National Aeronautics and Space Administration

EXPLORE MARS

Michael Meyer
Lead Mars Scientist

NASA Planetary Science Advisory Committee (PAC) Meeting
December 2022

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.

Belva

Mars2020

Perseverance Odometer: 13.68 km*
Ingenuity Log: 34 flights, 7392.0 m, 3539 s*
***November 30, 2022**

Delta Top Campaign Area

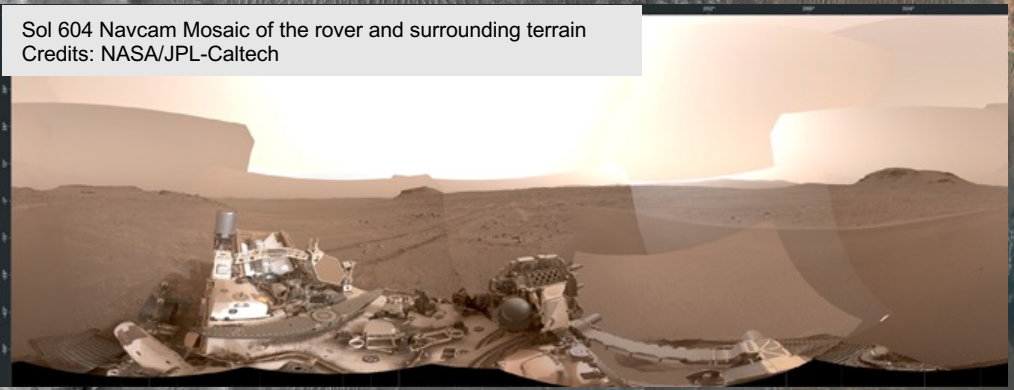
Delta Front Campaign Area

Three Forks

Octavia E. Butler Landing Site

Crater Floor Science Campaign Area

Sol 604 Navcam Mosaic of the rover and surrounding terrain
Credits: NASA/JPL-Caltech



Mars2020 Perseverance

Perseverance set to deploy the Three Forks Cache!

- Perseverance will discontinue paired sampling and retain all acquired samples onboard after the initial depot placed
- After Three Forks cache deposited, Perseverance plans to ascend the delta front and begin the Delta Top Campaign
- Perseverance Prime Mission ends Jan 6, 2023

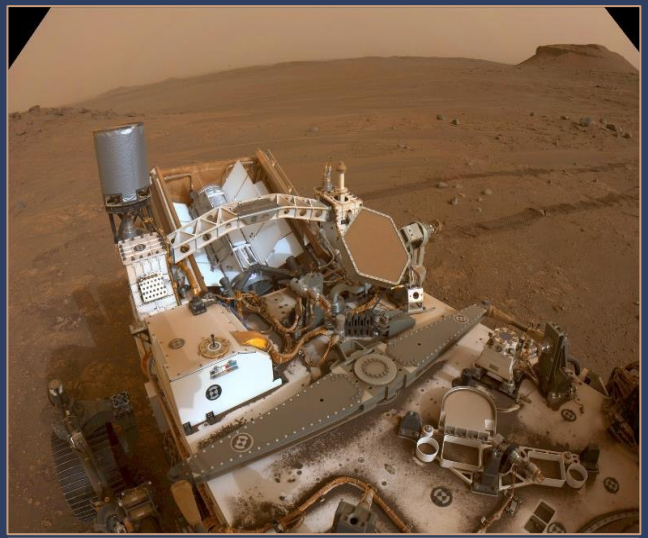
Future Perseverance Campaign Plans

Inside Jezero (2024)

- Crater Margin Campaign: possible lake shoreline carbonates
- Jezero crater rim: possibly deep crustal rocks; possible hydrothermal systems and alteration, rim ascent

Beyond Jezero (2025-2029)

- Fundamentally different geologic environment from crater interior
- Nili Planum: impact megabreccia from both Jezero and Isidis; ancient crustal rocks, aqueously altered basement

