National Aeronautics and Space Administration

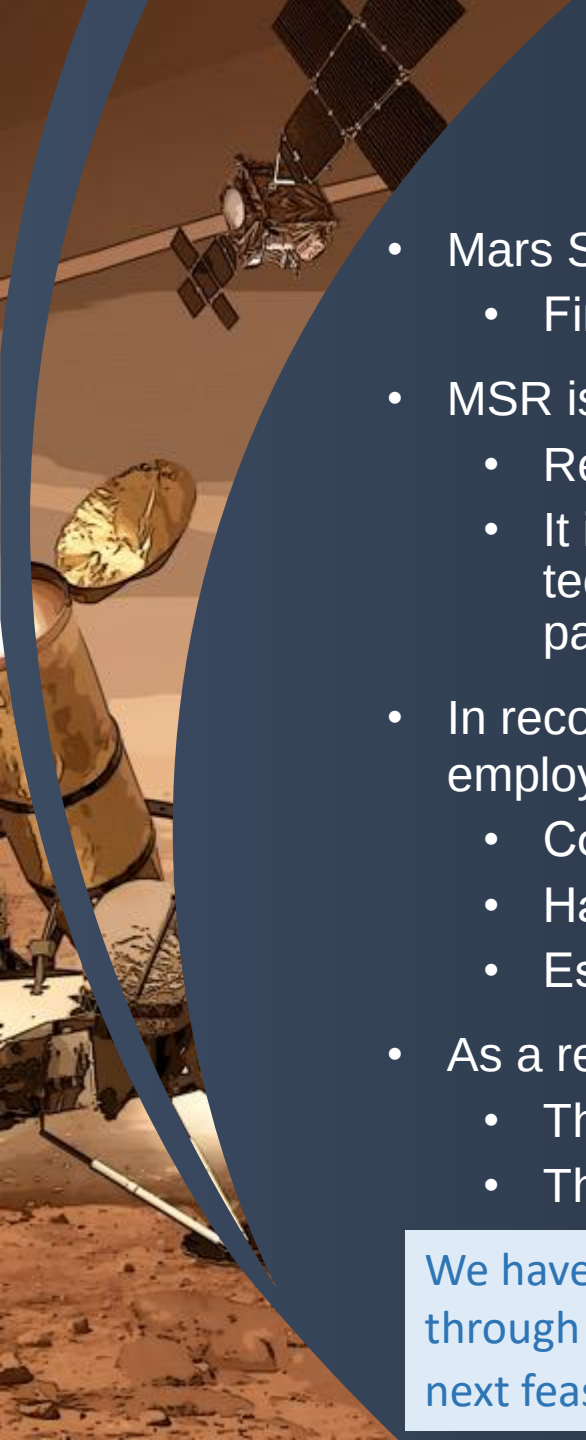
EXPLORE MARS SAMPLE RETURN

Jeff Gramling, MSR Program Director, NASA/HQ
Michael Meyer, Mars Lead Scientist, NASA/HQ
Bobby Braun, MSR Program Manager, JPL

