National Aeronautics and Space Administration

EXPLORE
MARS SAMPLE RETURN

Eric Ianson, Mars Exploration Program Director

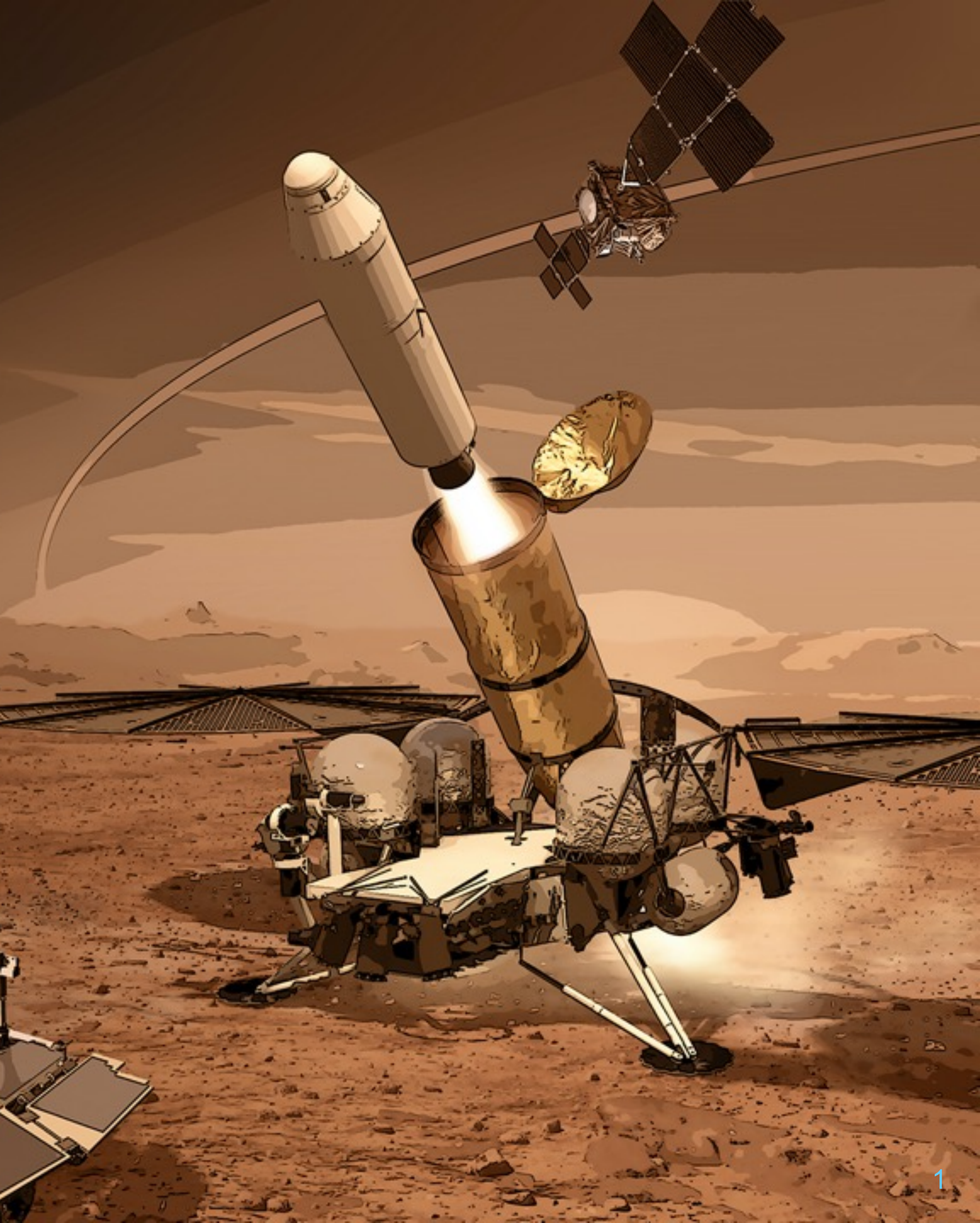
Jeff Gramling, MSR Program Director

Michael Meyer, Mars Lead Scientist

NASA HQ

Presentation to the PAC

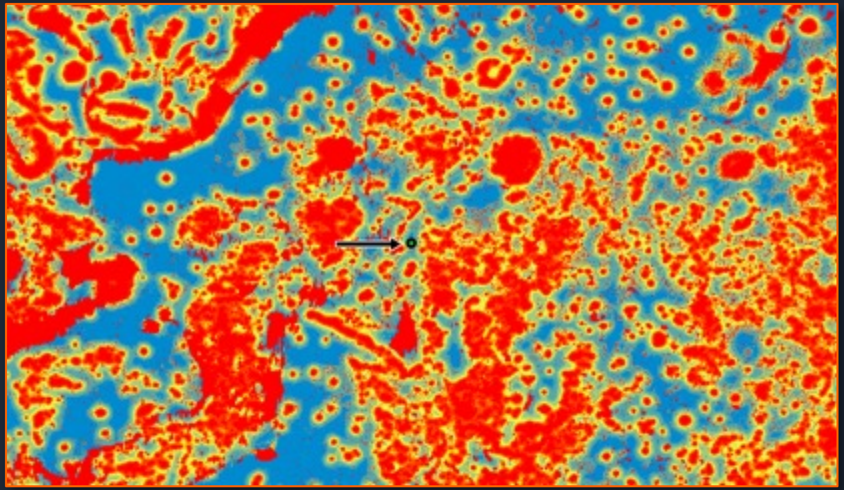
March 1, 2021

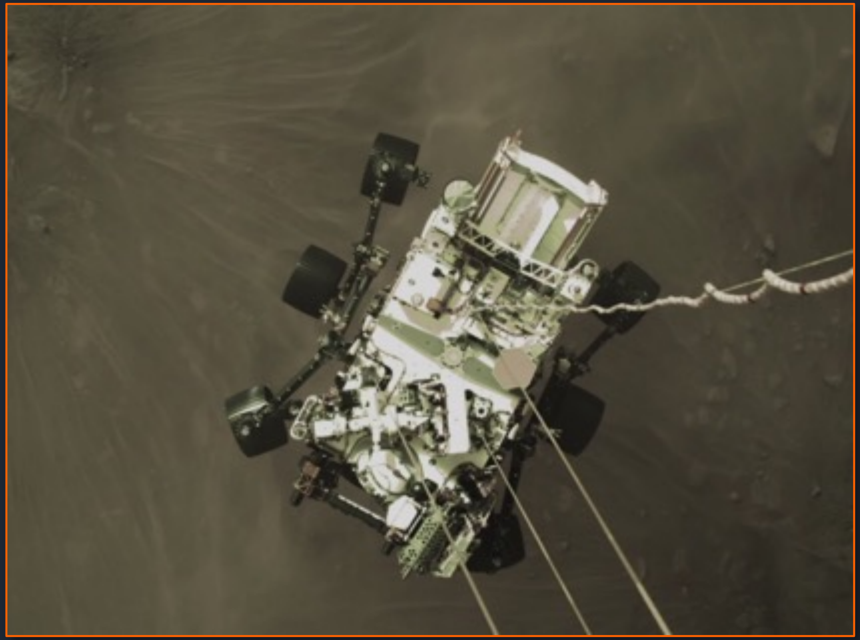


Mars Exploration Program

Mars Exploration Status Highlights

- Mars 2020 / Perseverance rover successfully conducted Entry, Decent, and Landing (EDL) on February 18, 2021
  - Perseverance landed in a safe location in Jezero Crater, just 1.7km southwest of the planned target
  - Initial surface operations are proceeding nominally
  - Early images have been spectacular



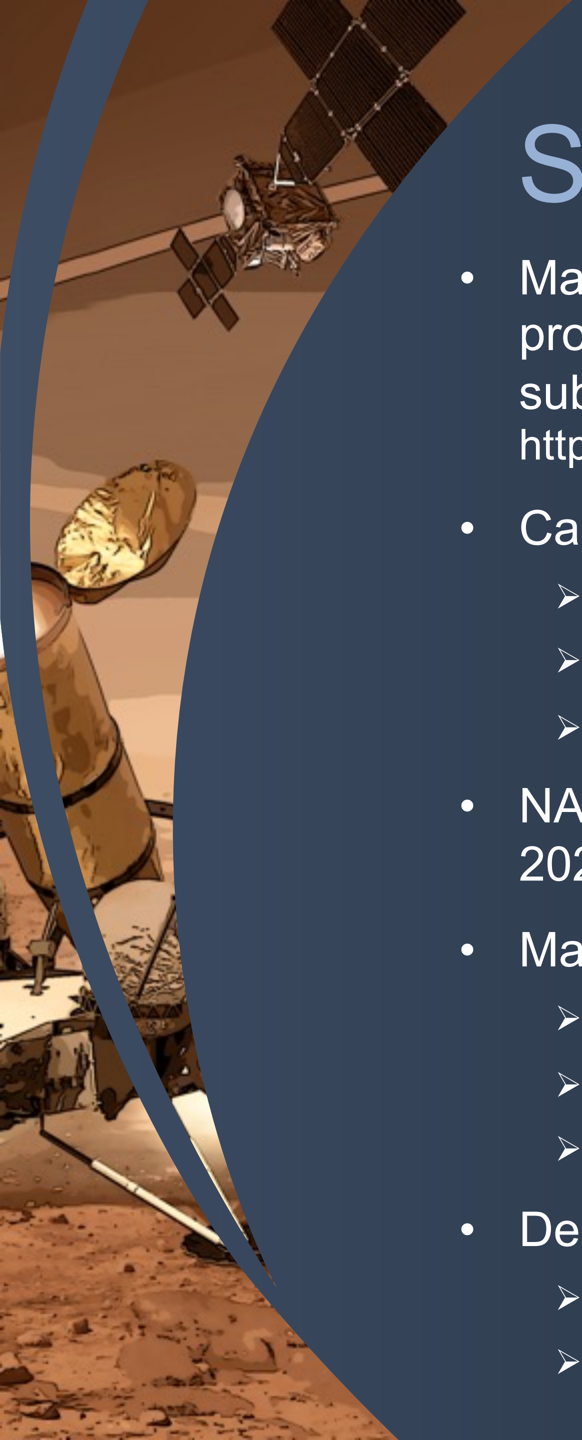


Other Updates

- InSight made a final attempt on Jan 9 to penetrate further with the HP^3 mole. Unable to gain the friction it needs to dig, efforts to continue have ended. InSight will spend its extended mission listening for more marsquakes. To help get the clearest signal, the team plans to bury the cable running between the lander and seismometer. More science to come.
- 2019 and 2020 Senior Review letters have been sent to MSL, MRO, MAVEN, Odyssey, Mars Express, and InSight
- Mars Ice Mapper Statement of Intent sign by the four partners (ASI, CSA, JAXA, NASA)
  - NASA is planning a “pre-Acquisition Strategy Meeting” in March to establish the NASA project
- Ongoing NASA missions are healthy, productive, and funded through FY21
  - Odyssey: Providing most of the relay support for InSight
  - MRO: Support Mars 2020 EDL
  - MSL: Achieved 3,000 sols on Mars
  - MAVEN: Exciting science ahead during solar cycle 25; Supported Mars 2020 EDL
  - ExoMars/TGO (ESA): Provides ~50% of relay data for Curiosity/InSight; supported Mars 2020 EDL
- Integration of Mars activities (HEOMD, SMD) across the Agency
  - SMD is participating in the NASA Federated Board to better integrate Lunar and Mars activities
  - Significant studies are underway to better understand Moon-Mars exploration synergies and to guide future work and collaboration.
- MEP is working with NASEM to start a study on planetary protection for Mars missions

Budget Status

- FY21 Appropriation provides the resources to fulfill MEP’s objectives and priorities:
  - Supports initiation of Perseverance’s science & sample caching campaign on the surface of Mars
  - Ensures continued successful operation of existing missions
  - Supports Mars fundamental research & analysis
  - Supports and cultivates existing and future international partnerships
  - Promotes future mission opportunities for Mars science
  - Supports planning for the receiving and curation of returned samples
- Mars Sample Return budget fully supports planned FY21 Phase A activities

