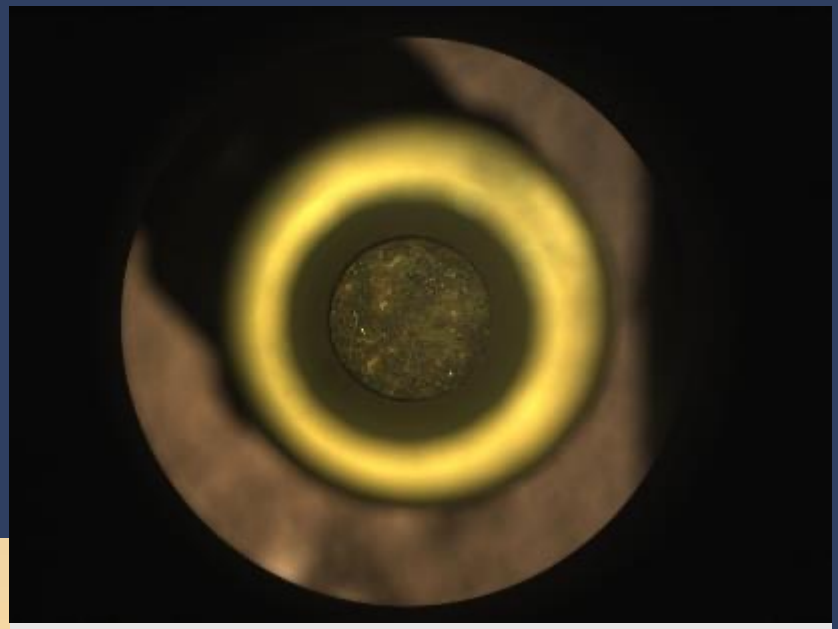
Eric Ianson
Mars Exploration Program Director

Michael Meyer
Lead Mars Scientist

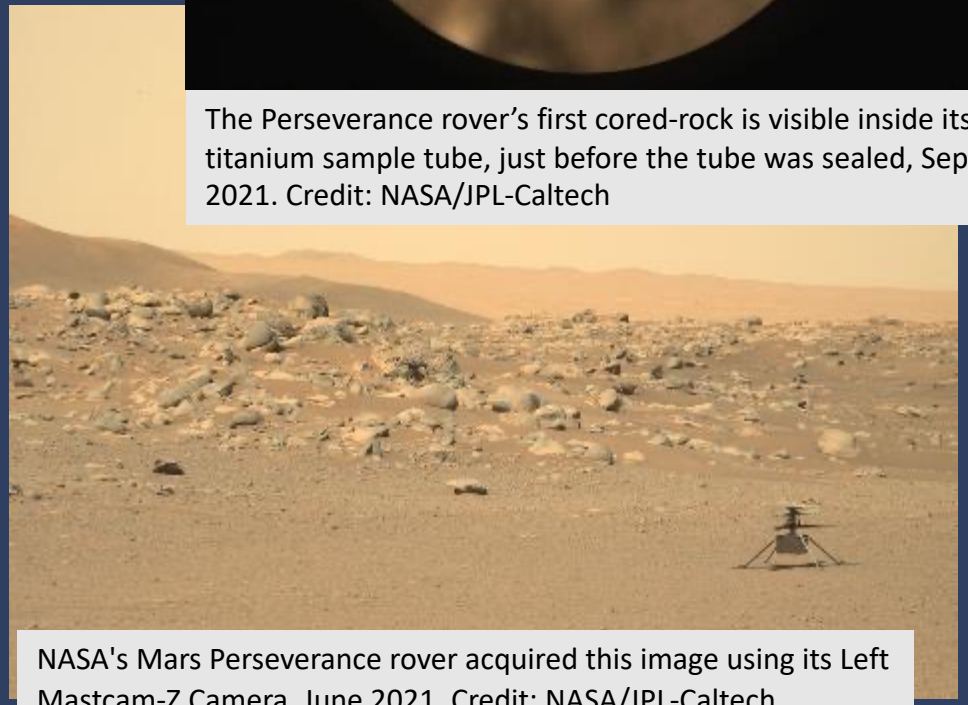
NASA Planetary Science Advisory Committee (PAC) Meeting
November 15, 2021

Mars Exploration Status Highlights

- Perseverance successfully acquired a pair of sample cores from “Rochette”
- Ingenuity helicopter completed flight test phase and has successfully performed 15 flights to date
- International Mars Ice Mapper Measurement Definition Team (MDT) selected and announced
- Mars assets successfully exited Solar Conjunction ~ Oct 20, 2021
- MEP Program Implementation Review (PIR) held at HQ Oct 18-19, 2021
- Perseverance science team published its first scientific findings post-landing in *Science*, Oct 2021
- Low-Cost Science Mission Concepts for Mars Exploration Workshop Jan 11-13, 2022 in Pasadena



The Perseverance rover’s first cored-rock is visible inside its titanium sample tube, just before the tube was sealed, Sept 2021. Credit: NASA/JPL-Caltech



NASA's Mars Perseverance rover acquired this image using its Left Mastcam-Z Camera, June 2021. Credit: NASA/JPL-Caltech

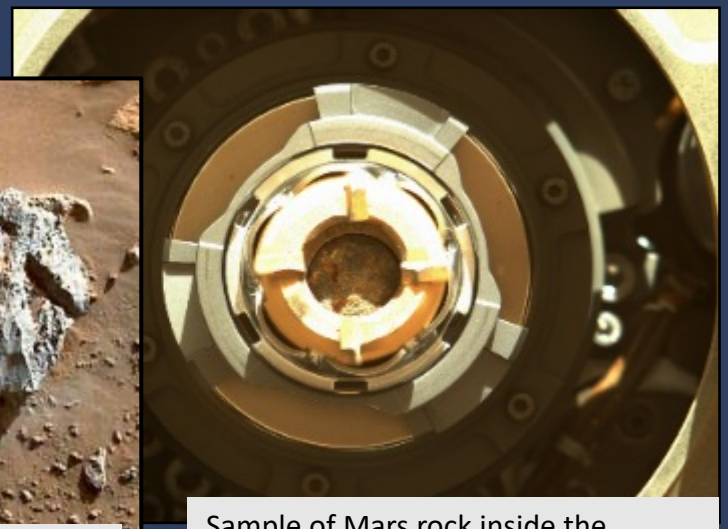
Perseverance Sampling

Coring Sample: After making the first sample acquisition using a multi-sol plan with ground-in-the-loop sequences of imaging to confirm core in tube, the second sample acquisition operation from drilling through sealing/storing process was conducted in a single sol plan.