Presentation to the MEPAG

January 27, 2021



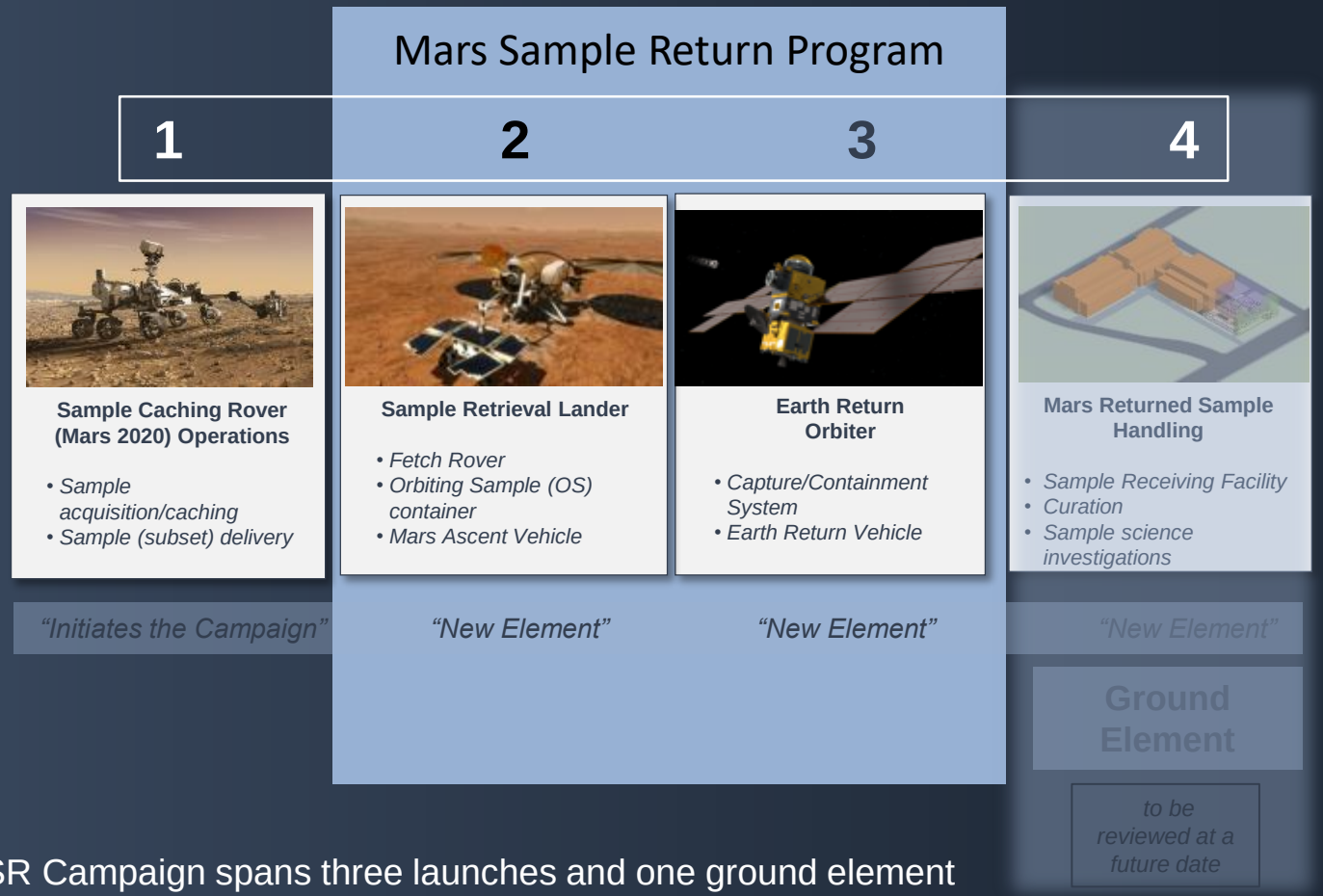


Introduction

- 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 intense, independent review in 2020, we better understand our challenges forward
  - The 2026 launch date is challenging
  - The budget phasing requires adjustment

We have the right team and a strong international partnership. We have validated our approach through unprecedented scrutiny in Pre-Phase A. We can launch in 2026 or in 2028. After 2028, the next feasible opportunity is 2035. **The time to execute MSR is now**

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

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

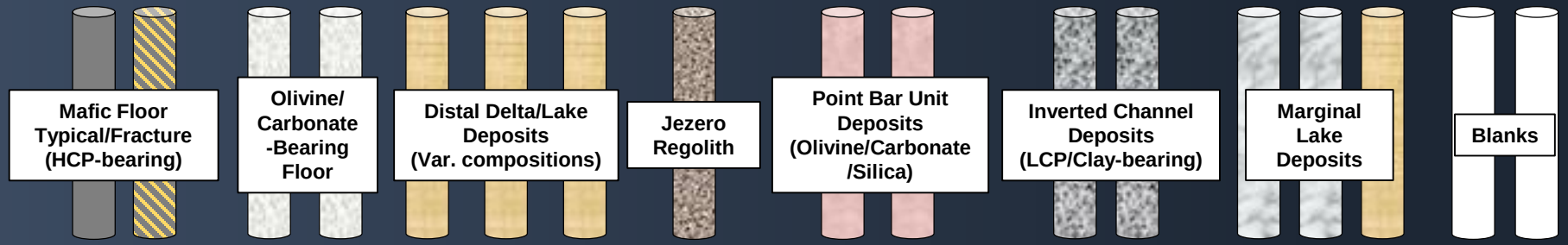
Mars Returned Sample Science

- Mars Exploration Program has established the intellectual foundation and the engineering capability to characterize a region on Mars and to scientifically select samples worthy of sample return.
- Perseverance is capable of selecting and caching 43 samples. 15 NASA/ESA Returned Sample Scientists have been competitively selected for the Perseverance Science Team.
- 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 Oct. 2020 <http://hdl.handle.net/2014/50446>
- NASA/ESA Mars Sample Return Science Planning Group – Phase 2 (MSPG2)* will 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
- 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. Report out Jan/Feb 2021
- A Sample Caching Strategy Workshop is planned for Jan. 2021.