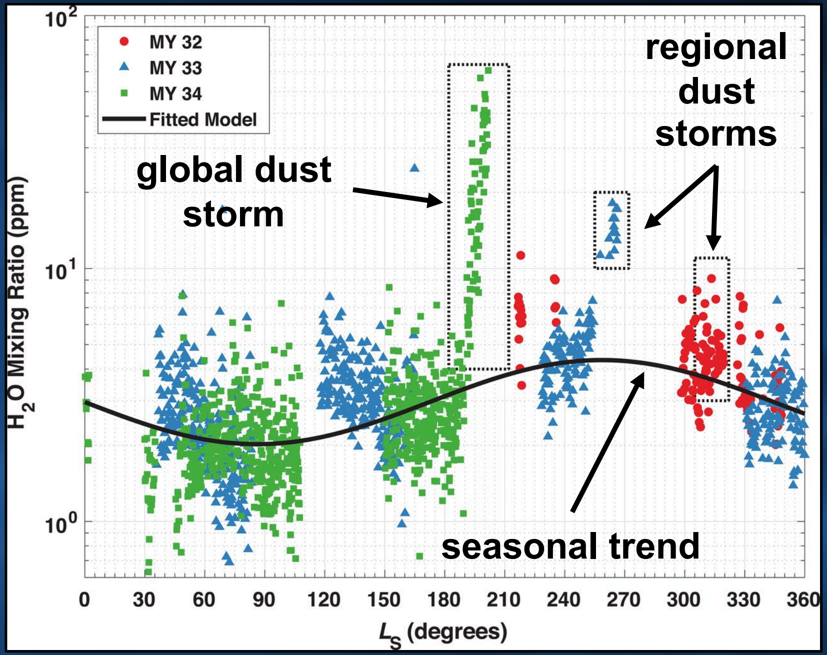


Science Highlights

- Mars Architecture Strategy Working Group (MASWG) report Nov. 2020. Proposed program for the scientific exploration of Mars that could be conducted in parallel with, and subsequent to, Mars Sample Return.
  https://mepag.jpl.nasa.gov/reports/MASWG%20NASA%20Final%20Report%202020.pdf
- Caching strategy workshop, 21 January 2021
  - Workshop attendance: 255 participants
  - Caching Strategy Steering Committee integrated workshop inputs
  - Report being finalized and agreed-to guidelines will be posted
- NASA/ESA MSR Science Planning Group-2 been meeting regularly. Report in Spring 2021
- Mars missions
  - UAE Hope MOI Feb 9
  - Tianwen-1 MOI Feb 10
  - Perseverance EDL Feb 18
- Deputy Program Scientists
  - Becky McCauley Rench – Curiosity
  - Lindsay Hays – MSR

Dust storms drive water loss at Mars

MAVEN measurements reveal surprising amounts of water in the upper atmosphere of Mars. How does this water abundance vary, and what impact does it have on escape to space?



The water abundance in the upper atmosphere varies with season (L_S). Different colors show observations from different Mars years. A repeatable annual cycle peaking in Southern summer is punctuated by strong water increases during dust storms (especially global storms).

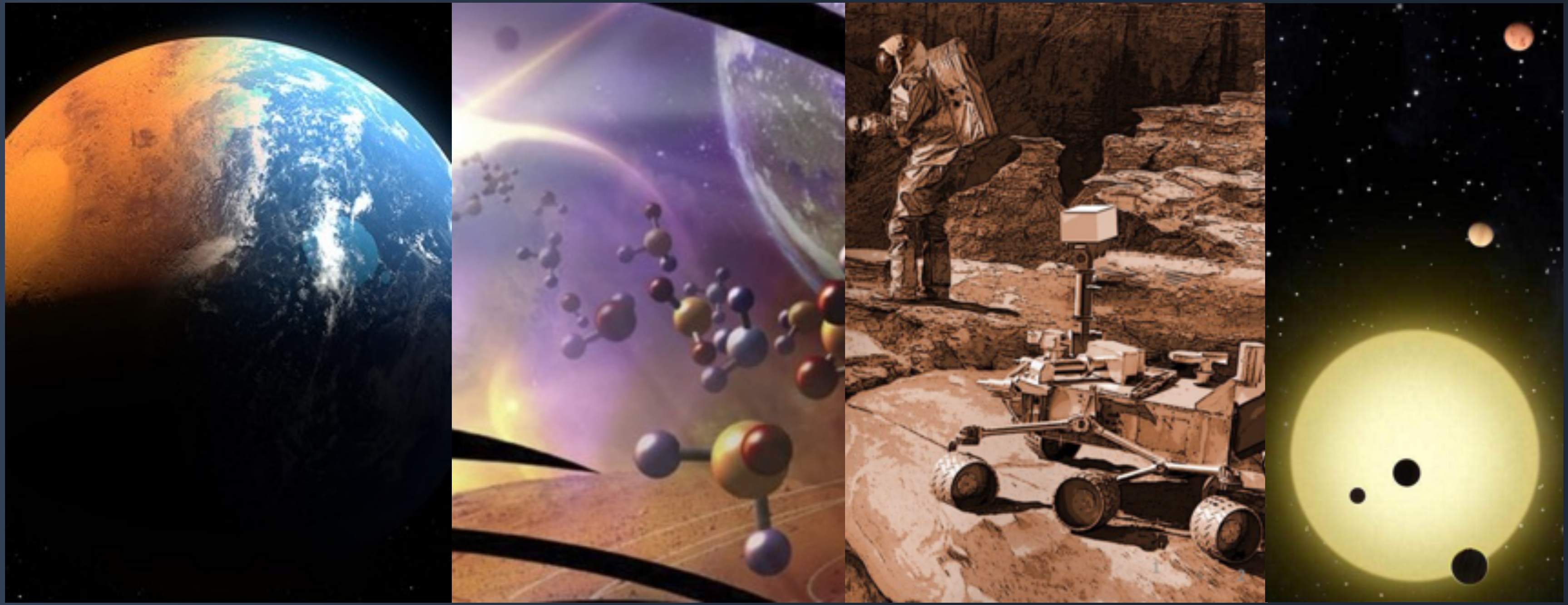
Stone et al., (2020) *Science*.

- MAVEN has measured H_2O^+ and H_3O^+ ions in the upper atmosphere that result from ionospheric chemical reactions. This implies an H_2O abundance at these altitudes that is much greater than expected.
- These observations challenge a previous view that the middle atmosphere is too cold to allow water molecules to diffuse upward. In the earlier scenario, sunlight would break water molecules apart at low altitudes, with the hydrogen diffusing slowly upward over decades before escaping.
- These new results are consistent with the transport of water to the upper atmosphere being enhanced when the atmosphere heats up during Southern summer – and especially during dust storms.
- The estimated escape rate of hydrogen that comes from the upper atmospheric H_2O inferred from this work shows that a single global dust storm can remove a year's worth of hydrogen. Thus, dust storms are major drivers of water loss at Mars.

Curiosity is nearing the transition from clay-bearing to sulfate-bearing strata on Mount Sharp. It records a major change in environmental conditions, potentially from a wetter to drier climate.

Clay-sulfate transitions are observed widely across Mars. Their importance for understanding Mars' climate history is one of the reasons that Gale crater was selected as Curiosity's landing site. Curiosity will be the first rover to explore such a transition from the surface.

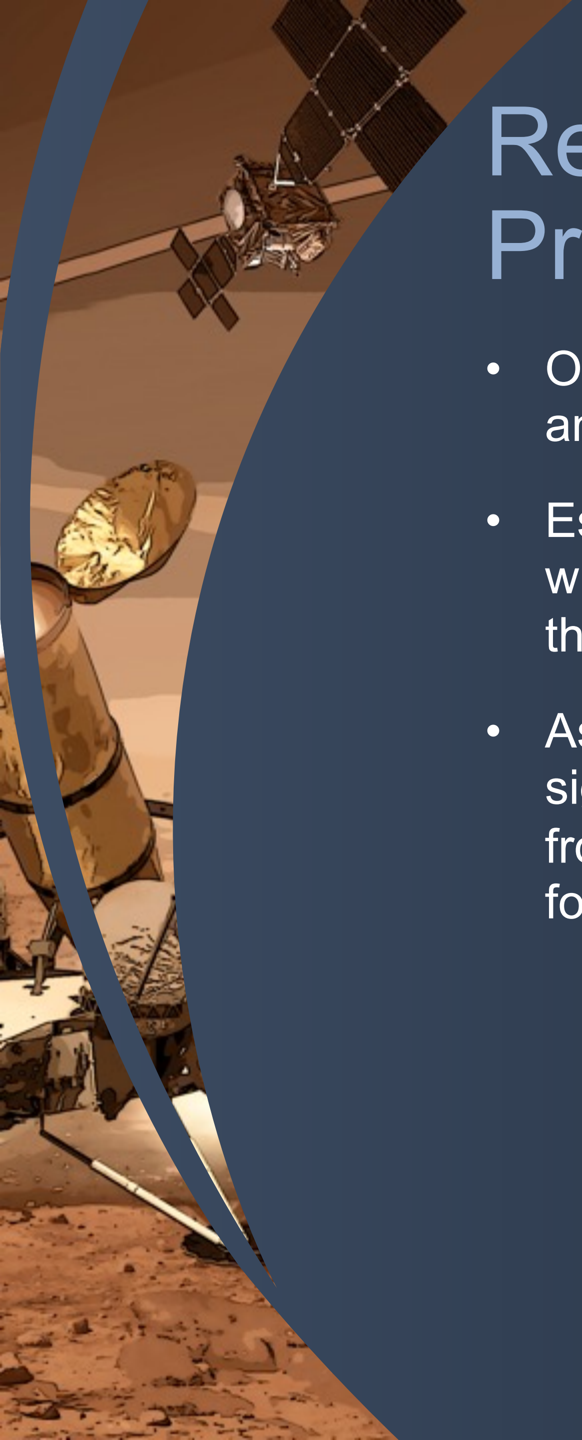
Mars, The Nearest Habitable World – Defining An Exploration Program



- Reading the Martian record:
  - Potential for life
  - Mars' habitability and changing climate
  - The first billion years of planetary evolution
  - Using Mars to understand exoplanet evolution
  - Mars as a destination for human exploration

MASWG High-Level Recommendations

1. Mars Sample Return should proceed as currently planned, as it will produce a major step forward in our understanding of Mars, as envisioned by *Visions & Voyages*.
2. NASA should support missions that address fundamental science objectives at Mars in addition to MSR, using the full range of technically viable mission classes. During the MSR era, the emphasis should be on achieving other high-priority science objectives, while developing the needed technologies for going forward.
3. For this next phase of Mars exploration, NASA should retain a programmatically distinct Mars Exploration Program. NASA should institute mission or budget lines that can allow Mars-specific missions, from small spacecraft through New-Frontiers-class missions, to be strategically integrated into a program, with missions chosen and implemented as appropriate for the science to be achieved.
4. To the extent possible, missions and instruments should be openly competed; where specific investigations are desired, objectives can be defined and then opened to competition.
5. A robust Mars exploration program will require affordable access to multiple places on the Martian surface and affordable long-lived orbiters. NASA should invest early to expedite the rapidly evolving small spacecraft technologies and procedures to achieve these capabilities at lower costs than past missions.



Relationship of the MEP and MSR Programs

- Over multiple decades, the success of the MEP has enabled ground-breaking science and built the engineering and science foundation for MSR.
- Establishing the MSR program as a separate implementation organization conforms with the 2019 NASA policy that Agency flagship missions are directly accountable to the responsible Mission Directorate Associate Administrator (AA).
- As the campaign to return samples from Mars is a highly challenging effort with a significant international partnership with ESA, the creation of an MSR program distinct from MEP provides for a focused approach to mission implementation and objectives for both programs.
  - ➢ MSR is tasked with retrieving and returning collected samples safely to Earth.
  - ➢ MEP continues to manage and organize the scientific exploration of Mars, including:
    - Operation of the Perseverance Rover (the “first leg” of the MSR campaign),
    - The future project to establish the sample receiving/curation facility, and
    - Curation of the samples returned to Earth by MSR.