- After collecting its first sample, named “Montdenier,” Sept 6, 2021, the team collected a second, “Montagnac,” from the same rock Sept 8, 2021
- Next sample attempt potentially at “Brac” in mid-November

Drill hole from Perseverance’s first sample-collection attempt, along with the shadow of the rover, Aug 2021. Credit: NASA/JPL-Caltech/MSSS

Two holes where the rover's drill obtained chalk-size samples from rock nicknamed "Rochette.“ Sept 2021. NASA/JPL-Caltech



Sample of Mars rock inside the sample tube , Sept 2021. NASA/JPL-Caltech

MEP Staffing Updates

Tiffany Morgan - Mars Exploration Program Deputy Director

Before joining NASA HQ, Tiffany was Project Manager for the Solar Electric Propulsion Project at NASA's Glenn Research Center. She spent over a decade working for Air Force Space Command (now Space Force) on rapid acquisitions, prototyping demonstrations.

Becky McCauley Rench, Ph.D. – Mars Science Laboratory Program Scientist

Becky is an astrobiologist and works as a Program Scientist in the Planetary Science Division at NASA HQ, where she leads the Planetary Protection Research & Habitable Worlds Programs. She is the Program Scientist on New Horizons and for the Planetary Data System.

Michael Mischna, PhD – Mars Exploration Program Principal Scientist

Michael is a research scientist with a focus on Martian climate and atmospheric evolution. He has supported numerous Mars missions since the early 2000's and last served as JPL's Associate Directorate Scientist for the Planetary Sciences Directorate.

Shannon Curry, Ph.D. – MAVEN Principal Investigator

Shannon is a planetary scientist and the Deputy Assistant Director of Planetary Science at the Space Sciences Laboratory at the University of California, Berkeley. She joined the MAVEN science team in 2013 and explores how the Sun's activity contributed to the loss of the Martian atmosphere.

Mission Updates

- MOMA MS: Instrument fully integrated with Rosalind Franklin rover. NASA providing assistance with ExoMars Rover parachute testing. Drop Test in Oregon scheduled for Fall 2021
- Ongoing NASA orbiter missions are healthy, productive and funded under the CR
  - MRO: Over 10 years beyond its original design life, MRO is fully operational and using “All-stellar mode” to preserve IMU lifetime.
  - MAVEN: Set a new solar system record for throughput during a single communications session at another planet during a relay session with the Perseverance rover. A total of 2.34 Gbits were transferred, well exceeding the prior record of 1.74 Gbits. The use of the low-density parity check (LDPC) encoder was a significant contributor.
  - MAVEN regularly disseminates "space weather alerts" to major stakeholders in MEP. MAVEN used its unique capabilities to detect a moderate-to-strong solar storm that hit Mars head-on on Oct 28, 2021.
  - Odyssey: > 20 years since launch, and still going strong; “All-stellar mode” is in use to preserve Inertial Measurement Unit (IMU) lifetime.
  - Odyssey's GRS neutron instruments (Neutron Spectrometer and High Energy Neutron Detector) also detected the effects of a large solar flare on Oct 28, 2021.
  - ExoMars/TGO (ESA): Continues to return over 55% of the total UHF relay science data from Mars landed assets

“mosaic image shows a rock outcrop in the area nicknamed "Citadelle" on the floor of Mars' Jezero Crater. “Rochette” is circled in yellow. Credits: NASA/JPL-Caltech.

Ingenuity taken by MastCamZ
Credit: NASA/JPL-Caltech

15 flights, over 1.5 mi flown

Octavia E. Butler Landing Site

Perseverance Path

Seitah

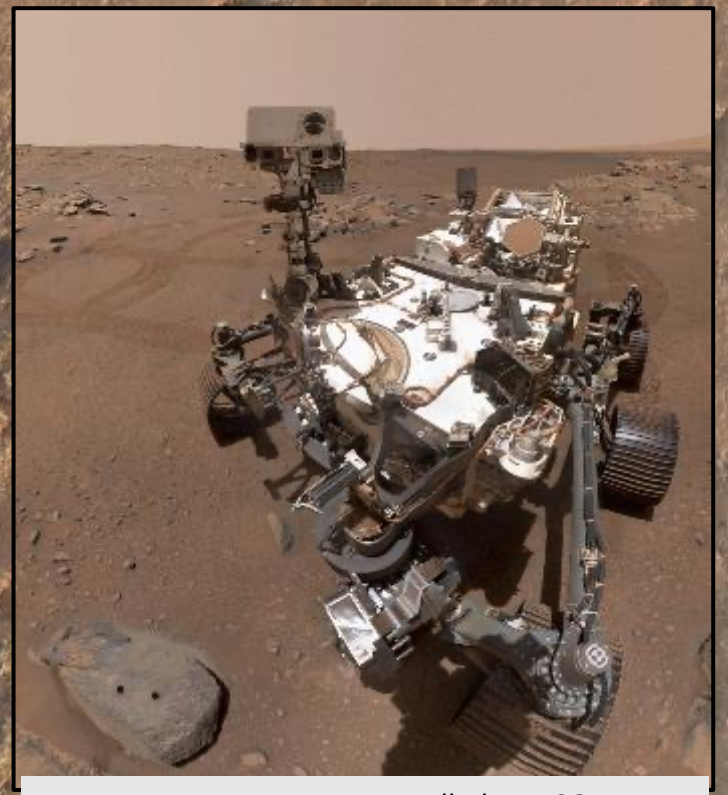
Brac

Artuby Ridge

Rochette

Ingenuity Path

Roubion & Atmospheric Sample



Perseverance uses a camera called WATSON on the end of its seven-foot-long robotic arm to take its selfies; seen here with Rochette, Sept 2021
Credit: NASA/JPL-Caltech/MSSS

Journeyed over 1.6 mi

International Mars Ice Mapper

Opportunity for a remote-sensing mission

Mission contributes to NASA's high priority of enabling human Mars missions

Mapping shallow water ice at mid-latitude locations:

1. Ice Science - sampling ice to answer profound climatology and astrobiology questions
2. Reconnaissance - identify candidate landing sites conducive to find resources to meet human needs (e.g., in situ production of "rocket fuel" for return trip to Earth)