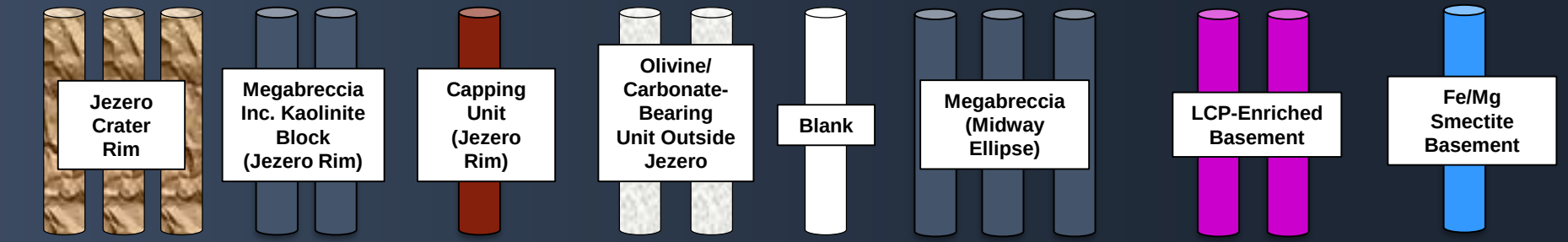
** MSPG report Nov 2019* <https://mepag.jpl.nasa.gov/reports.cfm?expand=mspg>

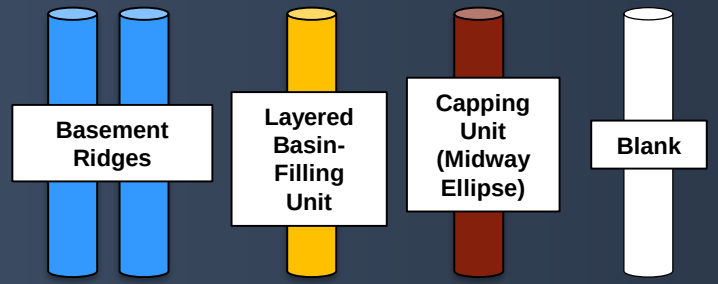
Diversity of Samples

Inside the Jezero system (20 samples)



Outside the Jezero system (17 samples; extended mission, if any)





Adapted from Ken Farley (CAPS, 2019)