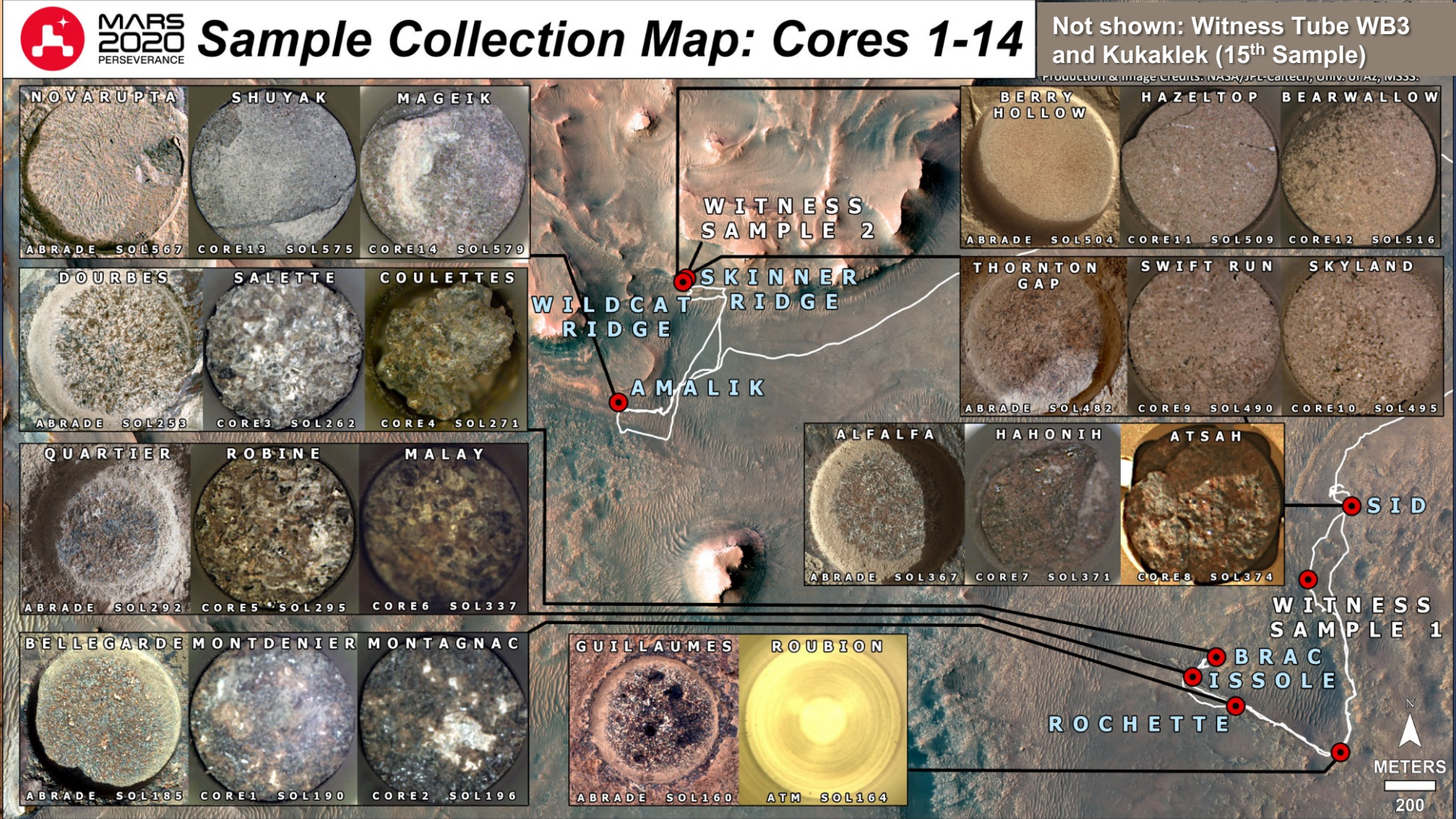


Sol 593 Navcam image showing rover deck, Kodiak (top right) and rover tracks. Credits: NASA/JPL-Caltech/ASU.

Sample Collection Map: Cores 1-14

MARS 2020 PERSEVERANCE

Not shown: Witness Tube WB3 and Kukaklek (15th Sample)



Mars2020 Ingenuity

Completed 34 successful flights!

As of November 29, 2022

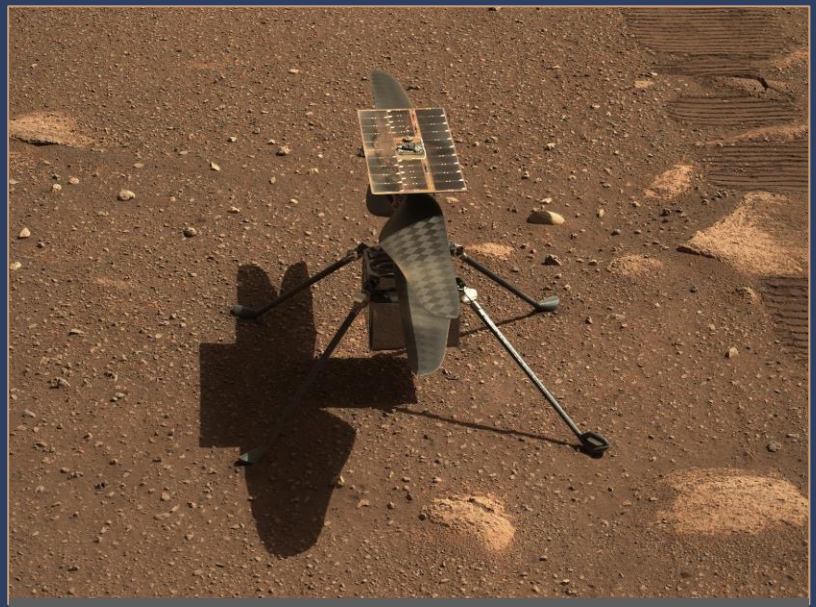
- 7,392 meters flown, lifetime
- ~59 min Flight time, lifetime

Survived 101 Martian sols of winter

- Flight 29 occurred June 11, 2022; Flight 30 occurred August 20, 2022
- Grounded because the solar-power wasn't getting enough sunlight to keep the batteries charged both day and night

Flight 34 validated installation and operation of new major software upgrade

- New software capabilities include hazard avoidance when landing and use of digital elevation maps to help navigate
- 18 sec flight with 5-meter hover



NASA's Ingenuity Mars helicopter is seen here in a close-up taken by Mastcam-Z, a pair of zoomable cameras aboard the Perseverance rover. This image was taken on April 5, the 45th Martian day, or sol, of the mission. Credits: NASA/JPL-Caltech/ASU.

Sample Receiving Project Status

Sample receiving facility modality study

- 30% draft reports from A&E contractors optimized strategies for utilizing existing BSL-4 facilities
- 80% draft reports due in December 2022
- Study tracking to completion in mid-2023

NEPA Environmental Impact Statement

- Developing work scope and schedule dependencies

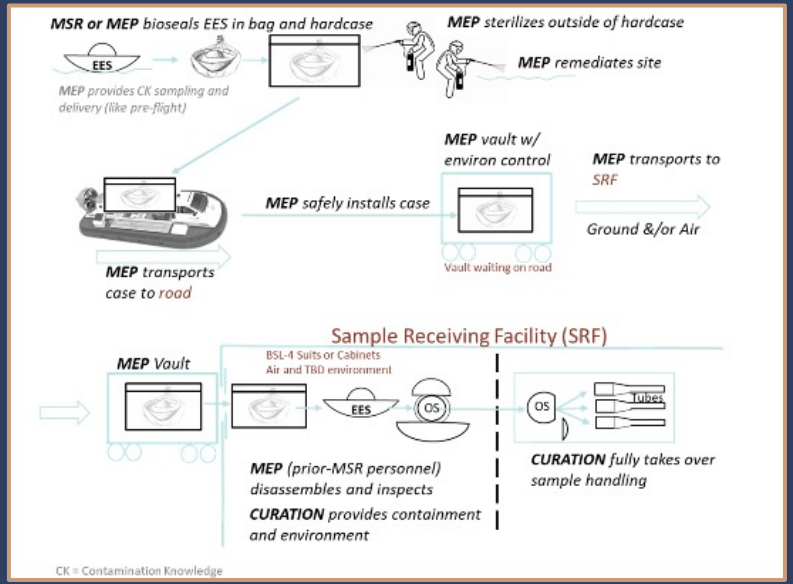
Returned Sample Safety Assessment

- Program personnel working with scientific teams, policy and Planetary Protection Office to establish implementation of sample safety assessment framework that ensures safety and enables expeditious distribution to the scientific community

ESA Collaboration

- Integrating ESA science and curation personnel into SRP team
- Sample and facility governance model assessment in progress

The SRP is the final element of the Mars Sample Return (MSR) Campaign that has a defined mission to recover, contain, transport, assess safety of, curate and scientifically investigate the samples returned to Earth by MSR.
Primary Goal: Enable safe and rapid release of the returned samples to world-wide labs for science investigations