SMD Mars Exploration Organization

Science Mission Directorate
AA: Thomas Zurbuchen

Planetary Science Division
Director: Lori Glaze
Deputy Director: Eric Ianson

Mars Exploration Program
Program Director: Eric Ianson
Lead Mars Scientist: Michael Meyer
Deputy Program Director/Lead Program Executive (Acting): George Tahu

Mars Exploration Program Office (JPL)
Fuk Li, PM

Mars Sample Return Program
Jeff Gramling, Director
Michael Meyer, Lead Scientist
Lindsay Hays. Deputy PS

Joe Gasbarre, Deputy PM - Tech
Rich Ryan, Business Manager
Ramon DePaula, PE
Erik Edwardson, PA

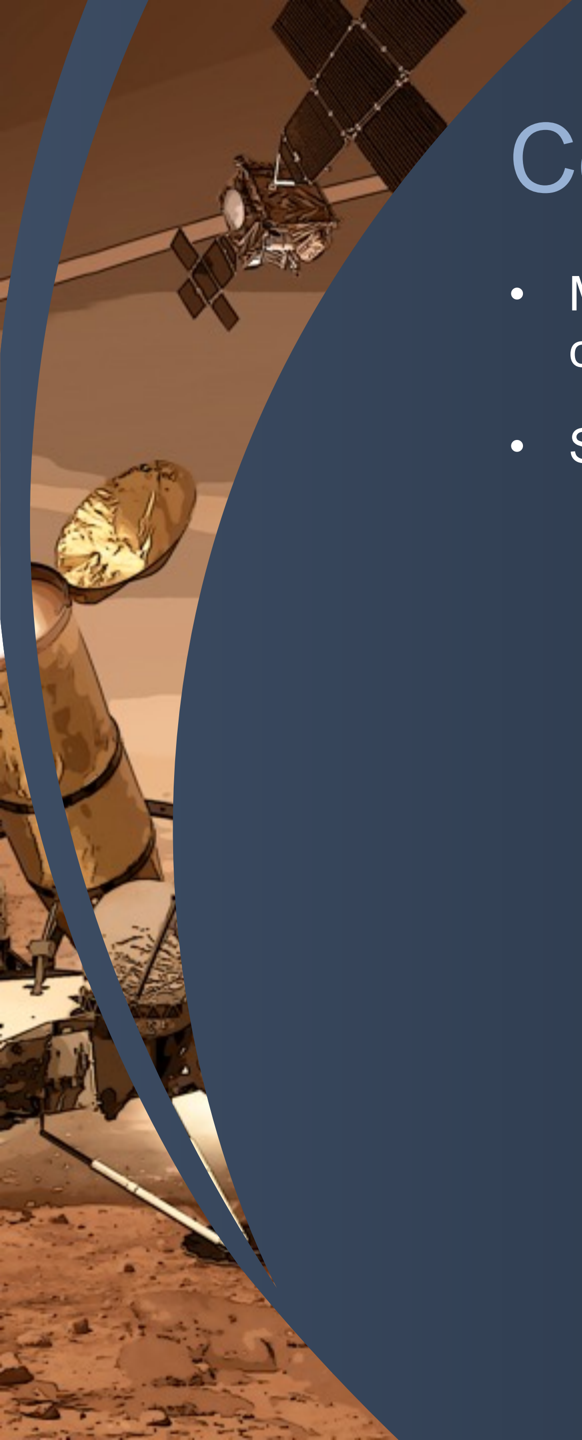
MSR Program Office (JPL)
Bobby Braun, PM

- **Mars2020 (Perseverance)**
  George Tahu, PE
  Mitch Schulte, PS
  Adrian Brown, DPS
- **MOMA**
  Dave Lavery, PE
  Mitch Schulte, PS
- **MAVEN**
  Ramon DePaula, PE
  K.C. Hansen, PS
- **MSL (Curiosity)**
  Dave Lavery, PE
  Michael Meyer, PS
  Becky McCauley Rench, DPS
- **MRO/Odyssey**
  Ramon DePaula, PE
  Mike Kelley, PS
- **Mars Express**
  Dave Lavery, PE
- **ExoMars**
  Ramon DePaula, PE
  Michael Meyer, PS
- **Ice Mapper International Collaboration**
  Rick Davis, PE

Mars R&A
Mitch Schulte, PS

Science/Exploration Integration
Rick Davis, Ass't Dir for Science and Exploration

Formulation Missions	Primary Operations Missions
Implementation Missions	Extended Operations Missions



Coordination between MEP and MSR (1 of 2)

- MEP and MSR are working on finalizing a “Memorandum of Agreement” (MOA) to codify the relationship between the two organizations; reviewed with Dr. Zurbuchen
- Some of the key areas of coordination in the draft MOA, include:
  - ➢ MEP and MSR Directors (and their staffs) will conduct bi-weekly coordination meetings.
  - ➢ PSD’s Lead Mars Scientist shall serve as both the MEP Lead Scientist and as MSR Program Scientist to facilitate coordination and provide cohesion.
  - ➢ A Joint Steering Group (JSG) between MEP and MSR will be used to resolve any issues between the programs
    - Co-chaired by the MEP and MSR Program Directors.
    - The JSG will be convened on an as-needed basis and the Co-Chairs will present the results of meetings to the PSD Director, SMD AA and/or NASA AA, as appropriate.
  - ➢ The MEP Director will serve as a member of the MSR NASA/ESA Joint Steering Board.
  - ➢ The MEP Director will present the MEP recommendation at MSR decisional meetings (DPMCs, APMCs, etc).

Coordination between MEP and MSR (2 of 2)

- Key areas of coordination in the draft MOA (continued):
  - ➢ MEP personnel will participate in MSR Life Cycle Reviews.
  - ➢ MSR personnel will participate in Mars 2020 Critical Event Reviews.
  - ➢ MEP and MSR will coordinate on MSR Campaign outreach and communication.
- The MSR and MEP Program Offices are both at JPL and the only two NASA programs in the JPL Planetary Science Directorate
  - ➢ The MSR and MEP Program Managers report institutionally to the JPL Director for Planetary Science
- Weekly HQ/JPL Planetary Science Leadership teleconference (not MEP/MSR specific) participants:
  - ➢ NASA HQ: PSD Director, MSR and MEP Program Directors, PSD Flight Programs Associate Director.
  - ➢ JPL: Planetary Science Director, MSR and MEP Program Managers.

➢ Recent example: Joint MEP/MSR coordination of NEPA work for the MSR SRF

Primary MEP/MSR JPL Program Offices Interactions

Mars Exploration Program

- Operational missions (Perseverance, Curiosity, ODY, MRO, MAVEN, MSL)
- Mars Relay Network
- Mars Advanced Studies
- Mars Technology
- Missions in Formulation/Pre-Formulation
  - Mars Ice Mapper
  - *Future missions TBD*
- Public Engagement
- Science Community Interaction
- HEO Interface
- Strategic Science Planning & Execution

- Returned Sample Project
  - Sample Receiving Facility
  - Sample Curation Facility
  - Returned Sample Science

Interactions

- Science community coordination
- Public outreach
- M2020/MSR surface operations coordination
- Mars Relay Network support of MSR
- MSR feedforward/coordination to MEP MRSP

Mars Sample Return Program

- NASA
  - Program Management
  - Campaign Systems Engineering and Integration
  - Sample Retrieval Lander Project
  - Capture, Containment and Return System
- ESA
  - Earth Return Orbiter Project
  - Sample Fetch Rover
  - Sample Transfer Arm

MEP/MSR Coordination Summary

- MEP is a long-term, ongoing program; it will continue after Mars Sample Return
- MSR is a single-project program with a defined beginning and end
- Both programs will collaborate to successfully implement the campaign to return samples from Mars and facilitate scientific investigations of those samples
- Over the coming decade, MEP will focus on science from its existing operational missions including Perseverance, develop a strategy for future scientific exploration of Mars, and implement a plan for the curation of the first samples to be returned from another planet
  - The Perseverance science team was specifically selected to identify and acquire the most compelling suite of samples for eventual return to Earth
  - The MEP is responsible for Returned Sample Science, including sample curation
- Over the coming decade, MSR will focus on the development and operation of the flight elements required to retrieve the cached samples and return them safely to Earth
  - MSR does not have a science team or science instruments
  - The landing site for the retrieval mission will be determined by the SMD AA, based on recommendations from the MEP and MSR programs and will incorporate science community input
  - Following return of Mars samples to Earth, the MSR Program will be complete

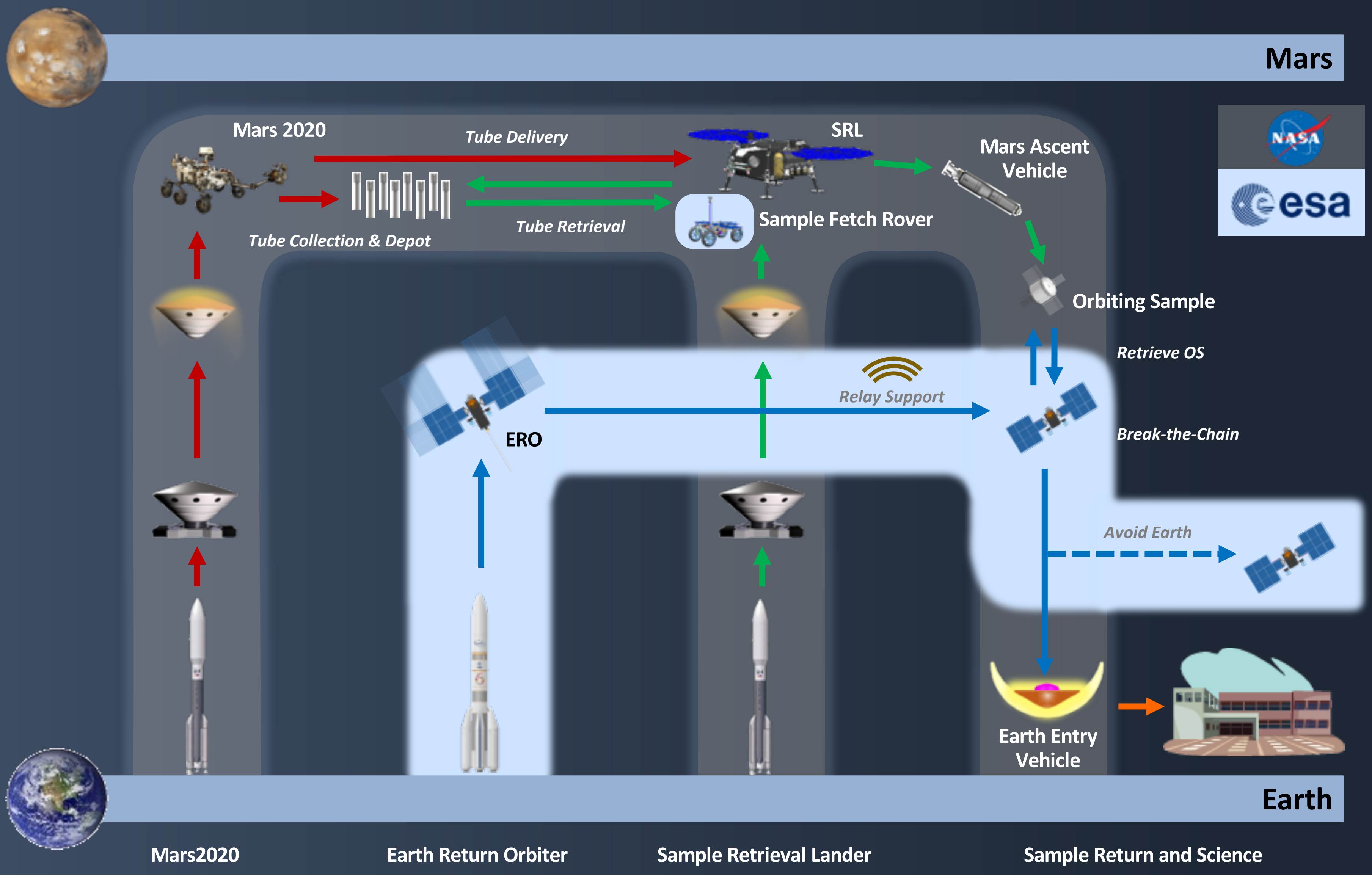
Mars Sample Return Program

Introduction

- Mars Sample Return has been a priority of the past two National Academy Decadal Surveys
  - First “round-trip” to another planet, paving the way for future human exploration
- MSR is a complex mission
  - Requires a set of capabilities that were not demonstrated 20, or even 10, years ago.
  - It is only possible today as a result of the $10+B investment made through the formulation, technology and operational projects of the past decades, coupled with a strong international partnership with ESA
- In recognition of the size, complexity, and technological and engineering advances required, SMD employed several processes much earlier in Pre-Phase A
  - Commissioned two Independent Cost/Schedule Estimates
  - Had an Independent Review Board (IRB) conduct a two-month examination of the program
  - Established the program’s Standing Review Board to conduct the MCR as an Agency review
- As a result of extensive independent review in 2020, we have a better appreciation of the challenges going forward
  - The 2026 launch date is challenging
  - The budget phasing requires adjustment

MSR was approved to proceed into Phase A in December following the IBR and the Mission Concept Review

MSR Architecture Overview



MSR Campaign

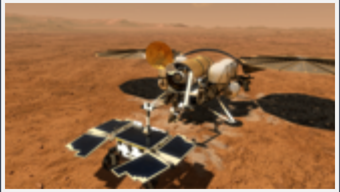
Mars Sample Return Program

1 | **2** | **3** | **4**

Sample Caching Rover (Mars 2020) Operations

- *Sample acquisition/caching*
- *Sample (subset) delivery*

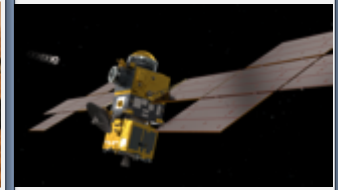
"Initiates the Campaign"