Mars Sample Return Challenge

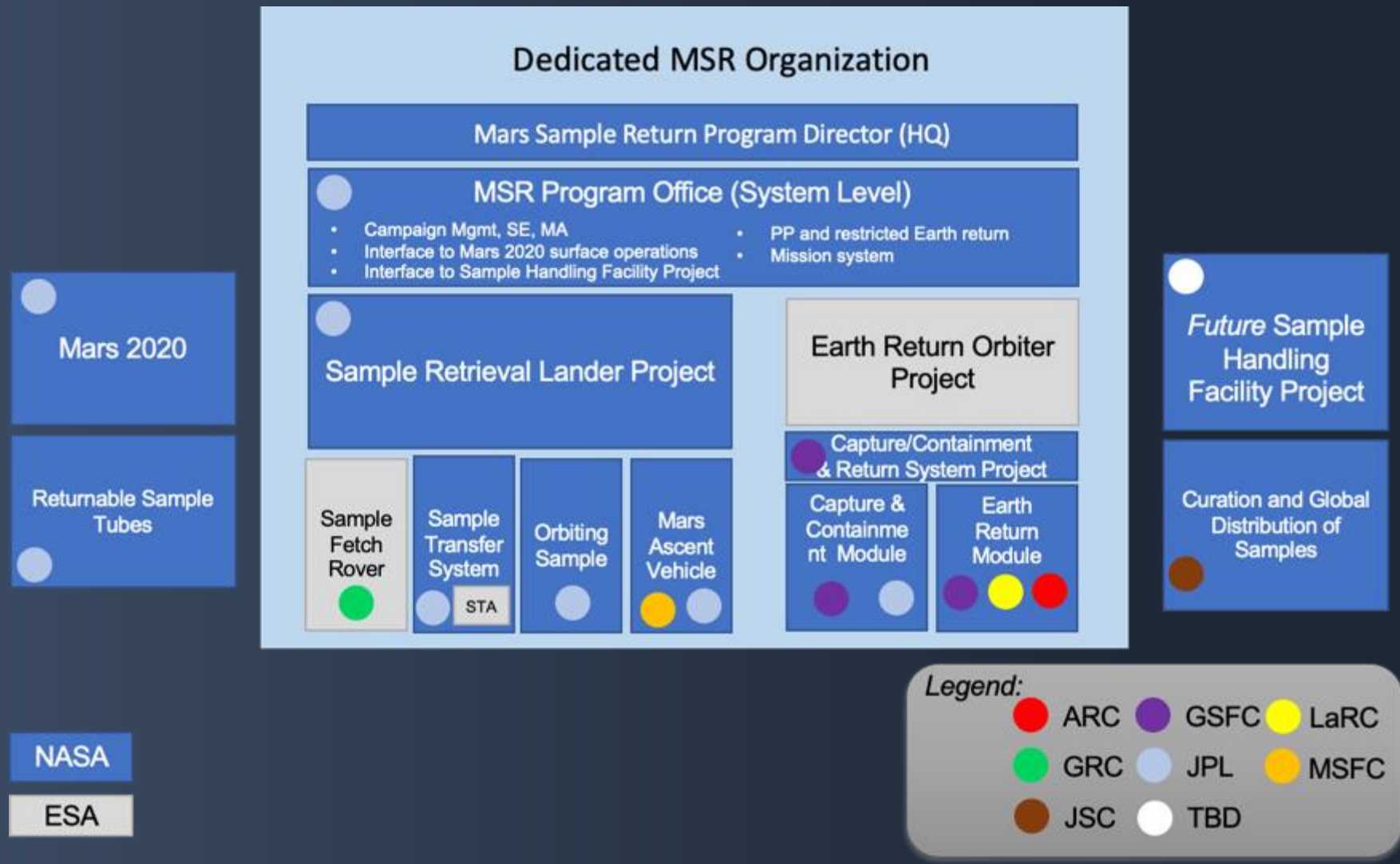
Protect the samples from Earth—