Mars Science Laboratory (MSL) Curiosity

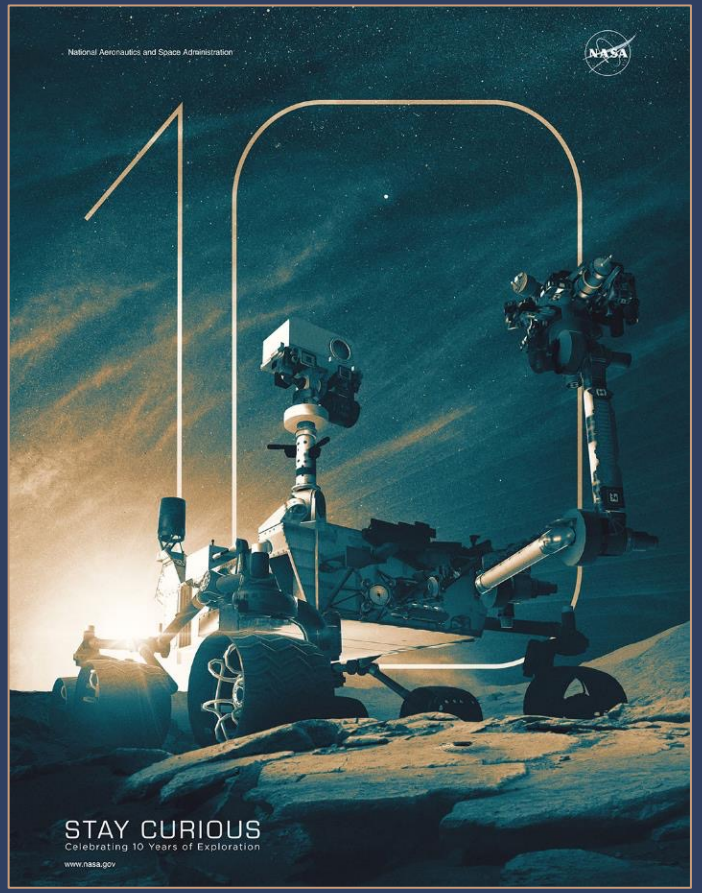
Curiosity celebrated 10 years on Mars on August 5, 2022!

- Driven over 17.5 miles (28 kilometers) and gained over 2,000-foot (600 meters) of elevation
- All science instruments performing as well as when Curiosity landed
- Analyzed 41 rock and soil samples; 36 drill holes
- Determined that liquid water as well as the chemical building blocks needed for supporting life were present for at least tens of millions of years in Gale Crater

Curiosity arrived at “sulfate-bearing unit” at Mount Sharp

- Scientifically compelling region enriched with salty minerals
- Residual salty minerals could indicate streams and ponds that dried up billions of years ago
- Navigated treacherous terrain of sharp rocks and sand to reach the region

New MSL Project Manager named: Kathya Zamora-Garcia of NASA’s Jet Propulsion Laboratory



MEP Orbiters

Mars Relay Network (MRN)

- MEP successfully managing network activities with aging orbiters that are well into their extended missions
- MRN Health Assessment conducted in July 2022; Only 1 asset (ESA's TGO) expected to be viable into mid-2030

Odyssey

- Results of propellant investigation (depletion prediction) expected in early December 2022
- Project began its 9th extended mission in October 2022

MAVEN

- Established scientific collaboration with United Arab Emirates' Emirates Mars Mission (EMM) Hope Probe to exchange data between the two orbiters; significant value to missions and scientists performing analysis
- Project began its 5th extended mission in October 2022

ExoMars/TGO

- Continuing to support relay operations for MEP; returning >50% relay data of landed assets

MRO

- 2 recent safe mode events (Oct & Nov 2022) successfully recovered
- MRO experiencing approximately 3 safe mode events per year since 2020; no root cause, but events associated with Galactic Cosmic Radiation maxima
- Project began its 6th extended mission in October 2022

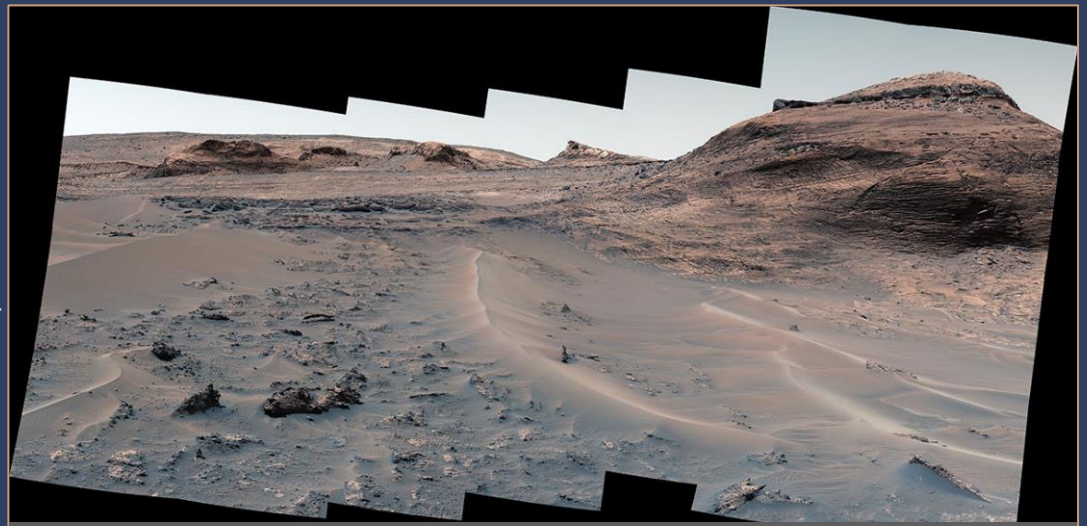
MEP International Collaboration

NASA Considering Potential Collaboration on ESA's ExoMars Rosalind Franklin Rover Mission

- ESA Ministerial approved 17% increase for overall ESA 2023-2025 budget
- Approved ESA budget includes funds to implement a renewed ExoMars/Rosalind Franklin mission; assumes NASA participation
- NASA participation subject to the availability of U.S. funding
- NASA and ESA are holding key conversations on the potential collaboration December 6-8, 2022

Mars Exploration Program Challenges

- Budget constraints while:
  - Executing Mars Sample Return is the highest science priority in the next decade
  - NASA's support to ESA's ExoMars Rosalind Franklin Mission
  - Commitment to Artemis is a central near-term strategy in the nation's Moon to Mars ambitions
- Mars Relay Network orbiters are aging, and not expected to last past ~2030, having already lived far past their original estimated lifetimes



October 19, 2022 NASA's Curiosity Mars rover used its Mast Camera, or Mastcam, to capture this panorama of a hill nicknamed "Bolivar" and adjacent sand ridges on Aug. 23, 2022, the 3,572nd Martian day, or sol, of the mission. This panorama was stitched together from 23 images once they were sent back to Earth. The color has been adjusted to match the lighting conditions as the human eye would perceive them on Earth.