Sample Retrieval Lander

- *Fetch Rover*
- *Orbiting Sample (OS) container*
- *Mars Ascent Vehicle*

"New Element"



Earth Return Orbiter

- *Capture/Containment System*
- *Earth Return Vehicle*

"New Element"

Mars Returned Sample Handling

- *Sample Receiving Facility*
- *Curation*
- *Sample science investigations*

"New Element"

Ground Element

to be reviewed at a future date

- 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

Mars Sample Return— First Sample Return From Another Planet

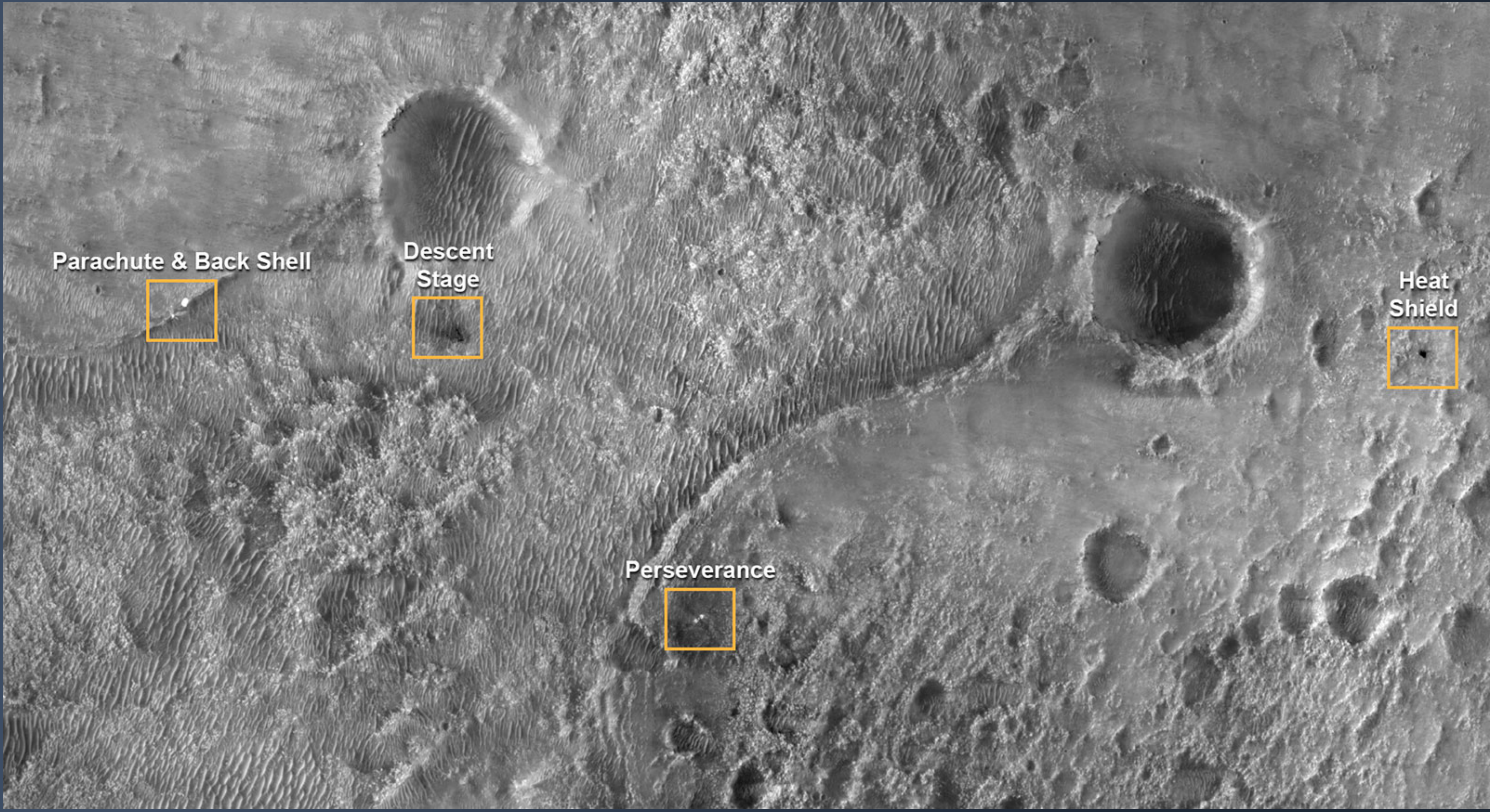
A priority since 1980 and of two National Academy Decadal Surveys
A first-step “round-trip” in advance of humans to Mars

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

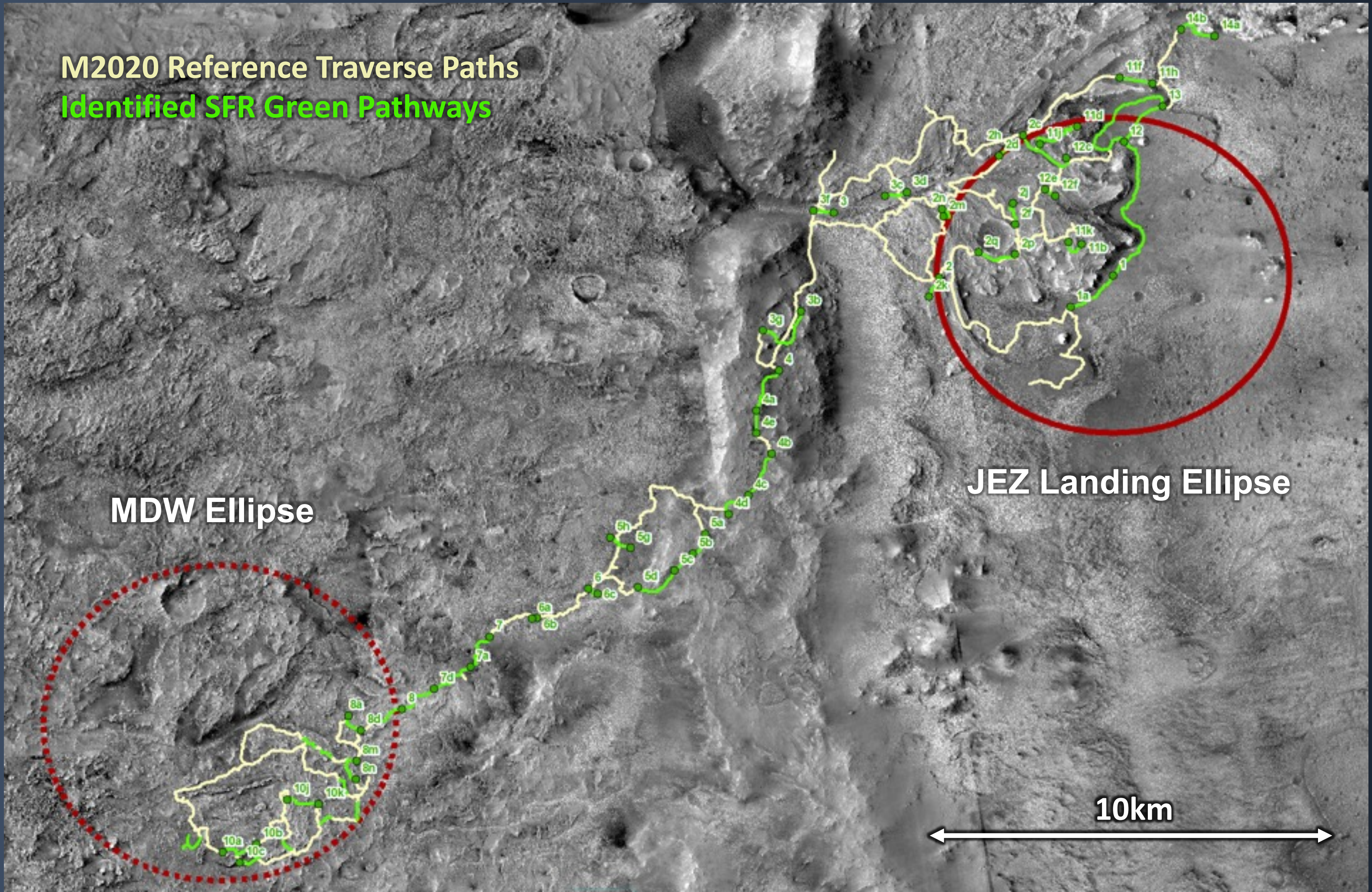
The first billion years and life’s beginning in the Solar System:
The record is on Mars

Mars Returned Sample Science

- Perseverance has landed and is capable of selecting and caching 43 samples.
  - 15 NASA/ESA Returned Sample Scientists have been competitively selected for the Perseverance Science Team.
- Caching Strategy Workshop held Jan. 2021 – recommended modifications to the Operations MOU between Perseverance and SRL.
- NASA/ESA Mars Sample Return Science Planning Group – Phase 2 (MSPG2) has been meeting weekly to develop a Science Management Plan, address science technical issues, propose a working list of high-level requirements for the Sample Return Facility, and develop a timeline of key decision points. Report expected Spring 2021
- A team (JPL & JSC) has visited 18 BioSafety Level-4 and contamination-controlled facilities to scope the containment challenges of conducting science with returned Mars samples. Report posted Nov. 2020 <http://hdl.handle.net/2014/50446>
- COSPAR Sample Safety Assessment Protocol Working Group (SSAP) with NASA and ESA members is developing a recommendation for determining when extraterrestrial samples are safe for distribution outside of containment. Progress reported at COSPAR Assembly 2021

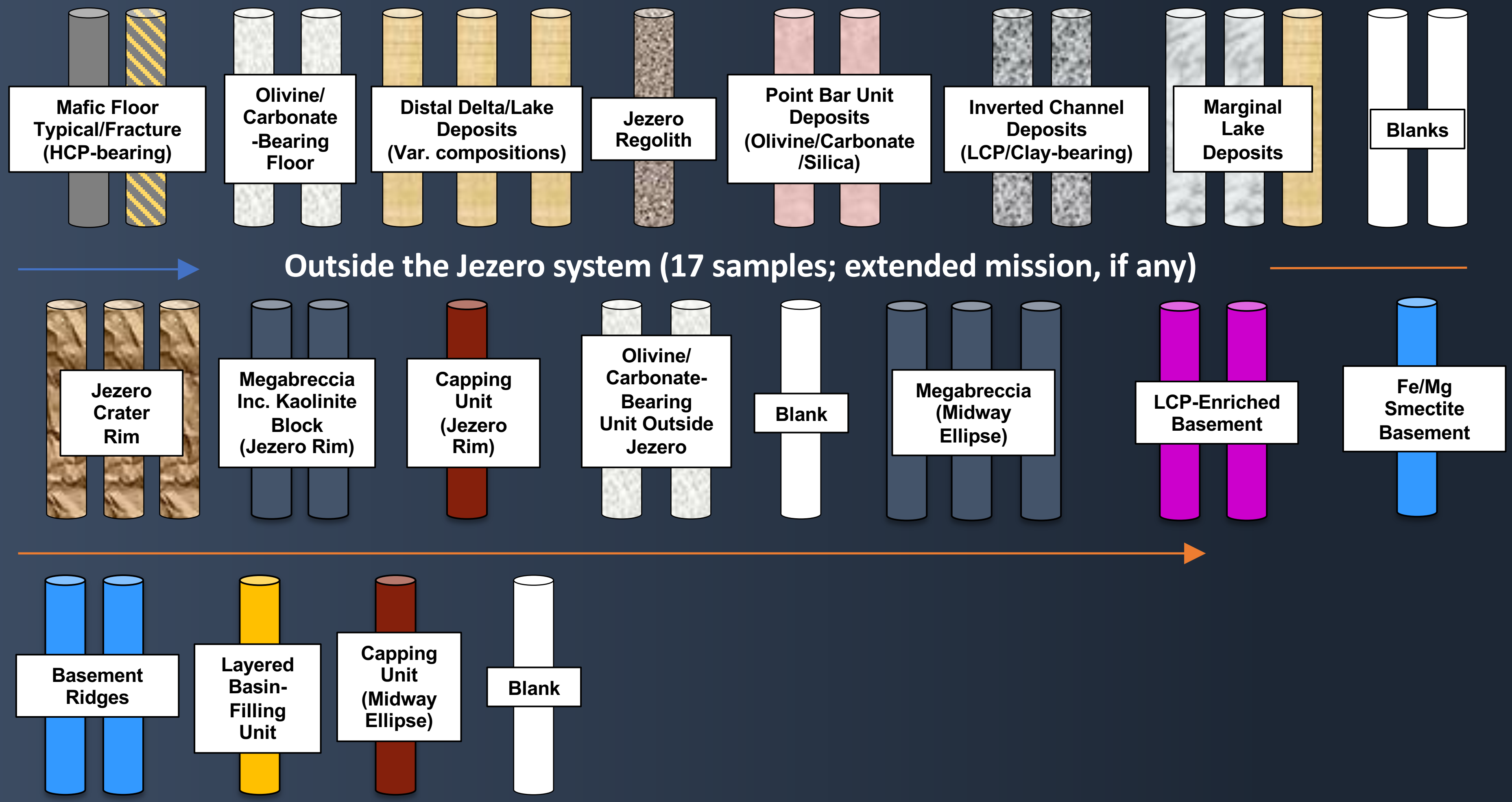

Parachute & Back Shell
Descent Stage
Heat Shield
Perseverance

Overview of Green Pathways Across Jezero-Midway Region



Diversity of Samples

Inside the Jezero system (20 samples)