Protect the Earth from the samples

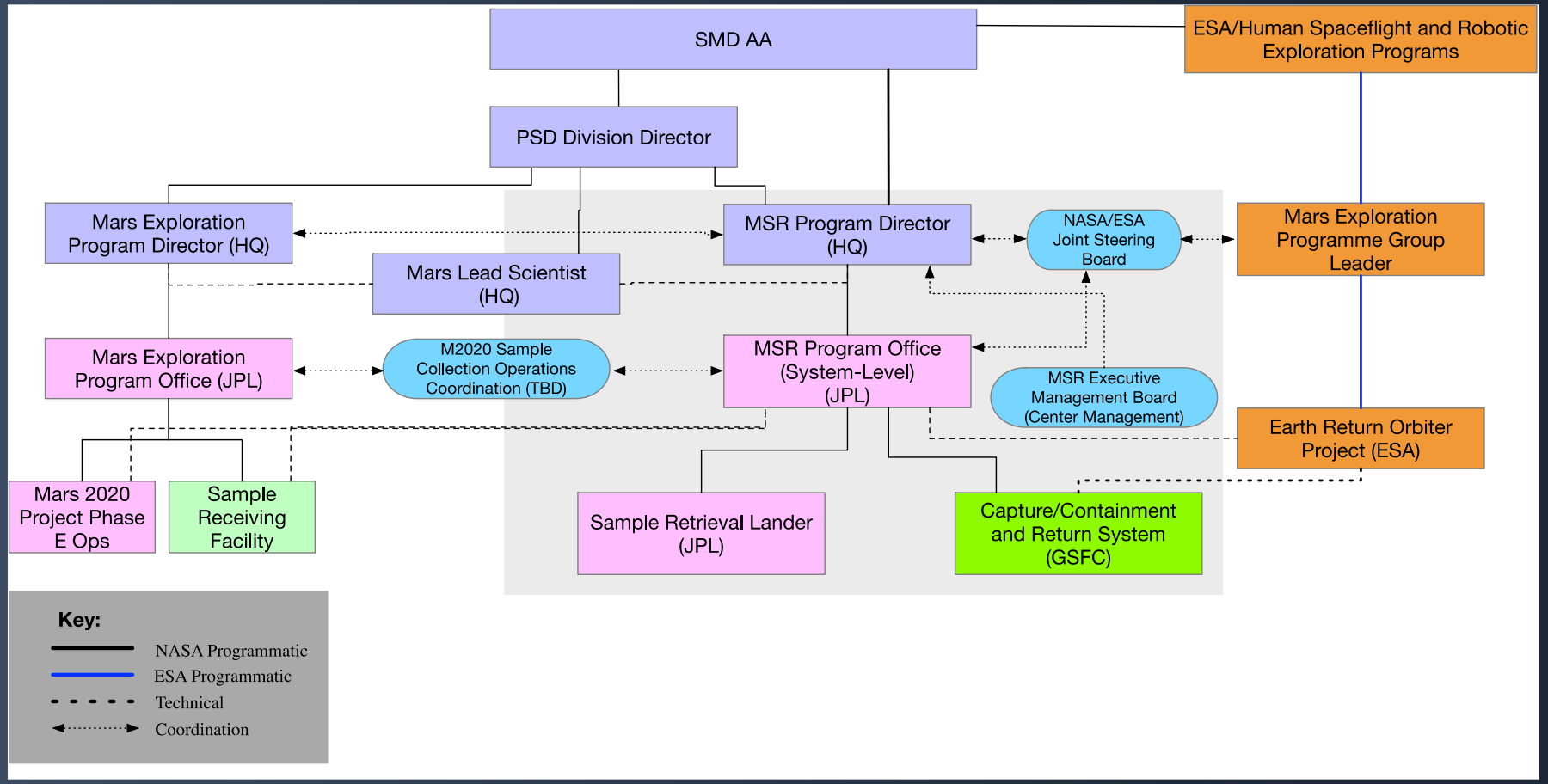
…to achieve a quantum jump

In our understanding of Mars.