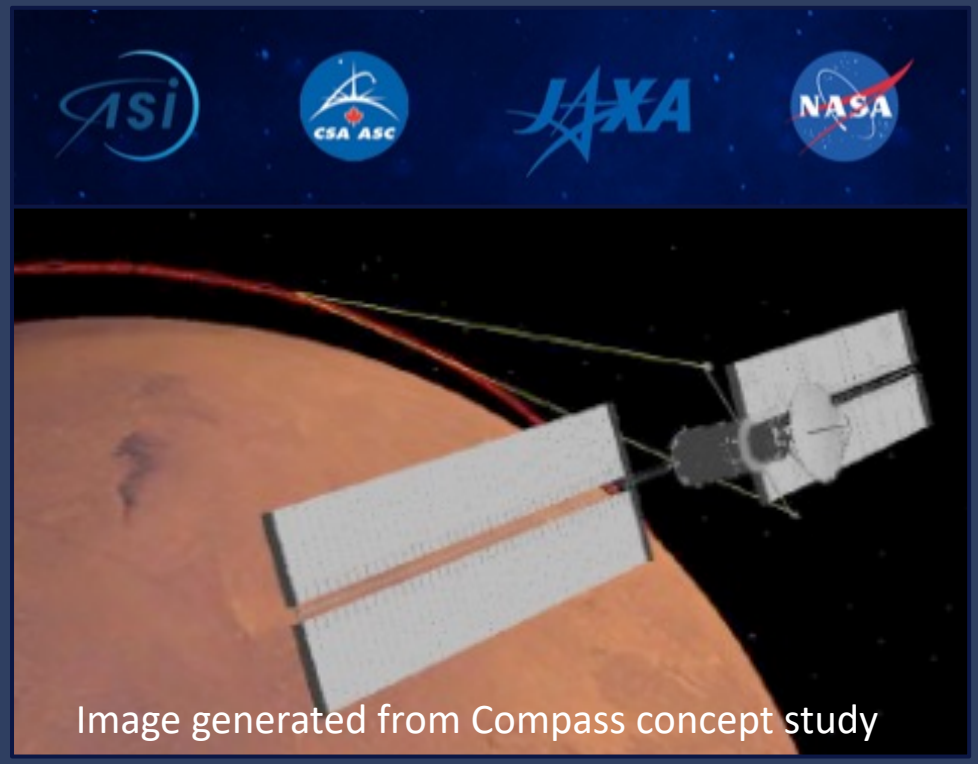


Image generated from Compass concept study

Multilateral Concept Team Study

- Collaboration underway per Jan 2021 Statement of Intent among NASA, CSA, ASI, and JAXA
- Netherlands Space Office is an additional active participant in the study
- Team is completing I-MIM Point Design 2.0 and a preliminary, coordinated mission schedule

Reconnaissance*/Science Measurement Definition Team (MDT)

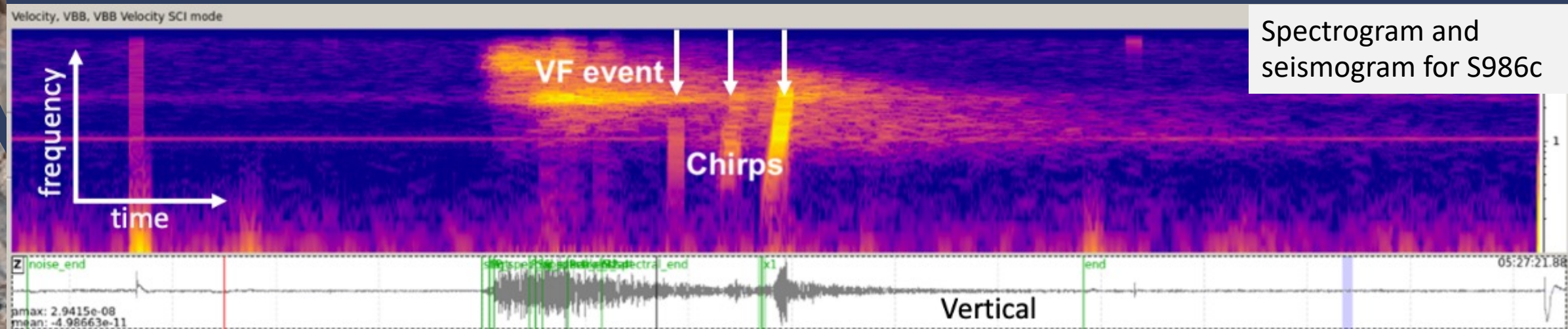
- MDT shall define measurements and recommend optimization for the SAR, provide options for high-priority, synergistic science augmentation and prepare a concept of operations
- A total of 53 members selected to form an international, multidisciplinary MDT
- https://twitter.com/Dr_ThomasZ/status/1458539994591678464

Insight

Studies published in July that utilize analysis of seismic data collected by InSight, conclude the estimated of the size of Mars's core, the thickness of its crust, and the composition of its mantle, plus the size of its molten core

The past few months have seen a flurry of unusual and scientifically fascinating marsquake detections by the InSight SEIS instrument, including:

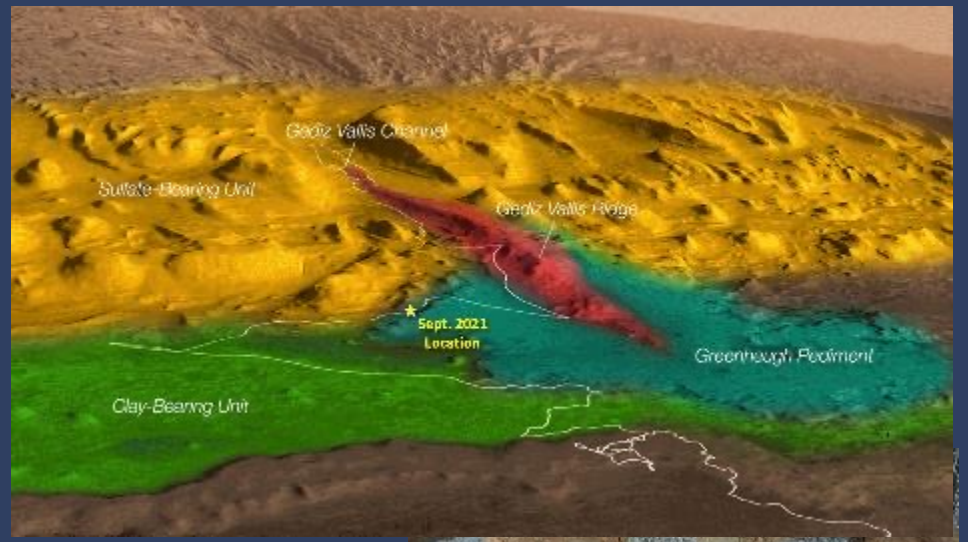
- **S0976a** (Aug. 25): The largest (mag. 4.2) and farthest (143 deg, 8450 km) marsquake so far; possible detection of waves traveling through the core
- **S0986c** (Sept. 5): Detection of several “chirp” signals, never seen before; possibly due to meteorite impact and infrasound from its passage through atmosphere; search underway for crater
- **S1000a** (Sept. 18): Longest (1.5 hours) and tied for largest (mag. 4.2) marsquake yet seen; another candidate detection of core-traversing waves
- **S1034a** (Oct. 23): Largest amplitude (>10 times more shaking at lander than any previous