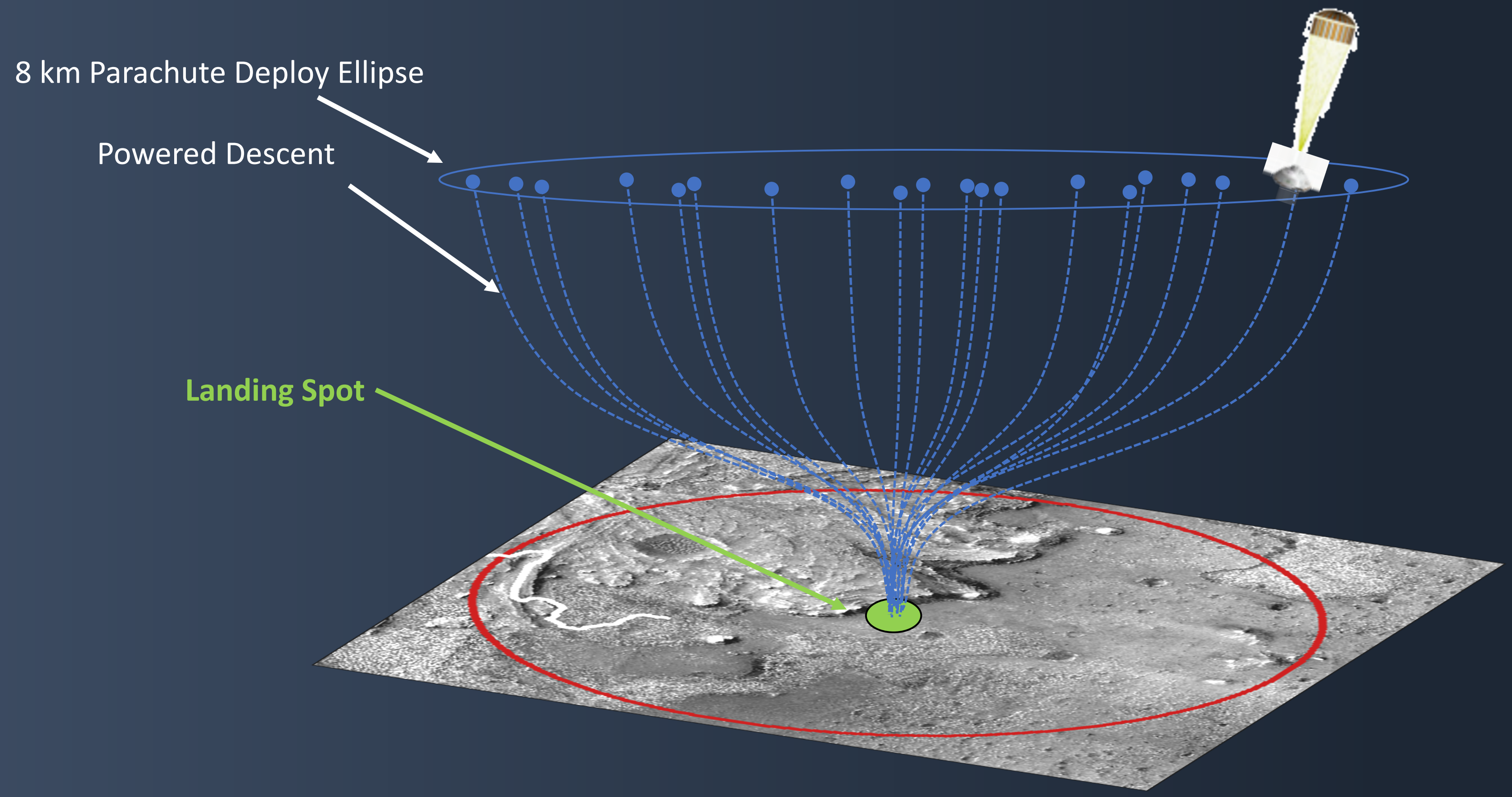


Adapted from Ken Farley (CAPS, 2019)

SRL EDL–Extended Divert

SRL will carry enough propellant to fly out the backshell separation ellipse (8 x 8 km) and land at a specific spot (~±20m accuracy)

Enables new capability of landing at a specific site pre-scouted from the Mars surface



Mars Sample Return Challenge

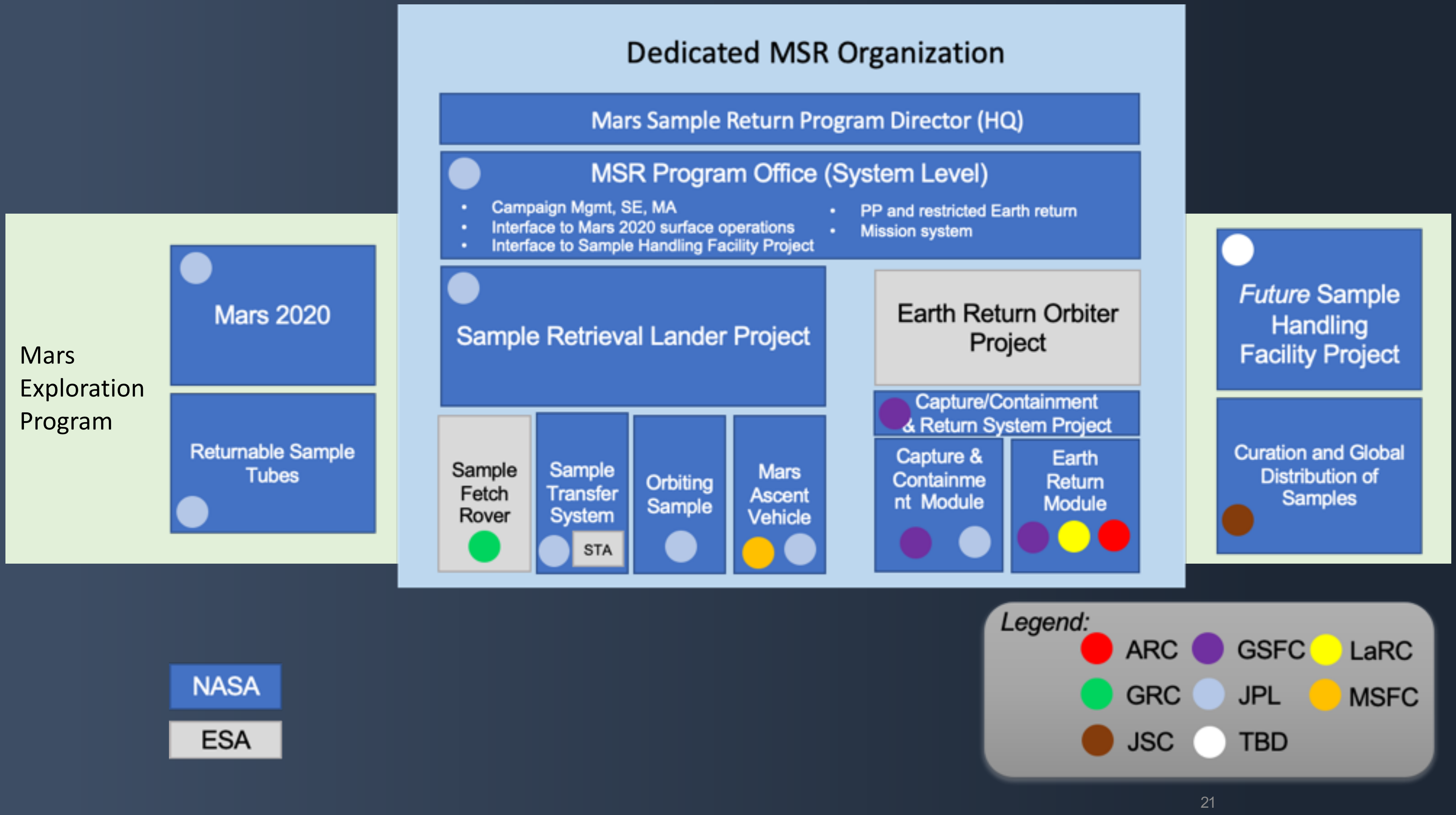
Protect the samples from Earth—

Protect the Earth from the samples

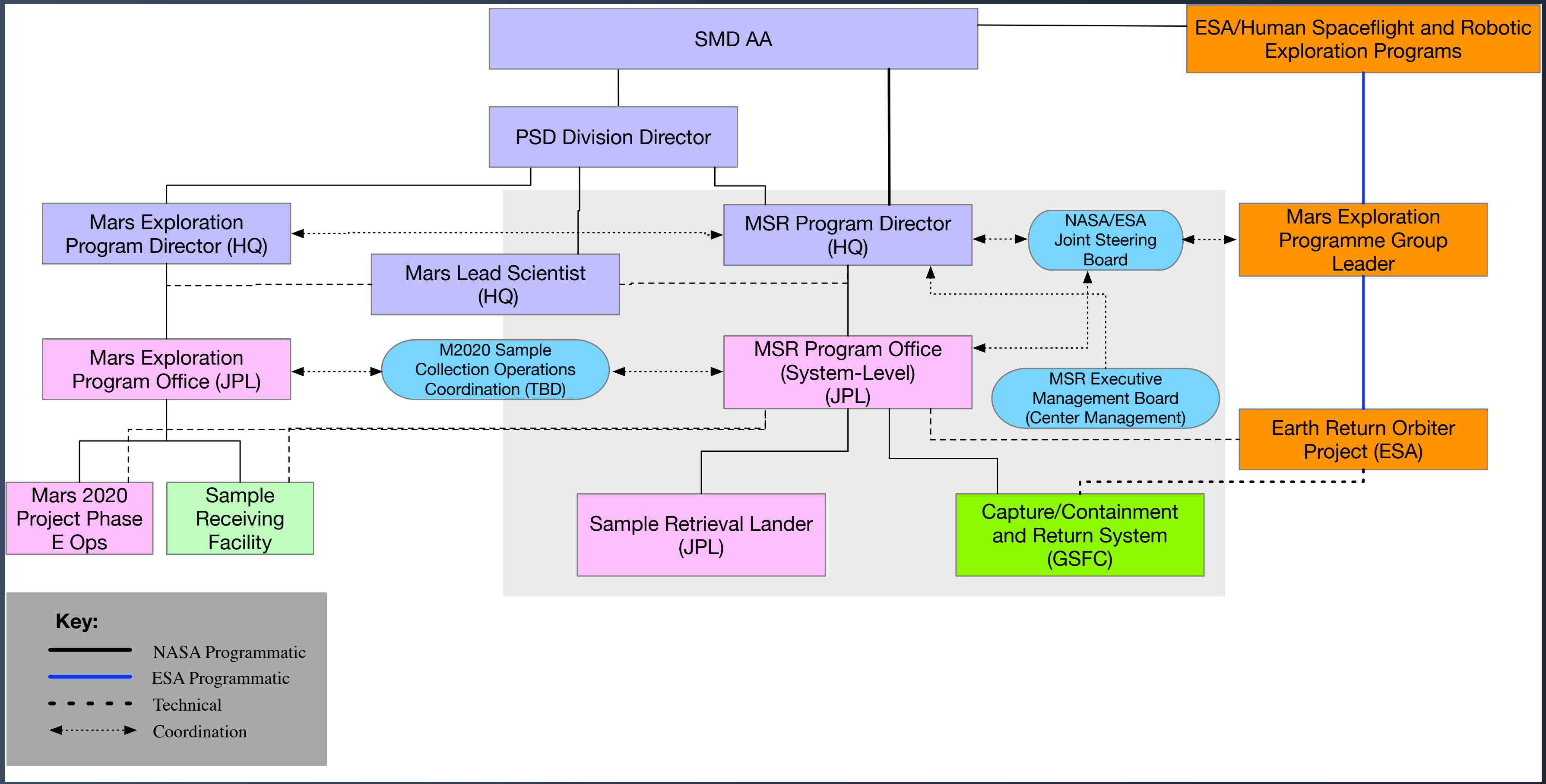
…to achieve a quantum jump

In our understanding of Mars.