- Steeper requirements for next steps in Mars exploration:
  - Replenishable networks of orbital and landed assets for systems science
  - Closing strategic knowledge gaps to support planning for a sustained human-robotic presence on Mars

Mars Exploration Program Strategy

The Mars Exploration Program (MEP) is developing a strategy that considers:

- Revalidating/updating MEP Science Objectives
- Refreshing communication and imaging infrastructure at Mars
- Defining technology investment priorities that map to science objectives
- Utilizing low-cost initiatives to meet science priorities
- Exploring airborne missions (helicopters, balloons, etc.) to advance science
- Leveraging collaborations – commercial and international partners
- Capitalizing on rideshare opportunities
- Establishing synergies with human exploration of Mars (prepare for, and science operations)
- Inspiring current and future generations to explore space

Program Science Goals:

- Search for past and present microbial life and habitable environments
- Discover dynamic Mars (system science of geologic and climatological processes)
- Advance human exploration of Mars

Mars Exploration Program Strategy

Strategy Development Events

• MEPO & HQ Strategic Planning Retreat #1	Dec 1-3, 2021
• Low-Cost Science Mission Concepts for Mars Exploration	Mar 29-31, 2022
• Science Objectives for Human Exploration of Mars Workshop	May 4-6, 2022
• MEPO & HQ Strategic Planning Retreat #2	Jun 22-23, 2022
• In-Person International Mars Exploration Working Group	Sep 14-16, 2022
• Industry Day	Oct 18-19, 2022
• MCE-SAG Report to MEP	Oct 27, 2022
• MEPO & HQ Strategic Planning Retreat #3	Nov 1-3, 2022

Strategy Development Timeline

• Draft Strategy Overview	Jan 2023
• Draft MEP Strategic Plan	Feb 2023
• Stakeholder Review & Comment	March 2023
• Finalize Strategy and build into MEP budget planning	Spring 2023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Mars Sample Return Program

Planetary Advisory Committee
December 5, 2022

Jeff Gramling, Director, MSR Program

Michael Meyer, Mars Lead Scientist

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.

Mars Sample Return mission architecture is designed to safely bring scientifically selected samples to Earth for study using the most advanced laboratory instruments—those that will exist in the coming decade and those in the decades that follow

- The campaign is designed around the ability to go where the science takes us, to facilitate bringing back the most valuable samples
- The architecture is complex and optimized to reduce development risk while ensuring scientific integrity of the samples

"The highest scientific priority of NASA's robotic exploration efforts this decade should be completion of Mars Sample Return as soon as is practicably possible with no increase or decrease in its current scope"

-- Origins, Worlds, and Life - A Decadal Strategy for Planetary Science and Astrobiology 2023-2032 (April 2022)

THE WHY? What Makes MSR so Valuable?

Four powerful technical advantages:

Access to sophisticated sample preparation

Organic prep. pathways

- *Reduces detection limits (by orders of magnitude)*
- *Improves precision*
- *Greater accuracy*
- *Required for many instruments*

Multiple, diverse, and large instruments that cannot be miniaturized

- *Opportunity to make confirming measurements using multiple methods*
- *"Gift that keeps on giving" – analysis by future instruments*
- *"Extraordinary claims require extraordinary evidence"*

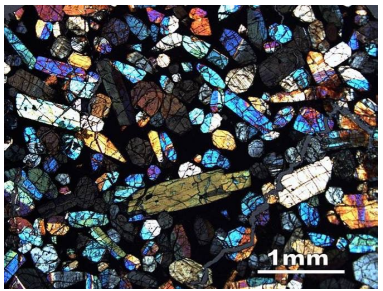
SEM

Discovery-responsive investigation pathways

- *Answers to early questions change choice/design of later experiments*

Thin section

Greatly improves spatial focus/resolution



Mars meteorite

- *For evaluating microbial life, microscopic scale is crucial*
- *Access to small grains crucial*

MSR Campaign & Program

- The MSR Campaign spans multiple launches and one ground element.
- The MSR Program manages development and operations of elements 2 and 3 and interfaces to elements 1 and 4.
- MSR Program concludes after recovery/containment of samples and transfer to a sample receiving facility.
- The Mars Exploration Program manages M2020 Phase E operations & the Sample Receiving Project (SRP) and would assume lead responsibility for recovery & containment of samples upon Earth landing.

Mars Sample Return Program

1

Mars 2020 Sample Caching

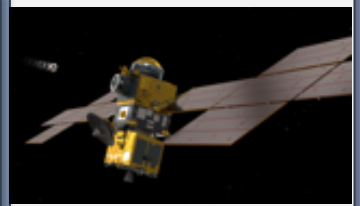
- *Collect samples of rock, regolith, and atmosphere*
- *Cache samples on the surface for retrieval*

2

Sample Retrieval Lander (SRL)

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

3



Earth Return Orbiter (ERO)