MSR Program Structure



MSR Organization



Integration with M2020 and Sample Receiving Facility

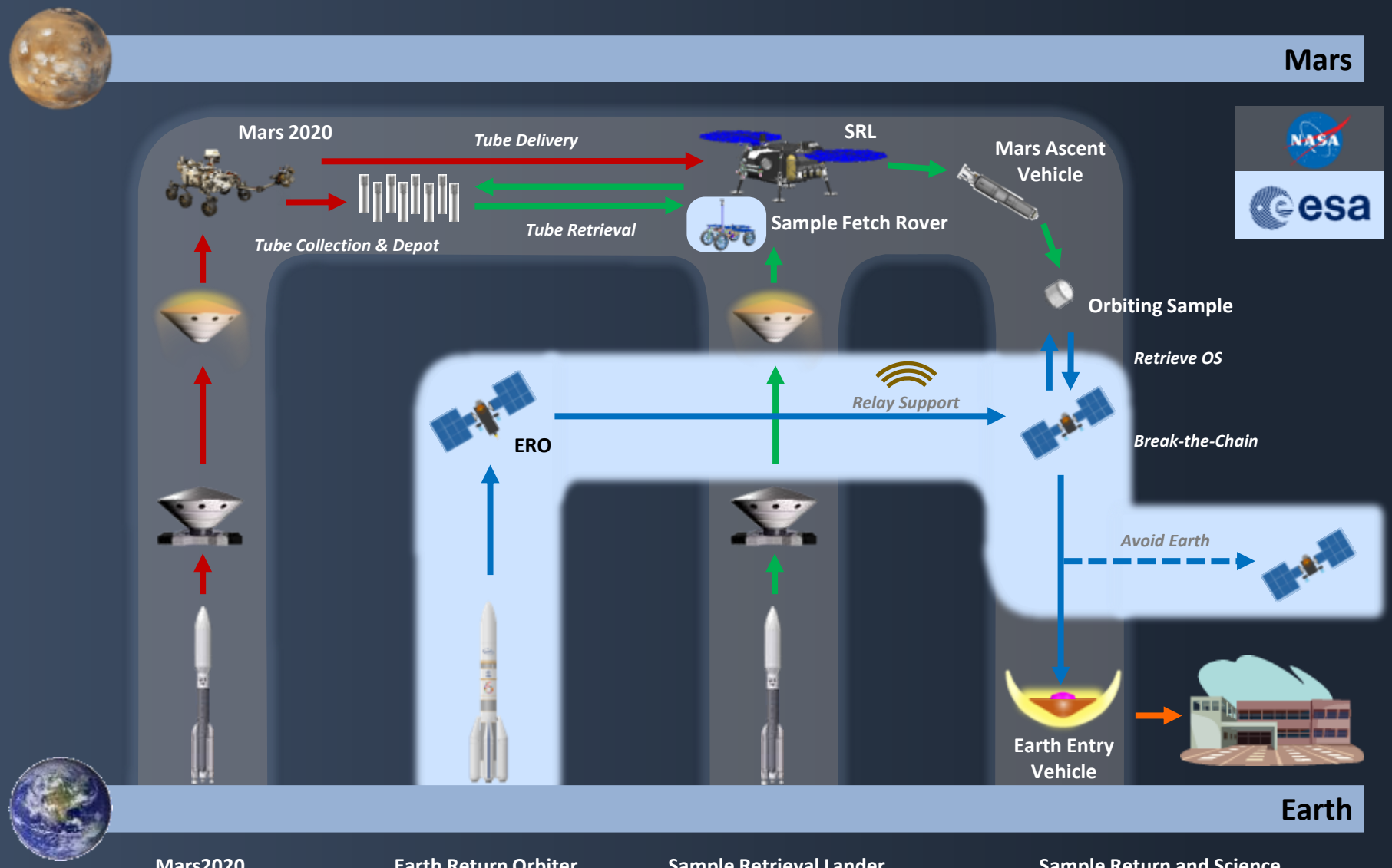
- MSR Program does not include M2020 or the Sample Receiving Facility (SRF), but interfaces and integration with those activities are critical to MSR success
- Program SE&I will balance capabilities and risks across M2020, SRL, ERO, and SRF
- Interface with M2020 (part of Mars Exploration Program (MEP)):
  - Focus on depot strategy and M2020 operations guidelines
  - Joint concept of operations working group with M2020 was conducted throughout 2019
  - October 2020 interface meeting included productive exchange of latest strategies for surface operations. Resulted in general agreement on draft MOU between MEP and MSR Programs with regards to M2020 operations
- Interface with SRF (part of MEP):
  - Initial programmatic and technical drivers on MSR from the receiving facility developed during the MSR Pre-Project phase through engagement with MEP as the proxy for the future SRF project
  - Plan to engage SRF as soon as this effort is stood up to mature associated interfaces, requirements, constraints (to be captured in associated MOU between MEP and MSR Programs)