MSR Program Structure



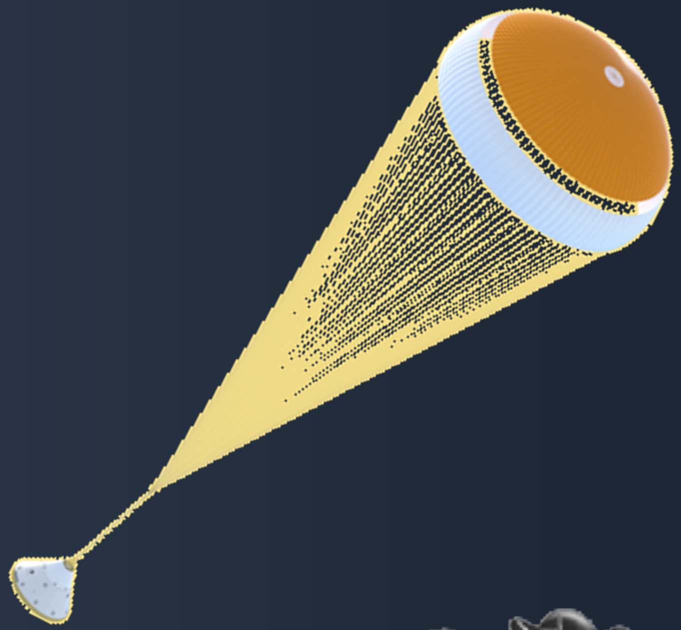
MSR Organization



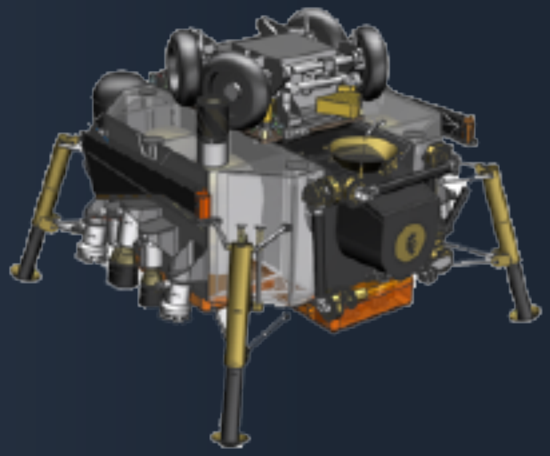
SRL Flight System Vehicle Summary

Cruise Stage (CS)
- Heritage Prop/GNC/FSW
- Redundant X-Band System with LGA and MGA

Entry Vehicle (EV)
- Heritage 4.7m Aeroshell with Backshell Mounted RCS
- Guided Entry
- 23m Parachute
- 4km Divert Capability for Pinpoint Landing
- EDL Communication via UHF System



Propulsive Platform Lander (PPL)
- Throttled-Engine Propulsive 4 Leg Platform
- Solar and Secondary Battery Power System
- Thermal Maintenance of the Mars Ascent Vehicle
- SFR Egress, STS and MAS Launch Execution
- 8 Context/Operational Cameras
- UHF Surface Communications



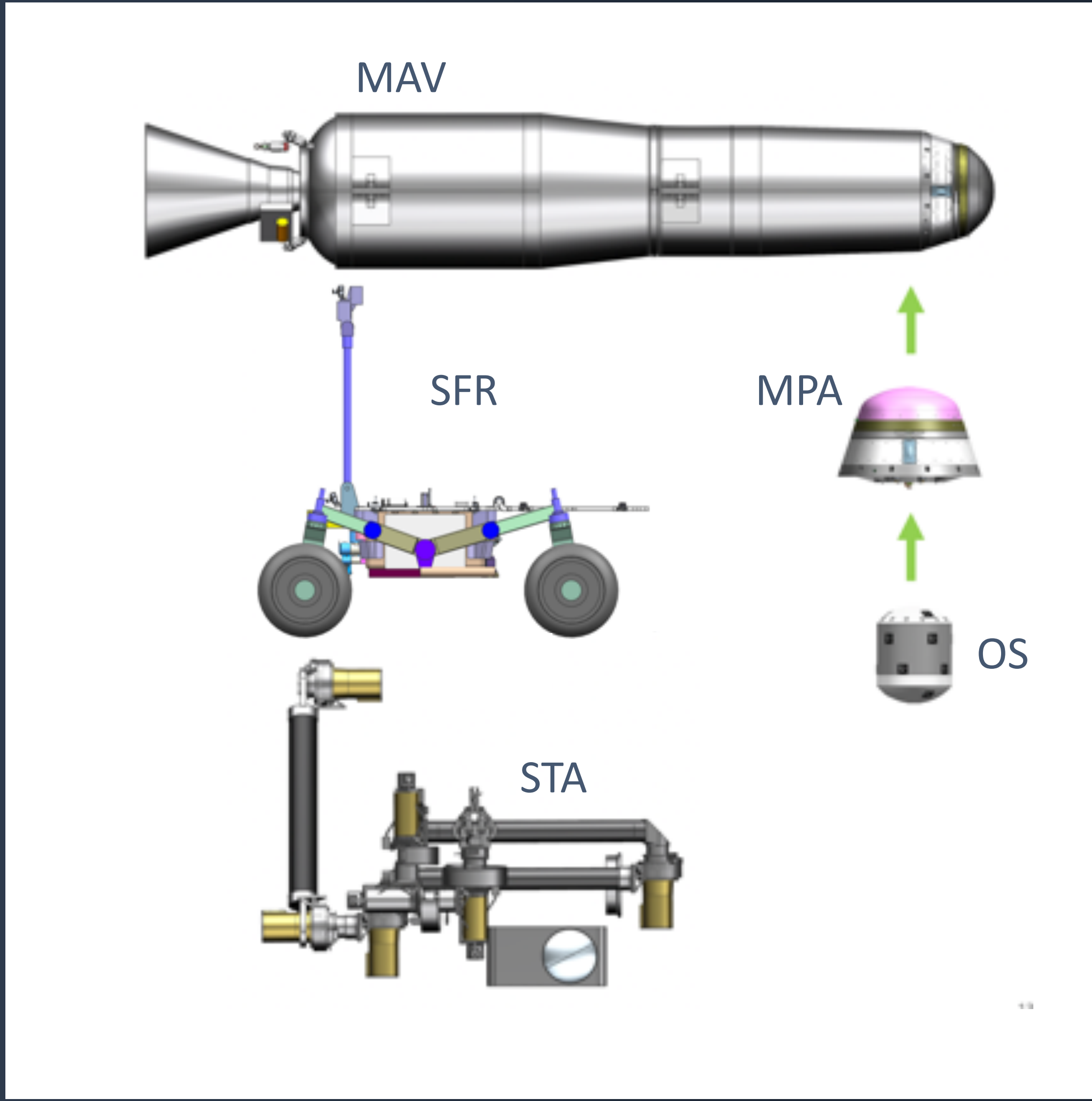
SRL Payloads

MAV
- Two stage solid rocket
- 380kg maximum mass
- 2.8 m length and 0.5m diameter
- -40 deg C non-op and -20 deg C op

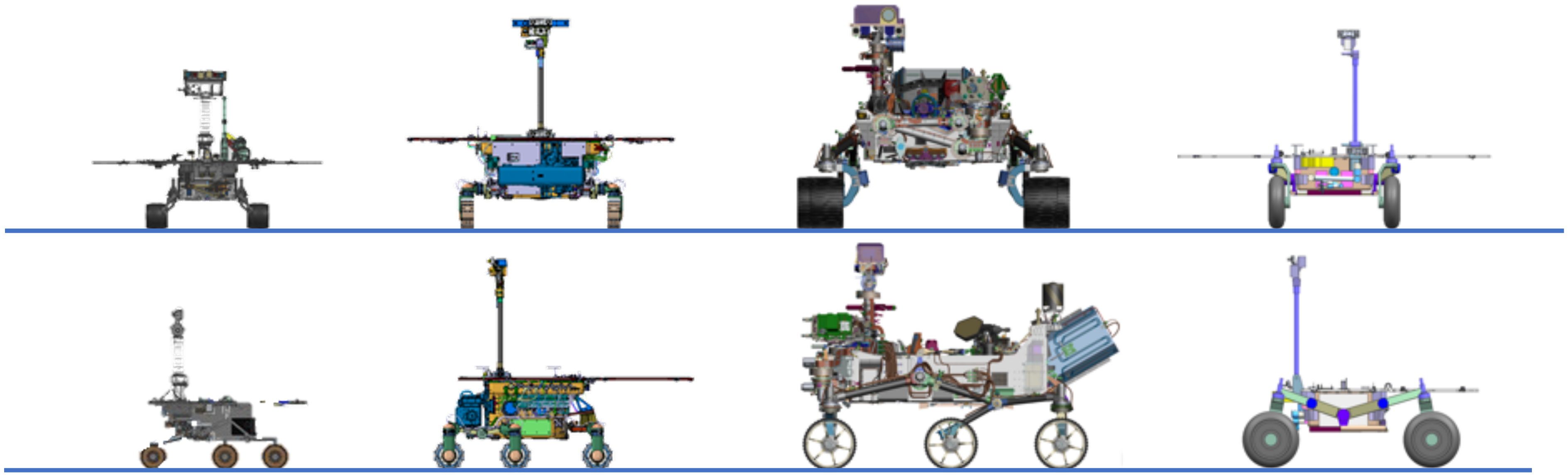
SFR
- 230kg NTE mass with specified volume envelope
- 4 wheels with 55cm diameter
- Umbilical power until power positive on surface

Sample Transfer Assembly (STA)
- 7 DOF arm to insert sample tubes & install OS
- Allow SFR and M2020 operations

Orbiting Sample (OS)
- Accommodates 30 sample tubes
- OS and MPA each have 8 kg maximum mass (51% and 88% margin, respectively)



Rover Size Comparison



MER

Mass = 173 kg

Number of wheels = 6
Wheel Diameter = 230 mm
Wheel Type = Rigid

Susp Type = Rocker-Bogie w/ internal diff

Ground Clearance = 300 mm

ExoMars

Mass = 310 kg

Number of wheels = 6
Wheel Diameter = 285 mm
Wheel Type = Compliant

Wheelbase = 1260 mm

Susp Type = 3x Bogie

Ground Clearance = est 250 mm

M2020

Mass = 1030 kg

Number of wheels = 6
Wheel Diameter = 526 mm
Wheel Type = Rigid

Wheelbase = 2260 mm

Susp Type = Rocker-Bogie w/ external diff

Ground Clearance = 584 mm

SFR

Mass = < 230 kg

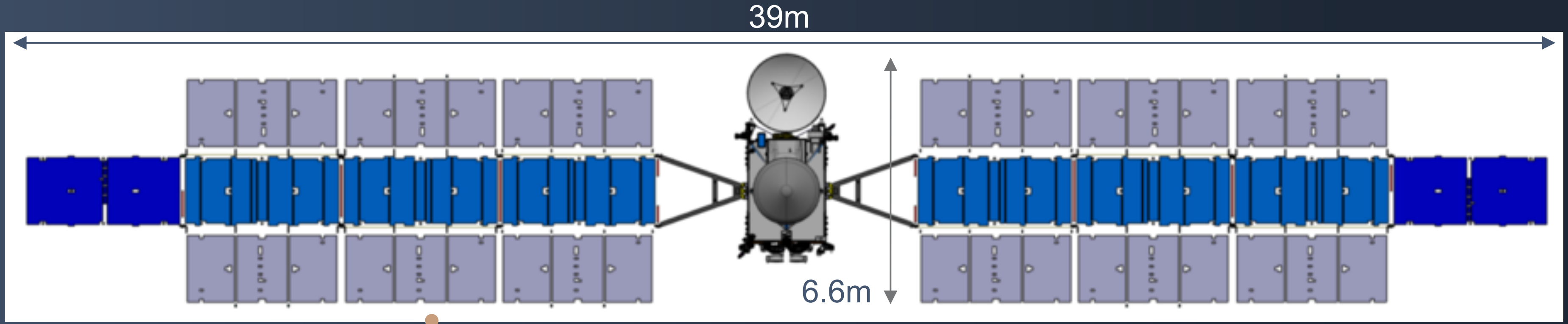
Number of wheels = 4
Wheel Diameter = 550 mm
Wheel Type = Compliant, Mesh