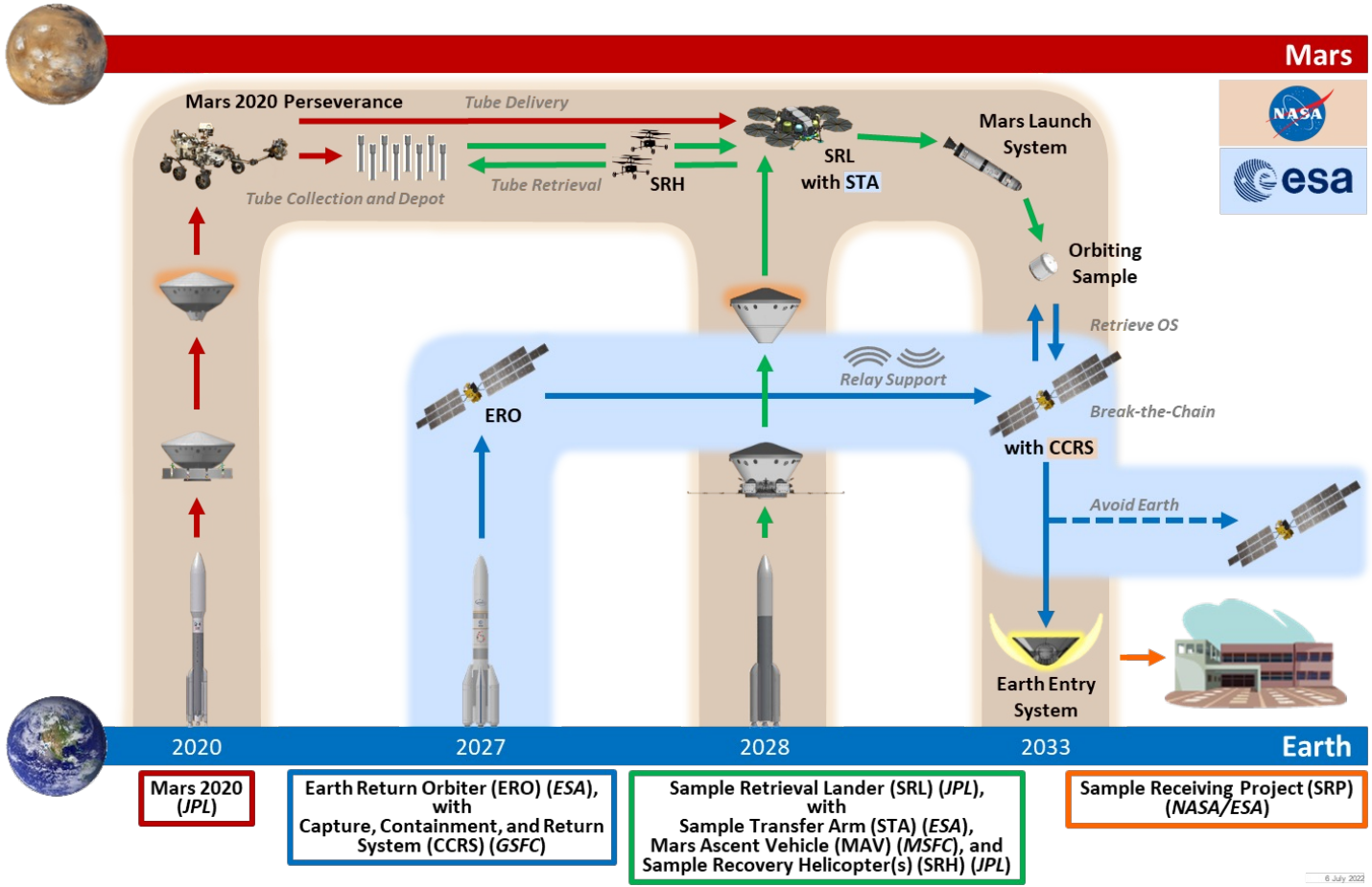
- *Capture and contain samples in Mars orbit*
- *Safely return samples to Earth for recovery at landing site*

4

Sample Receiving Project

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

Program Architecture (Updated)



Mars Sample Return Animation Video

https://mars.nasa.gov/msr/multimedia/videos/?v=523

Sample Recovery Helicopter (SRH)

Draft Top-Level Requirements:

- Accommodate two helicopters on SRL; to be used in the event Perseverance is unable to deliver samples directly to SRL
- Planned helicopter use case is recovery of 10 samples from the Three Forks surface cache
- Helicopters required to be capable of operating at elevations up to Jezero crater rim, including planned regions for Perseverance extended science mission.

Proposed Approach

- Maximize Ingenuity rotor/airframe heritage
- Add capability for sample recovery/transport to SRL

Key Challenges

- Mass
  - Testing ongoing in Winter ’22/’23 to validate flight envelope changes
- New capabilities (mobility, gripper)
- Schedule
  - Mission Concept Review conducted, June ‘22
  - System Requirements Review / Implementation Review Spring ’23

MSR Depot Strategy Overview

The initial depot is intended to be a risk mitigation against possible Perseverance catastrophic failure or major degradation (e.g., loss of mobility, loss of ability to drop tubes).

Guideline established in MSR-MEP/M2020 Conops Agreement that the first depot should be placed prior to reaching Perseverance qualified lifetime (1.5 Mars years; 20 km traverse distance)

First depot must be scientifically return-worthy (SRW)

- Science community workshop conducted on September 28th & 30th to help establish what constitutes a scientifically return-worthy sample cache
- Expected sample suite of 10 sample tubes consisting of 7 core samples, 1 regolith, 1 atmosphere, and 1 witness tube
- From each core sample pair, one sample will be placed in the initial depot, and the other sample will be retained onboard Perseverance

After placement of the initial depot, Perseverance will discontinue paired sampling and retain all acquired samples onboard until delivery to the Sample Retrieval Lander (SRL)

In the event of a degradation in Perseverance's state of health that threatens the ability to directly deliver samples to SRL, establishment of a second surface depot would be considered

MSR Campaign will select the target landing location during cruise

- Possible divert to first depot location in the event of a Perseverance failure late in cruise phase

A Joint ESA-NASA MSR Campaign Science Group (MCSG) has been established and a Science MOU signed

Phase 1 Participants

Co-Chairs


Michael Meyer

Gerhard Kminek

Joint Science Office


Dave Beaty


Elliot Sefton-Nash


Brandi Carrier


Fiona Thiessen


Tim Haltigin

Selected Members


Audrey Bouvier


Andy Czaja


Nicholas Dauphas

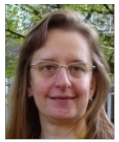

Kate French


Lydia Hallis


Rachel Harris


Ernst Hauber


Laura Rodriguez


Susanne Schwenzer


Andrew Steele


Kim Tait


Michael Thorpe


Tomo Usui


Jessica Vanhomwegen


Michael Velbel


Maria-Paz Zorzano

Ex Officio


Sam Edwin


Ken Farley


Danny Glavin


Andi Harrington


Lindsay Hays


Aurore Hutzler


Mini Wadhwa

The **MSR Campaign Science Group** will be implemented in two phases as the Campaign transitions from ensuring sample integrity to planning and guiding the investigations of the samples

- Openly competed and jointly selected.
- Phase 1: Focus on Campaign science and sample integrity planning, developing ground-based infrastructure, and science community engagement
- Phase 2: Focus on the implementation of the objective-driven science

