2030. Presently returning >50% of relay data from NASA’s landed assets.

Sample Receiving Project (SRP) Facility Options

Traditional Fixed – Brick and Mortar

Utilize an Existing BSL-4 Facility

Modular Construction

modular + *constructed annex* @ *existing BSL-4*