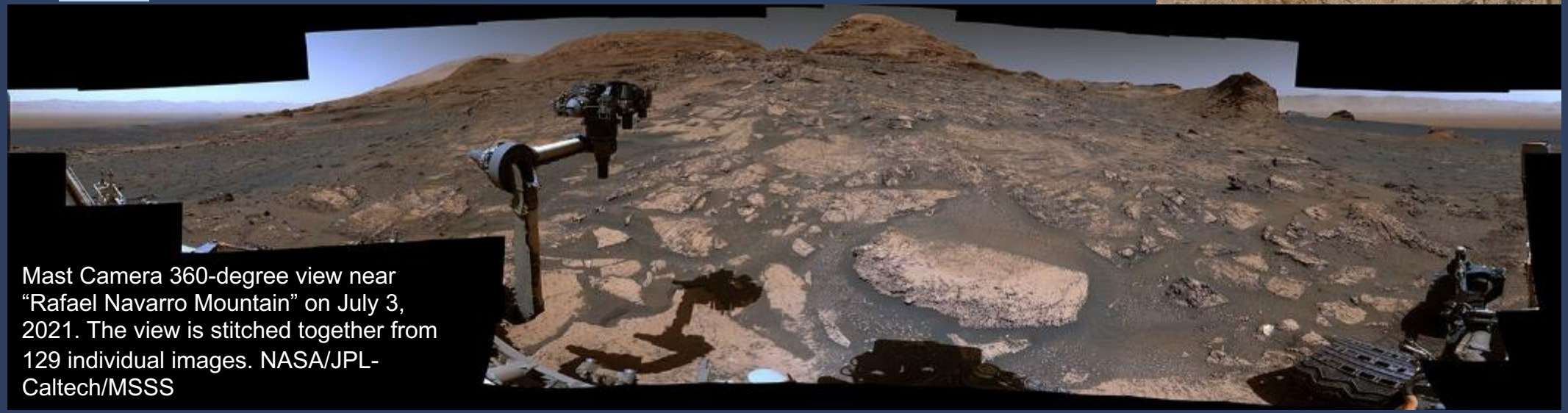
Spectrogram and seismogram for S986c

Mars Science Laboratory

- Curiosity continues its climb up Mt Sharp southward toward the Greenheugh Pediment
- Curiosity has used the drill on its robotic arm to take 34 rock samples to date
- Mast Camera captured the below panoramic view of a craggy hump that reaches 450 feet tall located on Mt Sharp in NW Gale Crater – Youtube video >1M views
  - https://www.youtube.com/watch?v=8DZl56tS9ko&list=PLTiv_XWHnOZpzQKYC6nLf6M9AuBbng_O8&t=2s



Mars Hand Lens Imager (MAHLI), a camera on the end of the robotic arm, provided the images in this collage

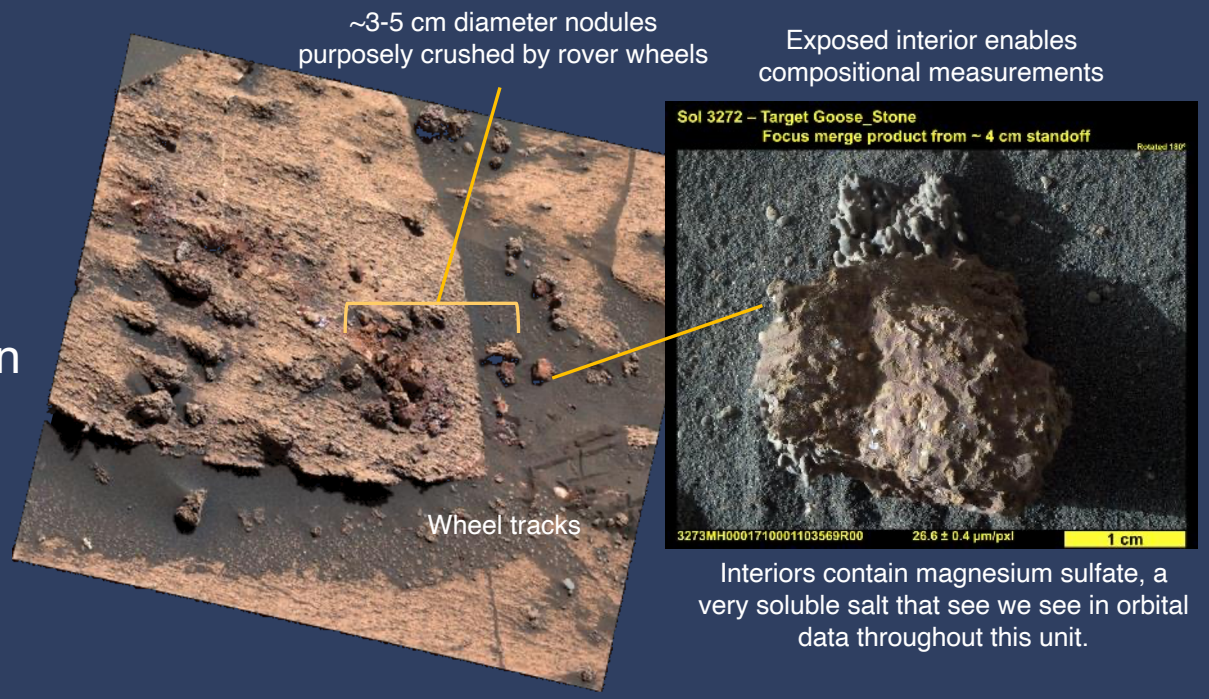


Mast Camera 360-degree view near “Rafael Navarro Mountain” on July 3, 2021. The view is stitched together from 129 individual images. NASA/JPL-Caltech/MSSS

Curiosity: Evidence of Past Groundwater at Mount Sharp

Curiosity has observed diverse types of nodules and veins in the clay-sulfate transition.

- Features formed when groundwater circulated through Mt. Sharp, long after sediments that built the mountain turned to stone.
- The science team is studying these features to extend our knowledge of the history of habitability at Gale Crater.



Interiors contain magnesium sulfate, a very soluble salt that see we see in orbital data throughout this unit.