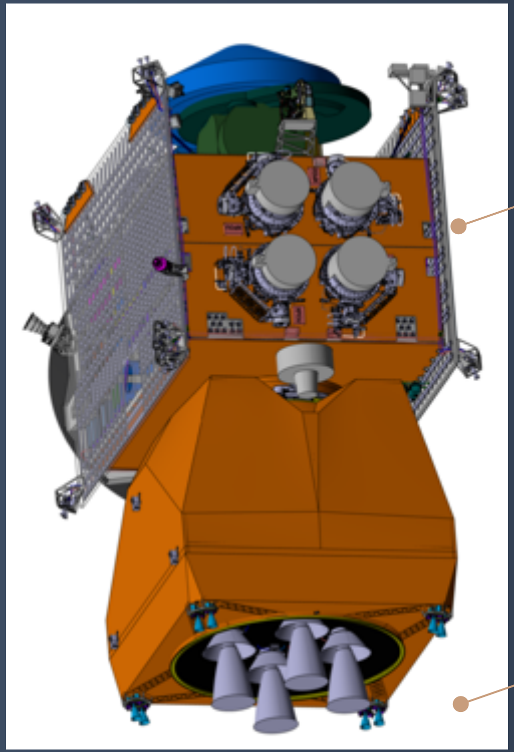
Wheelbase = 1550 mm

Susp Type = 4 wheel w/ external diff

Ground Clearance = 350 mm

ERO Anatomy



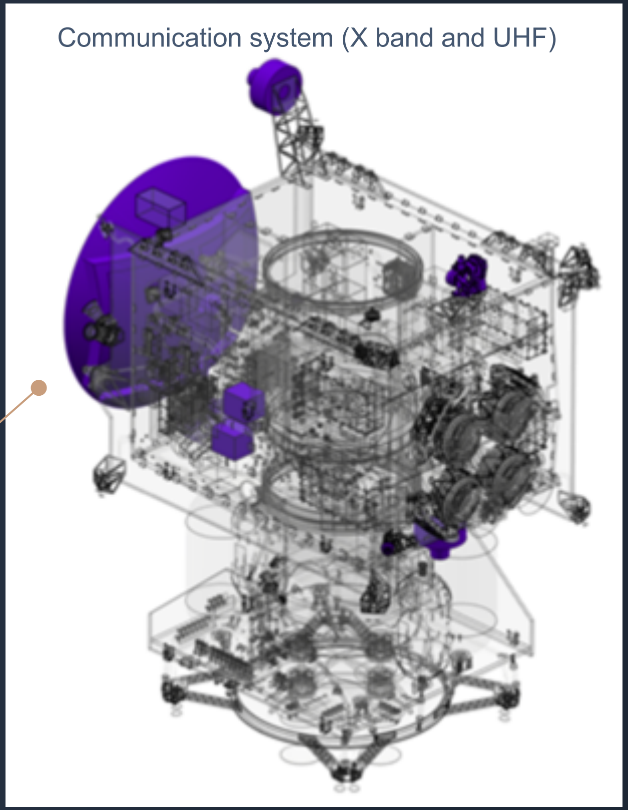


Solar Arrays:
~40 kW (at Earth, BoL), ~150 m^2

Electric Propulsion:
3 + 1 (spare)
Isp of 4000s, DeltaV ~10 km/s

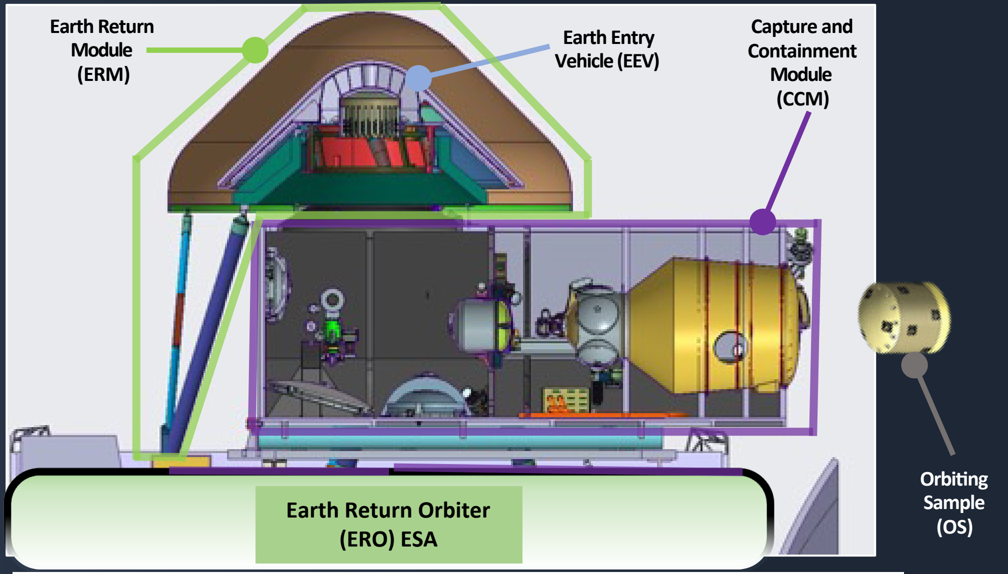
Communications:
HGA, 2DoF MGA, LGA (X-band)
UHF surface relay

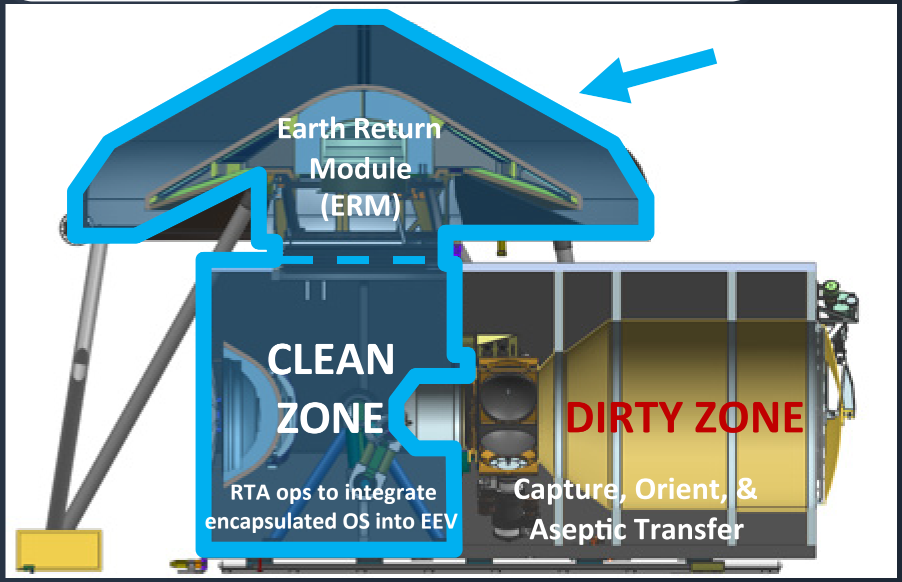
Bi-Prop Transit Stage:
Isp = 320 s



Capture, Containment and Return System (CCRS) Overview

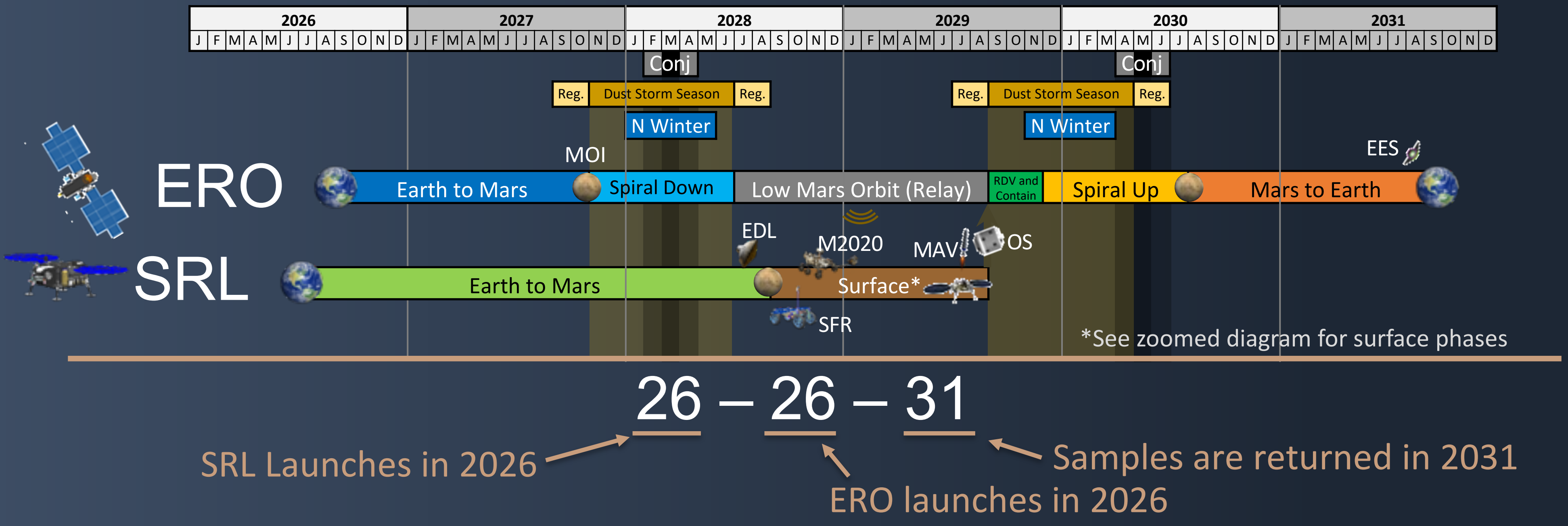
- CCRS is the payload on the ESA ERO
  - Capture the OS
  - Break-the-Chain and assure Containment
  - Deliver EES to UTTR while meeting BPP requirements
- Capture and Containment Module
  - Captures, constrains, and orients the OS
  - Transfers contained OS to the CCRS clean zone
  - Maintain clean zone integrity
- Earth Return Module
  - Protects EES from MMOD
  - Precision separation of EES
  - Passive EEV with carbon-phenolic heatshield





Capture Containment Module (CCM)

Campaign Timeline Overview



- SRL avoids winter and global dust storm season, enabling all-solar SRL/SFR
- EDL occurs in a favorable season, enabling significant SRL mass margin
- Surface operations timeline has 200% margin relative to peer-reviewed plans
- ERO (or another asset) can provide all relay services needed for MSR
- Architecture feasible across launch opportunities in the 2026-2028 timeframe.
- Next “good” opportunity for this architecture after 2028 is 2035

MSR Launch Opportunities

26/26/31 Reference Design
Slightly Worse than 26/26/31
Worse than 26/26/31
Much Worse than 26/26/31

Nomenclature: "28/27/33"

- SRL Launches in 2028
- ERO Launches in 2027
- ERO Returns in 2033

- MRN = Mars Relay Network
  - MRO, MAVEN, TGO

MSR Launch Opportunity Comparison	ERO 2026	ERO 2027-28	ERO 2029-30
SRL 2026	Return: 2031 Favorable EDL Atmosphere Solar-Only SRL/SFR Heavy SRL Launch Vehicle Relay: ERO & MRN MAS Launch Observed Reference ERO Traj ERO: 5 years M2020: 7 years Backup Does Not Require Redesign	Return: 2033 Favorable EDL Atmosphere Solar-Only SRL/SFR Heavy SRL Launch Vehicle Relay: MRN MAS Launch NOT Observed Similar ERO Traj ERO: 6 years M2020: 7 years Backup Requires Redesign	Return: 2037 Favorable EDL Atmosphere Solar-Only SRL/SFR Heavy SRL Launch Vehicle Relay: MRN MAS Launch NOT Observed More Challenging ERO Traj ERO: 9 years M2020: 7 years Backup Does Not Require Redesign
SRL 2028	Return: 2033 Favorable EDL Atmosphere Solar-Only SRL/SFR Super Heavy SRL Launch Vehicle Relay: ERO & MRN (+2 years) MAS Launch Observed Easier ERO Traj ERO: 7 years M2020: 9 years Backup Requires Redesign	Return: 2033 Favorable EDL Atmosphere Solar-Only SRL/SFR Super Heavy SRL Launch Vehicle Relay: ERO & MRN (+2 years) MAS Launch Observed Similar ERO Traj ERO: 6 years M2020: 9 years Backup Requires Redesign	Return: 2037 Favorable EDL Atmosphere Solar-Only SRL/SFR Super Heavy SRL Launch Vehicle Relay: MRN (+2 years) MAS Launch NOT Observed More Challenging ERO Traj ERO: 9 years M2020: 9 years Backup Requires Redesign
SRL 2030	Return: 2037 Unfavorable EDL Atmosphere **Nuclear SRL/SFR** Super Heavy SRL Launch Vehicle Relay: ERO & MRN (+5 years) MAS Launch Observed Similar ERO Traj ERO: 11 years **M2020: 12 years** Backup Does Not Require Redesign	Return: 2037 Unfavorable EDL Atmosphere **Nuclear SRL/SFR** Super Heavy SRL Launch Vehicle Relay: ERO & MRN (+5 years) MAS Launch Observed Similar ERO Traj ERO: 10 years **M2020: 12 years** Backup Requires Redesign	Return: 2037 Unfavorable EDL Atmosphere **Nuclear SRL/SFR** Super Heavy SRL Launch Vehicle Relay: ERO & MRN (+5 years) MAS Launch Observed More Challenging ERO Traj ERO: 9 years **M2020: 12 years** Backup Does Not Require Redesign