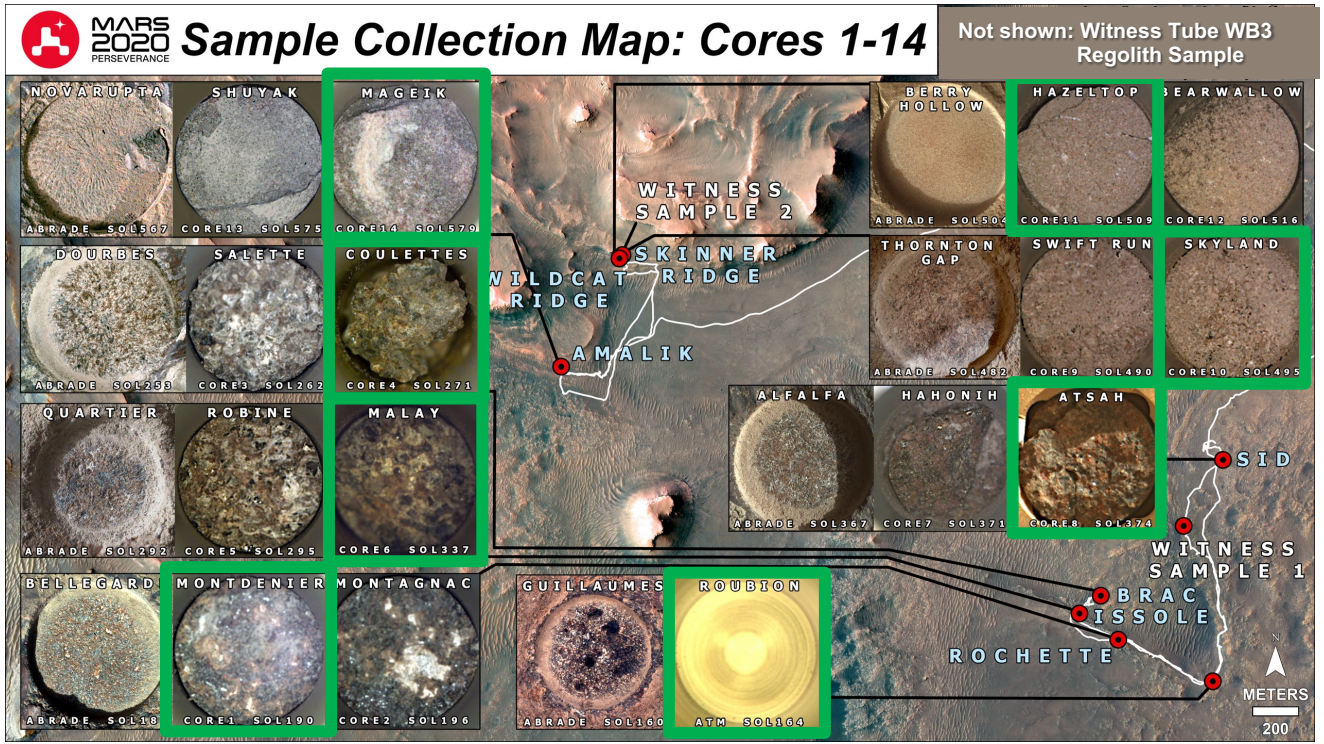
The **NASA-ESA Science Memorandum of Understanding (MOU)** is an agreement between agencies codifying our intended science collaboration.
Signed Nov. 7, 2022

Mars 2020 / MSR Sample Depot Science Community Workshop

- The open **Mars 2020/MSR Sample Depot Science Community Workshop** solicited input from the science community on the potential for the samples in the proposed depot to meet MSR's science objectives.
  - Organized by the MSR Campaign Science Group (MCSG)
  - Pre-workshop information sent out September 21, 2022
  - Workshop held over a two non-consecutive days, September 28 & 30, 2022
  - A maximum of 189 individual/group attendees (total unique individuals not tracked)
  - Feedback was accepted throughout all three days, facilitating participation and inclusion
- Initial cache was judged to be scientifically return-worthy (SRW) and recommended MSR depot formation at Three Forks.
  - Anticipated 10 sample tubes deposited containing core samples, regolith, atmosphere, witness tube(s)
    - For each core sample pair, the shorter sample would be placed in the initial depot, and the other sample will be retained onboard Perseverance
  - Recommended samples in the First Depot would be Roubion (atmospheric sample), WTA2 (witness tube WB3), Montdenier, Coulettes, Malay, Atsah, Skyland, Hazeltop, Amalik (TBD), Regolith (TBD).
- All workshop findings were accepted by the community

Ten Samples to Deploy to Cache

This sample suite is better than we had reason to expect to collect in the prime mission. It contains both igneous and sedimentary rocks, plus at least two and possibly four or even more distinct styles of aqueous alteration. Samples represent the full diversity of the rover's explorations:



A. Igneous rocks from the crater floor (4 samples)
- unaltered igneous minerals
- aqueous alteration products (subsurface water)

B. Sedimentary rocks from lake Jezero (3 samples)

(1) mudstone
- clay minerals and sulfate cement
- abundant organic molecule detections

(2) silty sandstone
- serpentine minerals
- heavy mineral concentrates, including zircons

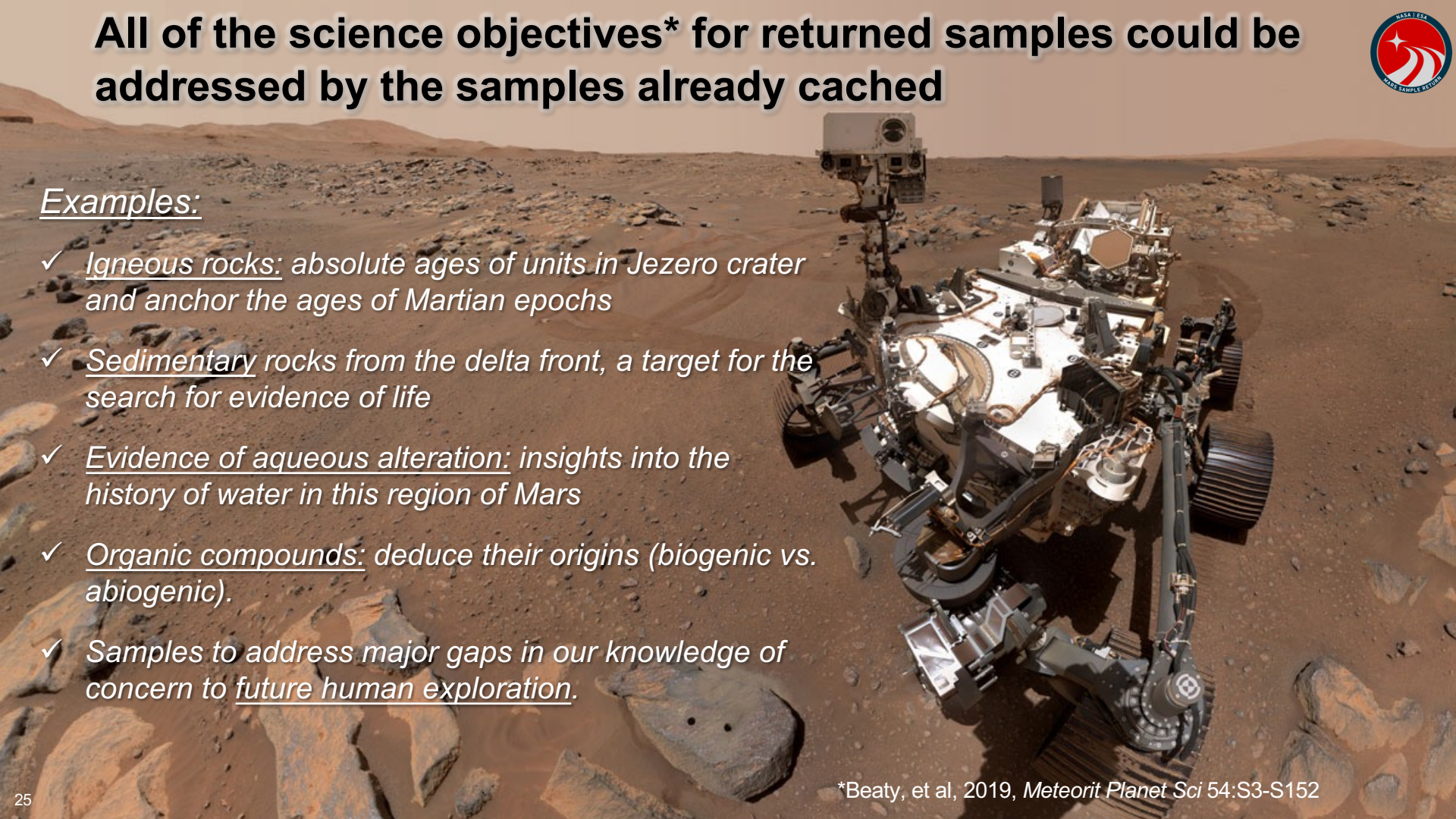
(3) medium sandstone
- rock fragment and grain diversity
- carbonate sediment