MSL has seen a wide diversity of textures in the clay-sulfate transition area

Mars Sample Return (MSR) Campaign

- Signed MOA between MSR Program and MEP for R&R on the Sample Return Campaign
- MSR Science Planning Group-2 report completed and submitted for publication; joint MSR Operational Scenarios Definition Team ongoing; a MSR Campaign Science Group is being formulated.
- Sample Receiving Project (SRP) making progress on defining project roles and responsibilities

- Astromaterials Acquisition and Curation Office is reviewing results of an RFI/Sources Sought, released in Sept 2021, pertaining to the sample receiving facility
- Mars Sample Return Sample Receiving Facility Assessment Study structure development is underway
- High level plan and schedule for SRP development complete in FY23

Report of the MSPG2 Study

Planetary Sciences Advisory Committee

Presentation, Nov. 15, 2021

MSR Science Planning Group 2 (MSPG2)[1]

Coordination Team: Gerhard Kminek[1] and Michael Meyer[2] (Co-Chairs), David Beaty[3], Brandi Carrier[3], Tim Haltigin[4], Lindsay Hays[2].

1. European Space Agency, 2. NASA Headquarters, 3. Jet Propulsion Laboratory, California Institute of Technology, 4. Canadian Space Agency

Members[2]: Carl Agee, Henner Busemann, Barbara Cavalazzi, Charles Cockell, Vinciane Debaille, Daniel Glavin, Monica Grady, Ernst Hauber, Aurore Hutzler, Bernard Marty, Francis McCubbin, Lisa Pratt, Aaron Regberg, Alvin Smith, Caroline Smith, Roger Summons, Timothy Swindle, Kimberly Tait, Nicholas Tosca, Arya Udry, Tomohiro Usui, Michael Velbel, Meenakshi Wadhwa, Frances Westall, Maria-Paz Zorzano

1. Members competitively selected through joint NASA-ESA process, 31 members representing 11 countries
2. Terms of Reference signed by ESA and NASA in April 2020; Report complete July 2021

MSPG2 Results

1. Science Management Plan

- Demonstrated the need for an overarching MSR Campaign Science Program and proposed an implementation approach

2. Technical Issues

- Established which sample related activities would have to be conducted in the SRF, because they are time-sensitive, sterilization-sensitive, and/or are needed for initial sample characterization

3. SRF Requirements

- Provided technical requirements that would enable the SRF to meet its objectives and accommodate activities that cannot be done in external laboratories

4. Integrated Timeline

- Some aspects are pinned to the left side of the timeline, and others to the right side (i.e. either 2031 or 2033); The MSR Science Program comprises multiple types of activities - some are tied to the sample return date, while others are tied to the planning and activity of the flight missions, and some must start immediately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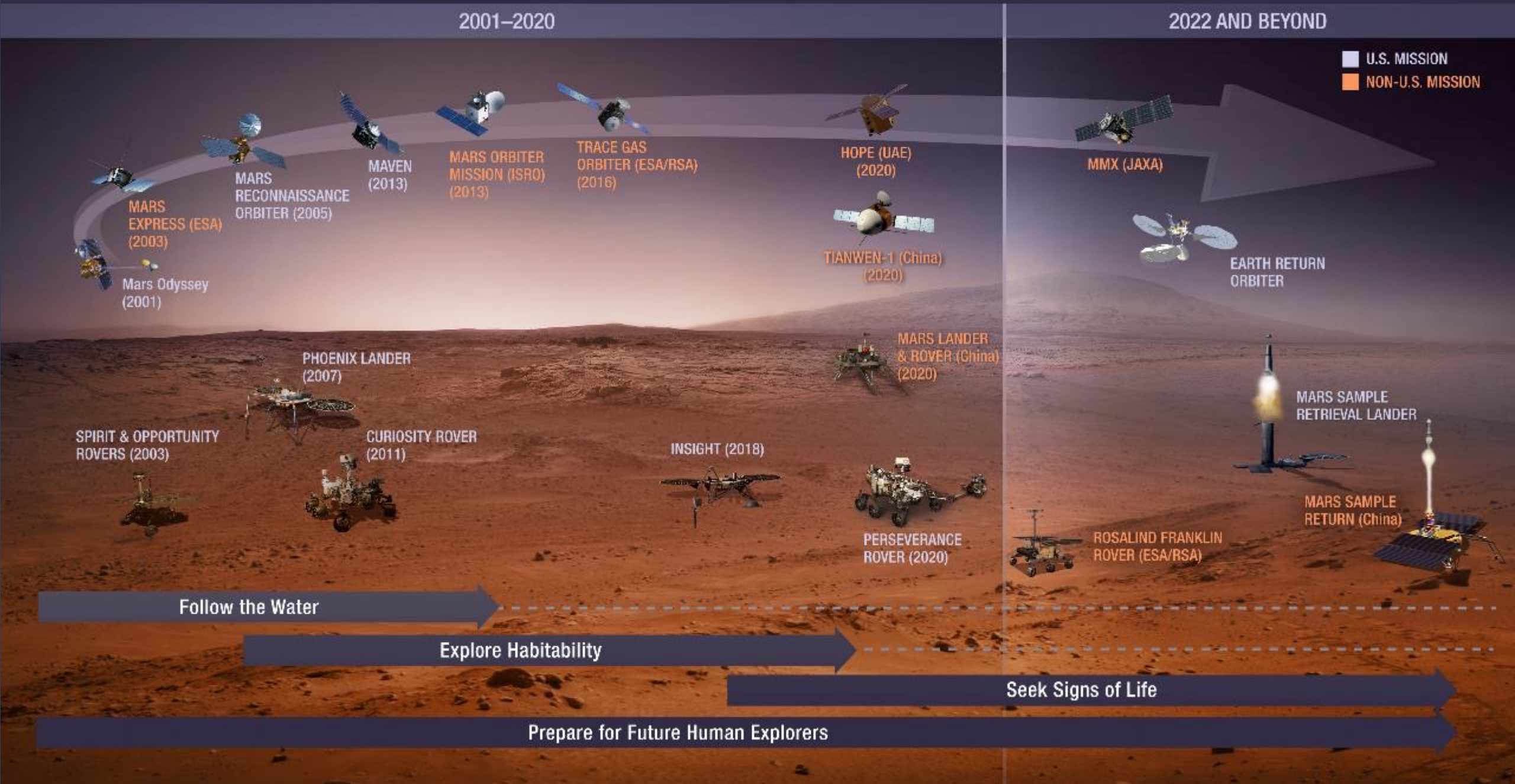