- The MOU between ESA and NASA targets the launch of both the SRL and ERO missions (on separate launch vehicles) in 2026, utilizing the remaining possibilities as backup launch dates
- MSR architecture allows for launch of the NASA SRL mission in either the 2026 or 2028 launch opportunity and the launch of the ESA ERO mission and its NASA CCRS payload in either 2026, 2027 or 2028
- The mission architecture provides for return of the samples to the Sample Retrieval Lander via both the ESA Sample Fetch Rover and Perseverance, providing redundancy
  - Delays impact the probability of Perseverance remaining operational, reducing surface sample transfer options and adding risk

<u>For this architecture</u>, next "good" opportunity after 2028 is 2035

- SRL Launches after 2028 and before 2035 requires architecture modifications
  - Need for nuclear power source on SRL and radioisotope heating on SFR
  - Further backup options involve costly architecture changes

Independent Review Board Summary Recommendations

- IRB Top Six Recommendations

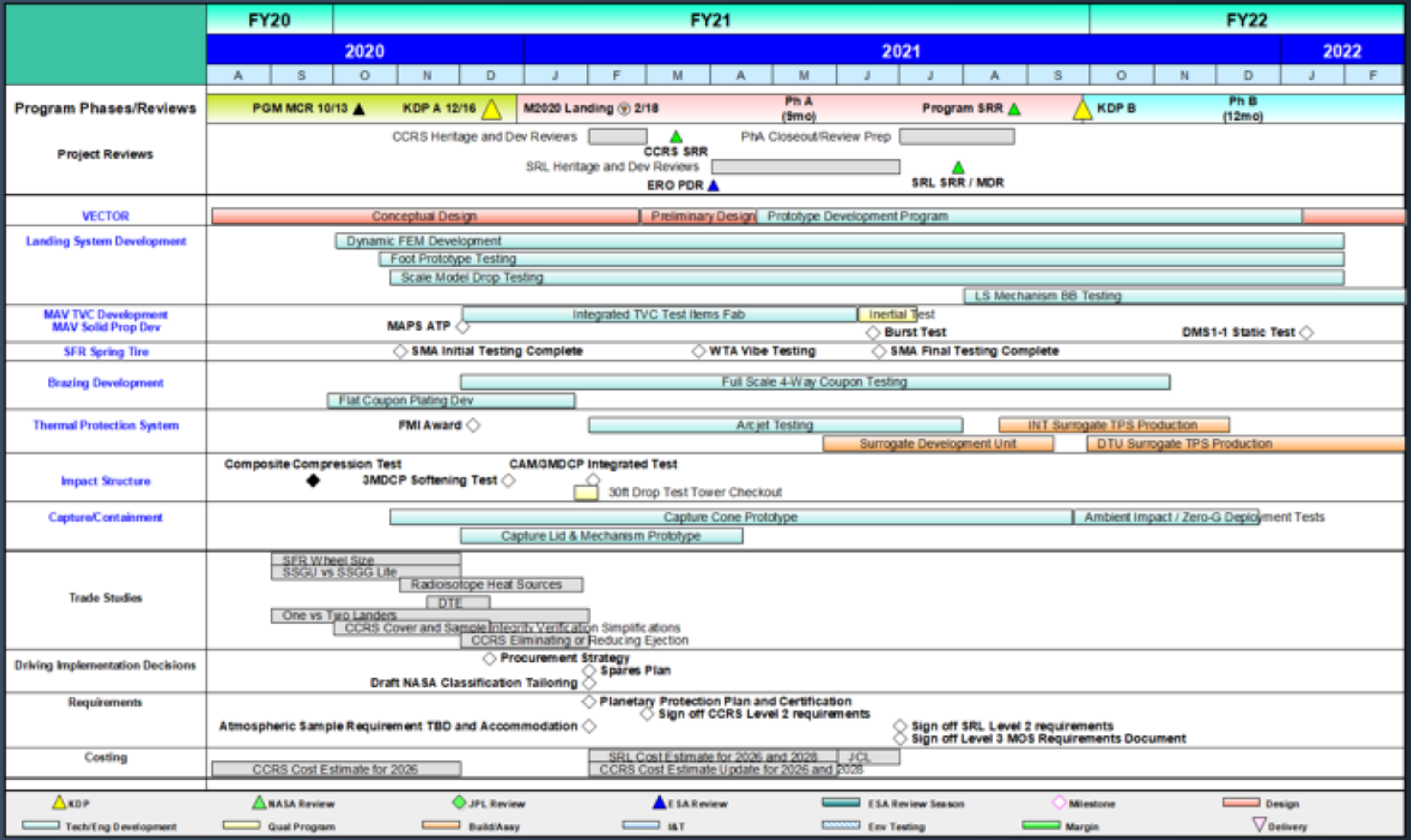
Recommendation	Planned MSR Action
1. ***Further explore mission architectural and vehicle options*** as currently planned 2026 MSR launch schedules are not compatible with NASA's Class A/Category 1 mission risk levels and planned Phase A trade studies need enhancement (e.g. one/two lander trade, risk reduction trades for MAV, SFR, CCRS and OS)	***This work is planned for Phase A.***
2. ***Replan the program for SRL and ERO launches in 2028*** with the potential of a 2027 ERO launch continuing to be studied for feasibility and potential benefits.	***The project is maintaining a schedule through PDR with 2026 LRD and will reevaluate at KDP-B***
3. ***Maintain the current schedule to PDR in order to minimize technical and schedule risk.***	***The project is maintaining a schedule through PDR with 2026 LRD and will reevaluate at KDP-B***
4. ***Increase the budget to reflect a most-probable Phase A-D cost between $3.8-4 .4 billion***. Includes increasing the 2022-2024 Fiscal Year (FY) budget profile by a total of approximately $500 million	***Budget being worked through Agency processes***
5. ***Simplify current Center organizational roles and responsibilities, which are unduly complex.***	***Review in progress; expecting a ΔASM in early 2021***
6. ***Consolidate HQ program management of MSR and M2020, and integrate the science and operations of both missions***	***Program will develop a M2020/MSR integration plan in Phase A but HQ program management will remain separate***

Summary

- With launch and successful landing of Perseverance, the MSR Campaign is underway
- This is the most important planetary science undertaking in a generation
- Organizational responsibilities are defined and team is moving out
  - MOU signed; full partnership with ESA
- Through the pre-phase A effort, the team developed a feasible baseline and broad set of options
  - Mission is technically constrained to launch in the 2026-2028 timeframe
  - M2020 has agreed to place surface samples in green zones enabling our surface operations strategy
- Program cost range analyses are aligned with internal and external ICEs
  - FY22 and FY23 funding are significant challenges to 2026 LRD
- The time is now to leverage investments and technology advances
- Team is working to mature architecture in Phase A
  - Close trades
  - Demonstrate viability on technology and engineering developments
  - Refine cost and schedule estimates with institutional commitments and updated FY22 budget profile
  - Continue refinement of backup LRD planning

Phase A Plan

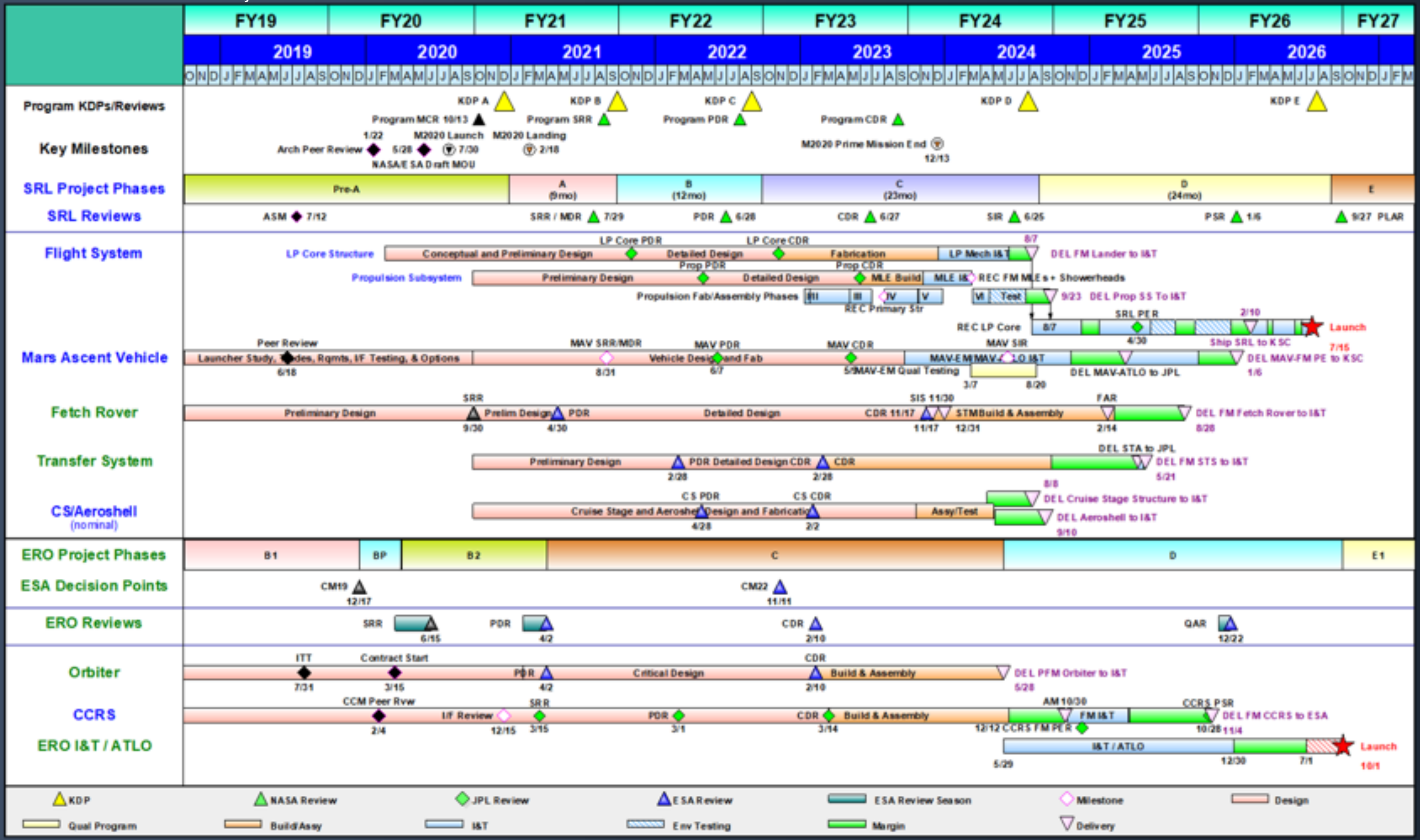
BLUE: Work Performed by NASA
GREEN: Work Performed by ESA



- Detailed Phase A plan in place with KDP-B planned for September 2021
- FY21 funding aligned with Plan
- Phase A Objectives:
    - Address SRB, IRB and LMS recommendations
    - Close out major trades and implementation decisions to solidify SRR/MDR baseline
    - Mature Engineering and Technology developments to confirm viability
    - Converge upon Class A tailoring, Spares, Procurement and PP classification approaches
    - Complete requirements flowdown
    - Refine cost estimate via integrated grass roots cost update for 2026 and 2027/2028 LRDs
    - Solidify Phase B plan and align to FY22 funding level (once known)

MSR Program Summary Schedule

BLUE: Work Performed by NASA
GREEN: Work Performed by ESA



- Program IMS established in pre-Phase A
- Program is tracking schedules and critical path margins across integrated system to assure risks are identified and institutional requirements are maintained
- Overall margins managed through Program IMS and MSR schedule management process
- Schedule margins meet or exceed institutional requirements for 2026 LRD
- Plan requires completion of PDR by the end of FY22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