C. Regolith sample

D. Atmospheric sample

E. Witness tube

All of the science objectives* for returned samples could be addressed by the samples already cached

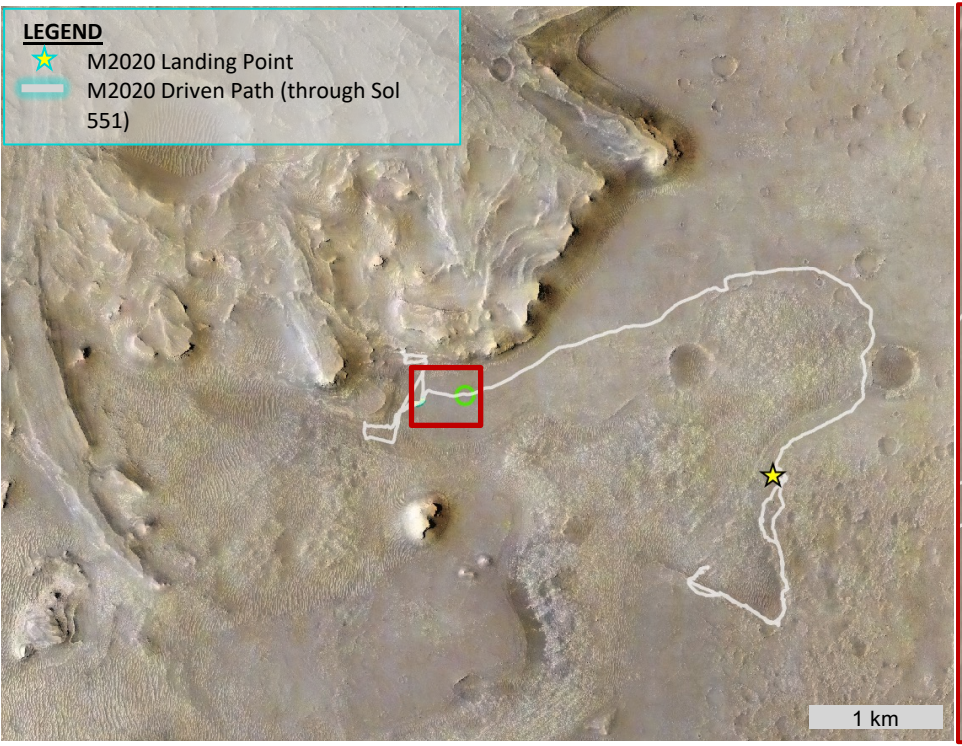


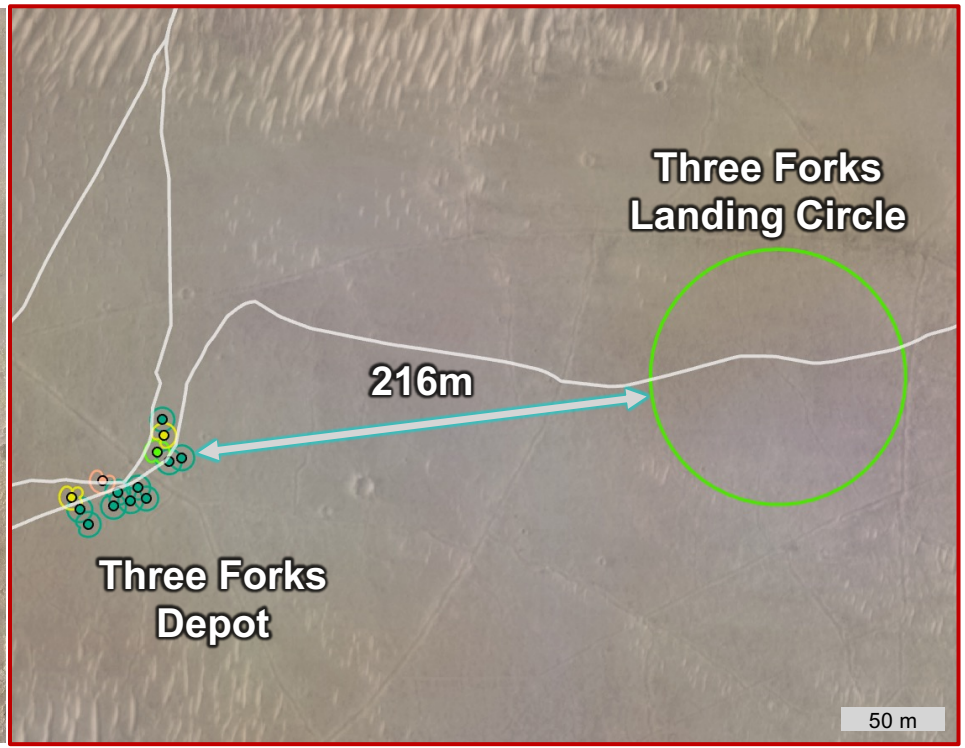
Examples:

- ✓ *Igneous rocks: absolute ages of units in Jezero crater and anchor the ages of Martian epochs*
- ✓ *Sedimentary rocks from the delta front, a target for the search for evidence of life*
- ✓ *Evidence of aqueous alteration: insights into the history of water in this region of Mars*
- ✓ *Organic compounds: deduce their origins (biogenic vs. abiogenic).*
- ✓ *Samples to address major gaps in our knowledge of concern to future human exploration.*

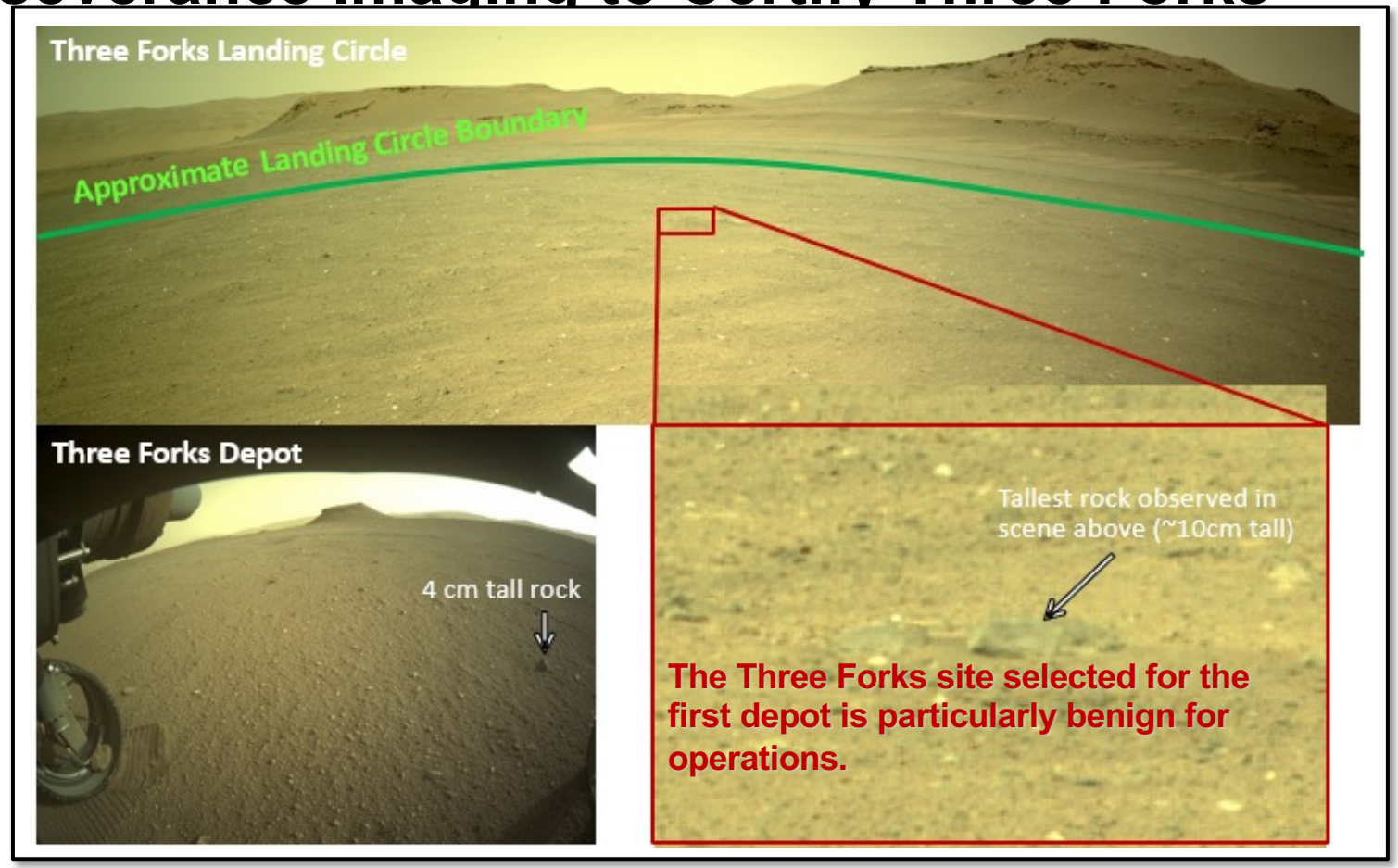
*Beaty, et al, 2019, *Meteorit Planet Sci* 54:S3-S152

Three Forks Campaign Site





Perseverance Imaging to Certify Three Forks



MARS 2020

Three Forks Initial Sample Cache

NASA SMD Associate Administrator recently approved the Mars 2020 project to establish an initial cache at the Three Forks location in Jezero Crater

- Proposed sample cache represents the full diversity of Perseverance exploration to date and is deemed scientifically return worthy
- Mars 2020 project and MSR Program determined that the Three Forks location meets all site certification criteria
- Mars 2020 is ready to proceed and construct initial sample depot
  - Operational readiness review completed (full operational plan, process, procedures, and products in place)
  - Traverse plan and sample tube drop zones defined
  - Depot construction expected to take <2 months to complete

MARS 2020

Mars Sample Return Milestones

Accomplishments FY22/FY23

- November 2021: Mars Ascent Vehicle (MAV) SRR/MDR completed
- March 2022: Sample Retrieval Lander (SRL) SRR completed
- July 2022: Mars Sample Return Program SRR/MDR
- September 2022: Program entered Phase B: KDP-B APMC
- November 2022: ESA Sample Transfer Arm (STA) PDR

Upcoming Events

- NEPA public comment meetings Nov 30 & Dec 6-7
- December 2022: CCRS Preliminary Design Review (PDR) Part 1 (systems, project)
- February 2023: CCRS PDR Part 2 (flight segment, programmatics)
- ERO Mission PDR, Jan-Feb 2023
- February 2023: SRH SRR
- March 2023: MAV PDR
- April 2023: SRL PDR
- June 2023: Program PDR

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Looking Forward

- Now is the time
  - Perseverance continues to collect samples, increasing the value of the cache on board
  - Orbital relay assets in place around Mars
  - Mission and Science MOUs in place for joint NASA/ESA mission
- Key Program Focus Areas
  - First-of-a-kind technical developments (MAV, CCRS on-orbit assembly, OS rendezvous, SRH, EDL/pinpoint landing)
  - Schedule execution (staffing, supply chain, funding profile)
  - Planetary Protection implementation and verification
  - Coordination of complex multi-program partnership

As a result of the success of Perseverance, the Campaign has compelling samples ready to return. Establishment of initial cache retires substantial Campaign risk.