2001–2020
2022 AND BEYOND
U.S. MISSION
NON-U.S. MISSION
MARS EXPRESS (ESA) (2003)
MARS RECONNAISSANCE ORBITER (2005)
MAVEN (2013)
MARS ORBITER MISSION (ISRO) (2013)
TRACE GAS ORBITER (ESA/RSA) (2016)
HOPE (UAE) (2020)
MMX (JAXA)
TIANWEN-1 (China) (2020)
EARTH RETURN ORBITER
Mars Odyssey (2001)
PHOENIX LANDER (2007)
MARS LANDER & ROVER (China) (2020)
MARS SAMPLE RETRIEVAL LANDER
SPIRIT & OPPORTUNITY ROVERS (2003)
CURIOSITY ROVER (2011)
INSIGHT (2018)
PERSEVERANCE ROVER (2020)
ROSALIND FRANKLIN ROVER (ESA/RSA)
MARS SAMPLE RETURN (China)
Follow the Water
Explore Habitability
Seek Signs of Life
Prepare for Future Human Explorers

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
MAVE 	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 ~10 kg remaining. “All-stellar mode” in use to preserve IMU lifetime. Loss of redundancy in reaction wheel assembly; loss of another wheel would reduce remaining mission lifetime to 1-2 yrs.
MEX 	Some onboard memory issues persist. Fuel load extremely low and uncertain.
MRO 	Fuel usage ~10 kg/yr, with ~190 kg remaining. Battery recently reconditioned to recover state of charge. “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 through late 2020s.
MAVEN 	Aerobraking performed in early 2019 to lower orbit to enhance relay. “Nadir-sun” mode added to enhance relay. Fuel usage planned to allow operations through 2030. “All-stellar mode” in development as a contingency measure.
TGO 	Onboard memory issues resolved. Relay services expected to remain viable through 2030.

National Aeronautics and Space Administration

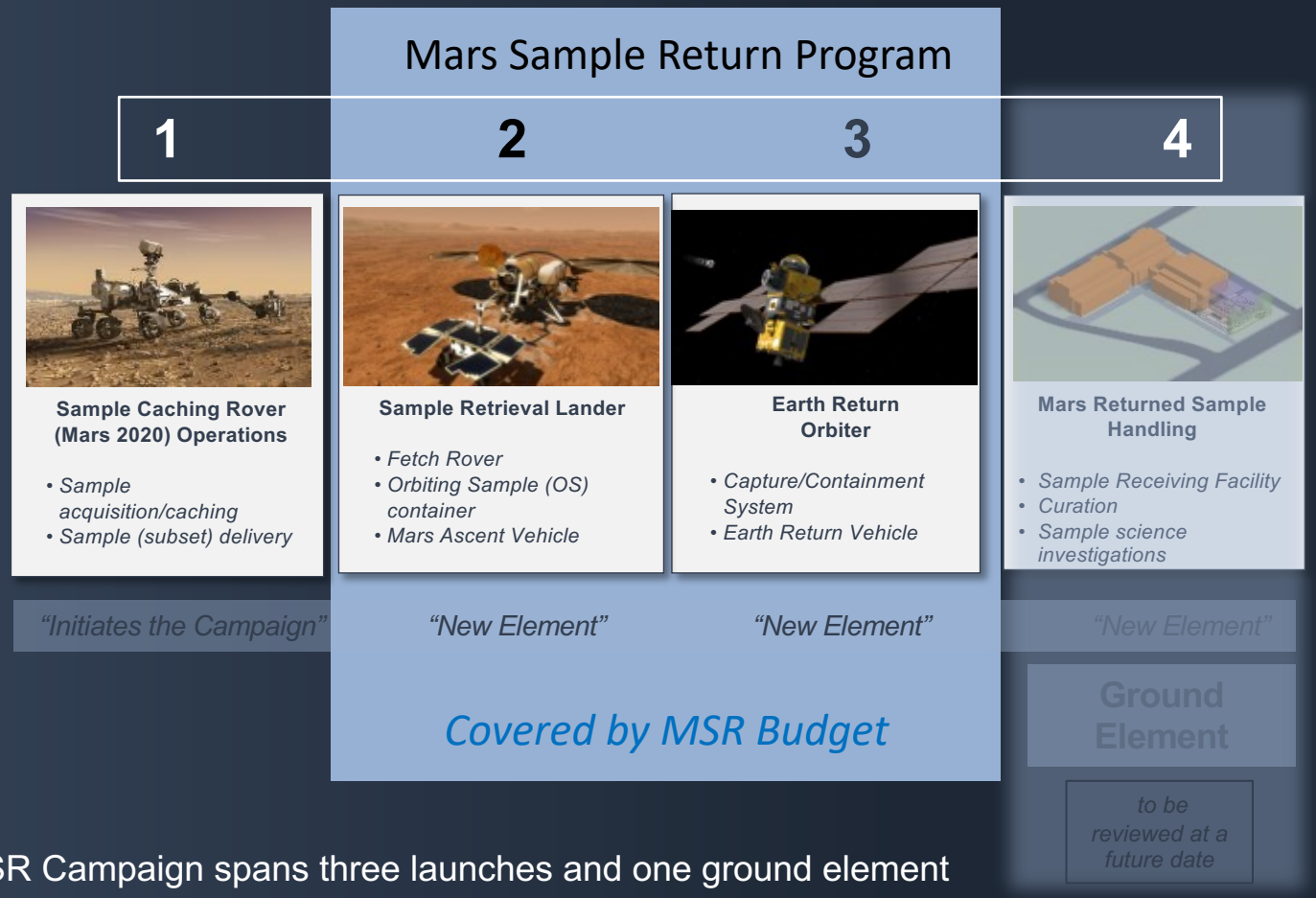
EXPLORE MARS SAMPLE RETURN

Jeff Gramling, MSR Program Director
NASA HQ

Briefing to PAC

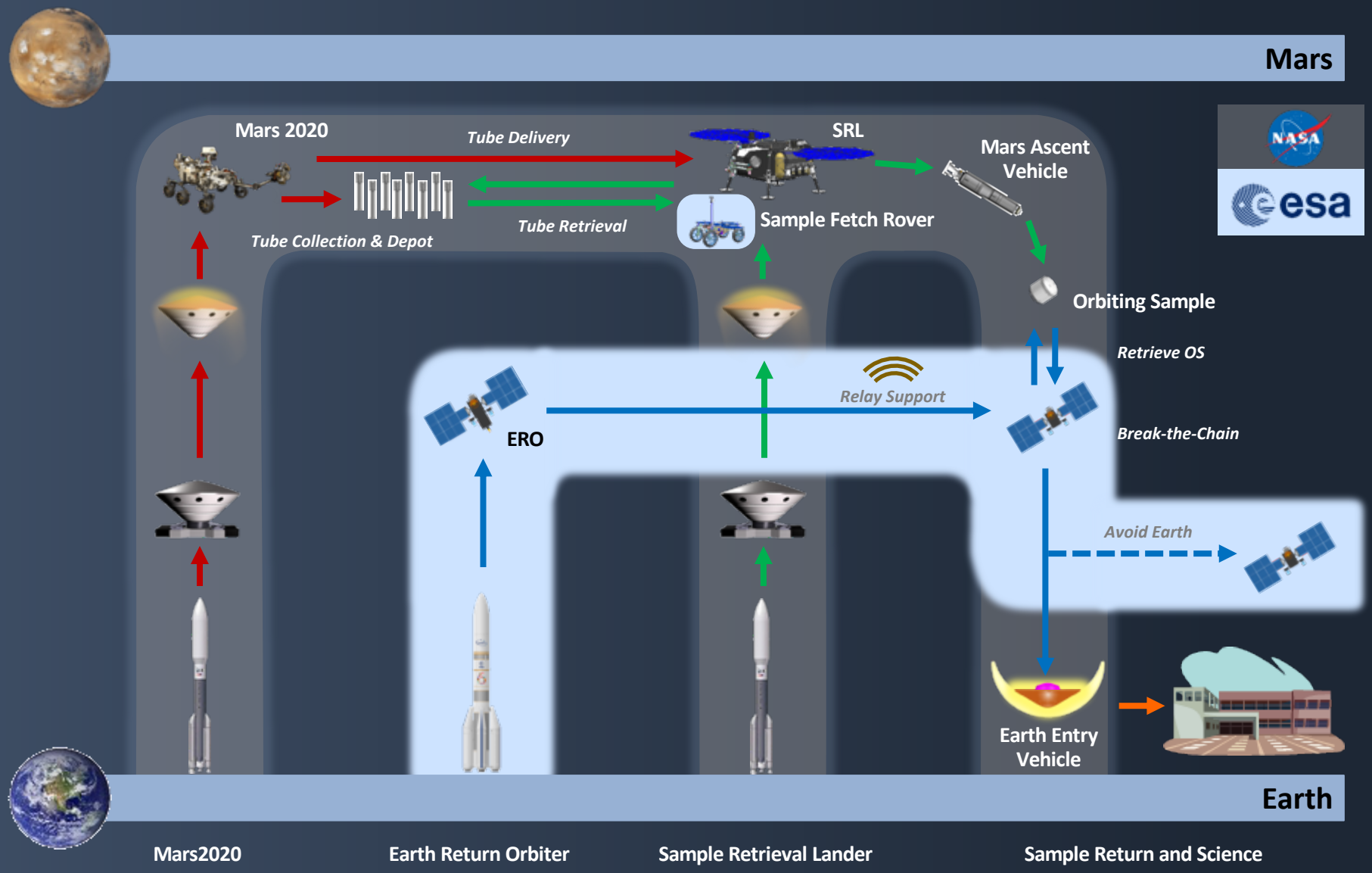
November 15, 2021

MSR Campaign



- The MSR Campaign spans three launches and one ground element
- The MSR Program manages development and operations of elements 2 and 3 above and interfaces to elements 1 and 4; program concludes with recovery/containment of samples for transfer to SRF
- The MEP Program manages M2020 Phase E operations & will be the home of the future SRF Project

MSR Architecture Overview



First Scientifically Selected Samples Collected

Perseverance has successfully acquired paired rock samples

Rochette' After Perseverance Sampling: Sept. 7, 2021, PDT, shows two holes where the rover's drill obtained samples from rock nicknamed "Rochette." Credits: NASA/JPL-Caltech.

- 10% of the 43 sample tubes on Perseverance are now sealed and awaiting Earth return; in 2023, this will be over 33%

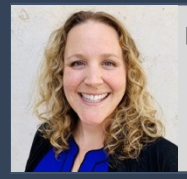
Multiple Paths to Deliver Sealed Samples on the Mars Surface

Progress

- Perseverance has collected first samples
- Program is emerging as a constructive collaboration with Europe
- Program making significant progress in establishing a viable, implementable architecture
- Resolved center roles & engaged industry in more significant ways
  - Significant progress on long-lead procurements
- Augmented team with numerous experienced implementation personnel
- Advanced key technologies & engineering developments and assessed a broad range of options in Phase A

MSR Organization – Recent Additions

HQ Program Office



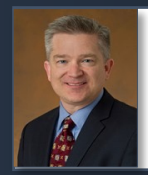
Lindsey Hays
Deputy Program Scientist

Dewayne Washington
Comms Lead

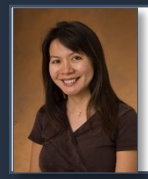
JPL Program Office

Deputy Program Manager
Ann Devereaux

Campaign System Eng Manager
Al Chen

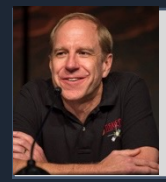


Campaign System Engineer
Keith Comeaux



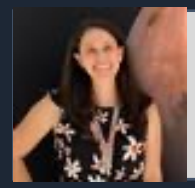
Program Mission Assurance
Thuy Nguyen-Onstott

Projects

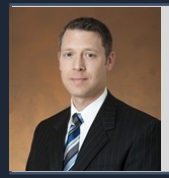


Guy Beutelschies
SRL PM

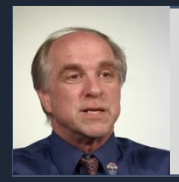
Kalyani Sukhatme
SRL DPM



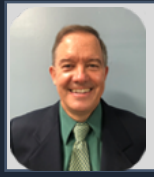
Ashley Karp
SRL Ascent Mgr



Chris Salvo
SRL FS Mgr



Dave Littmann
CCRS PM

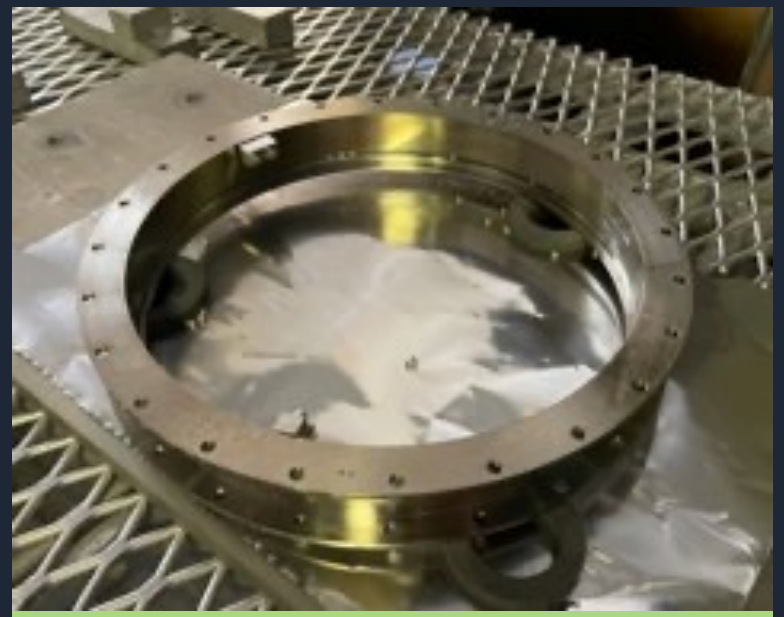


Keith Walyus
CCRS DPM

Trade Study Highlight: Break-the-Chain Containment Assurance - Aseptic Transfer/Sealing

- The program is currently trading two aseptic transfer/sealing approaches to complete the primary containment vessel (PCV) assembly around the Orbiting Sample (OS) container
  - Baseline is use of brazing at joint
  - Alternate is a heat-shrink fit (HSF) approach
- Baseline autonomous brazing is TRL 4-5; efforts on track to demonstrate TRL 6 by CCRS PDR
- Alternate approach, heated shrink fit, is in work to mitigate TRL development risk
  - Relies on well-understood joining method and maintains the capability to sterilize the PCV joint
  - Potential improvement in ground and on-orbit verification

Brazing Development: 1-Way Full Scale Ring



2nd FS ring from August 2021:
He tight and sealed to < 4x10-10 atm.cc/s.

Development Highlight: VECTOR

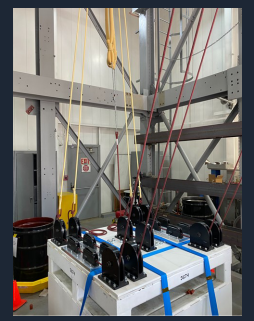
What is it?

- The Vertically Ejected Controlled Tip-Off Release (VECTOR) system "tosses" the MAV before ignition
- This minimizes dynamic coupling with launch dynamics and plume interactions while increasing ground testability/verification

VECTOR Prototype with MAV Simulator

Overall

- Design continues to mature
- Held an architecture review that confirmed the basic VECTOR approach
- Held development review to ensure solid maturity plan by PDR
- Prototype version 1 has been built



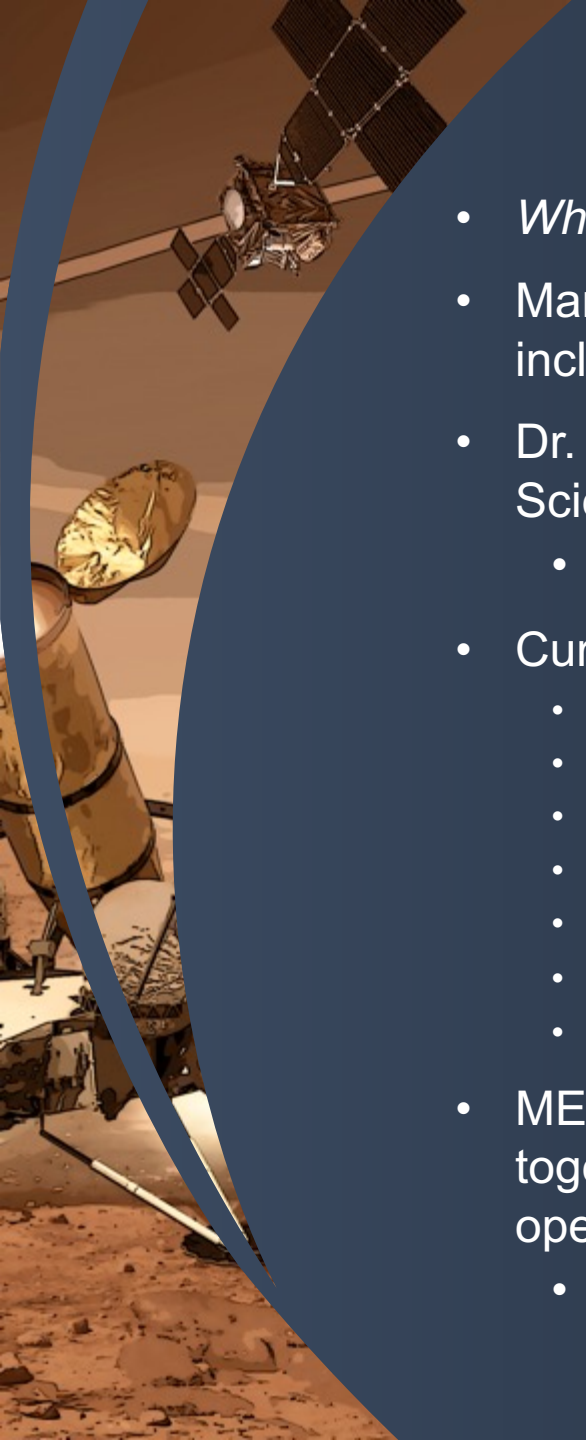
Gravity Offload and Catch System

Testing

- Using JPL Building 280 with an MSL Z-Hangman structure utilizing a gravity offload and catch system
- Have started testing prototype with testbed (see next slide)

Testing Underway

VECTOR Prototype Testbed



MSR Science Question

- *What will Science Involvement with Mars Sample Return Campaign look like?*
- Mars Exploration Program has the responsibility for the science of Mars Exploration, including MSR
- Dr. Meyer/MEP is leading development of the Campaign Science Plan and Campaign Science Team in response to MSPG2 recommendations
  - Developing Science MOU with ESA
- Current Science Involvement
  - MSR Lead Scientist is also the MEP Lead Scientist (NASA HQ)
  - Deputy MSR Program Scientist (NASA HQ)
  - MSR Principal Scientist (JPL)
  - Deputy MSR Principal scientists (JPL) - interviews in progress
  - Lead Sample Integrity Scientist (JPL)
  - CCRS Sample Integrity Scientist (JPL)
  - Sample Return Project Scientist (TBD) (JPL)
- MEP and MSR Programs developed a MOA in March to define how the programs will work together to coordinate M2020 Phase E operations, the MSR program design and operations, and the Sample Receiving Facility
  - Definition of joint agreement in operational planning and operations concept development

Summary

- Perseverance has successfully acquired paired rock samples
- Staffed key leadership roles across program
- Completed Delta ASM, finalized center roles
- Working to complete technical & programmatic trades
- Long-lead procurements in progress
- Project and Program reviews scheduled in Winter 2021 and Spring 2022

The program has made significant progress in Phase A, maturing its technical, cost and schedule baseline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