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***

MSR Architecture Overview



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

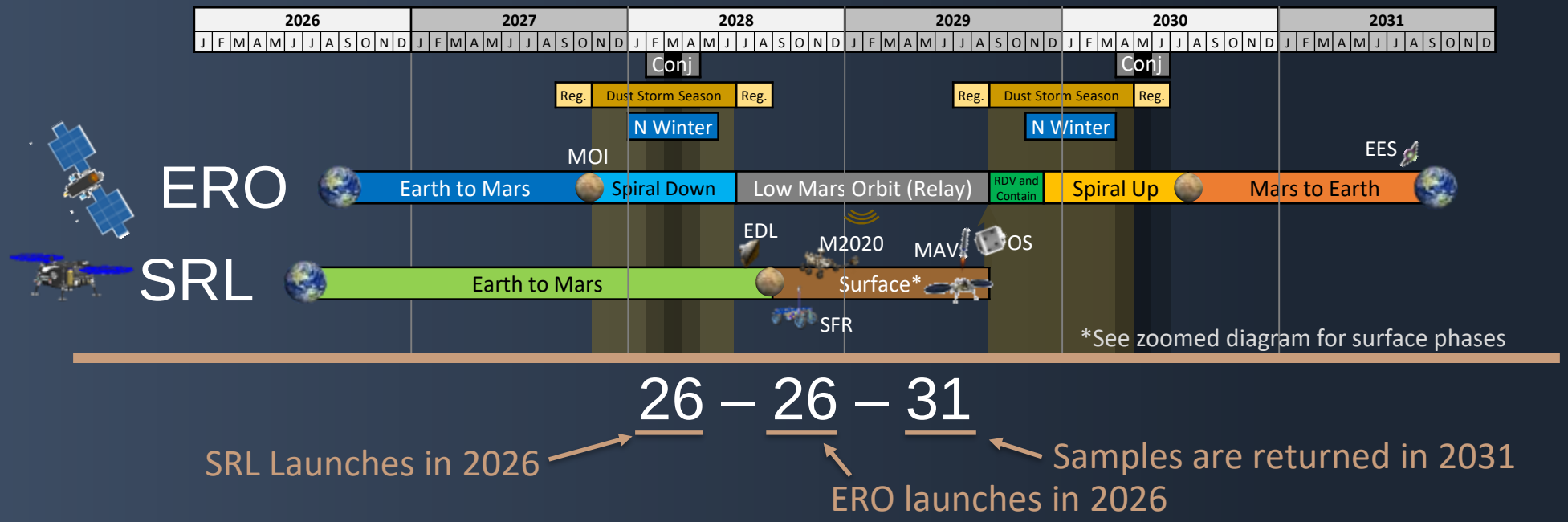


MSR Launch Opportunity Comparison	ERO: 2026	ERO: 2027-28	ERO: 2029-30
SRL: 2026	Return: 2031 Favorable EDL Atmosphere Solar-Only SRL/SFR Heavy SRL Launch Vehicle Relay: ERO & MRN MAS Launch Observed Reference ERO Traj ERO: 5 years M2020: 7 years Backup Does Not Require Redesign	Return: 2033 Favorable 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

For this architecture, 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

Campaign Timeline Overview



26 – 26 – 31

SRL Launches in 2026

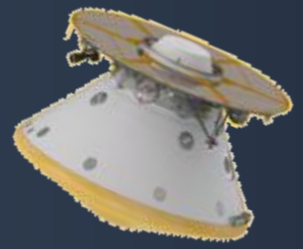
ERO launches in 2026

Samples are returned in 2031

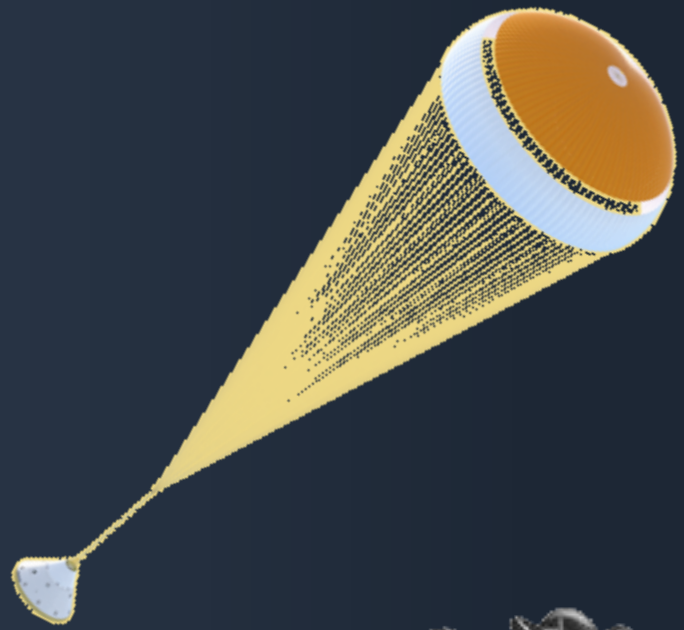
- SRL avoids winter and global dust storm season, enabling all-solar SRL/SFR
- EDL occurs in a favorable season, enabling significant SRL mass margin
- Surface operations timeline has 200% margin relative to peer-reviewed plans
- ERO (or another asset) can provide all relay services needed for MSR
-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

SRL Flight System Vehicle Summary

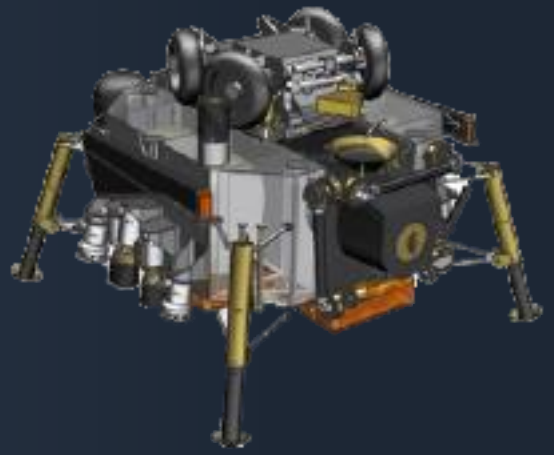
Cruise Stage (CS)
- Heritage Prop/GNC/FSW
- Redundant X-Band System with LGA and MGA



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



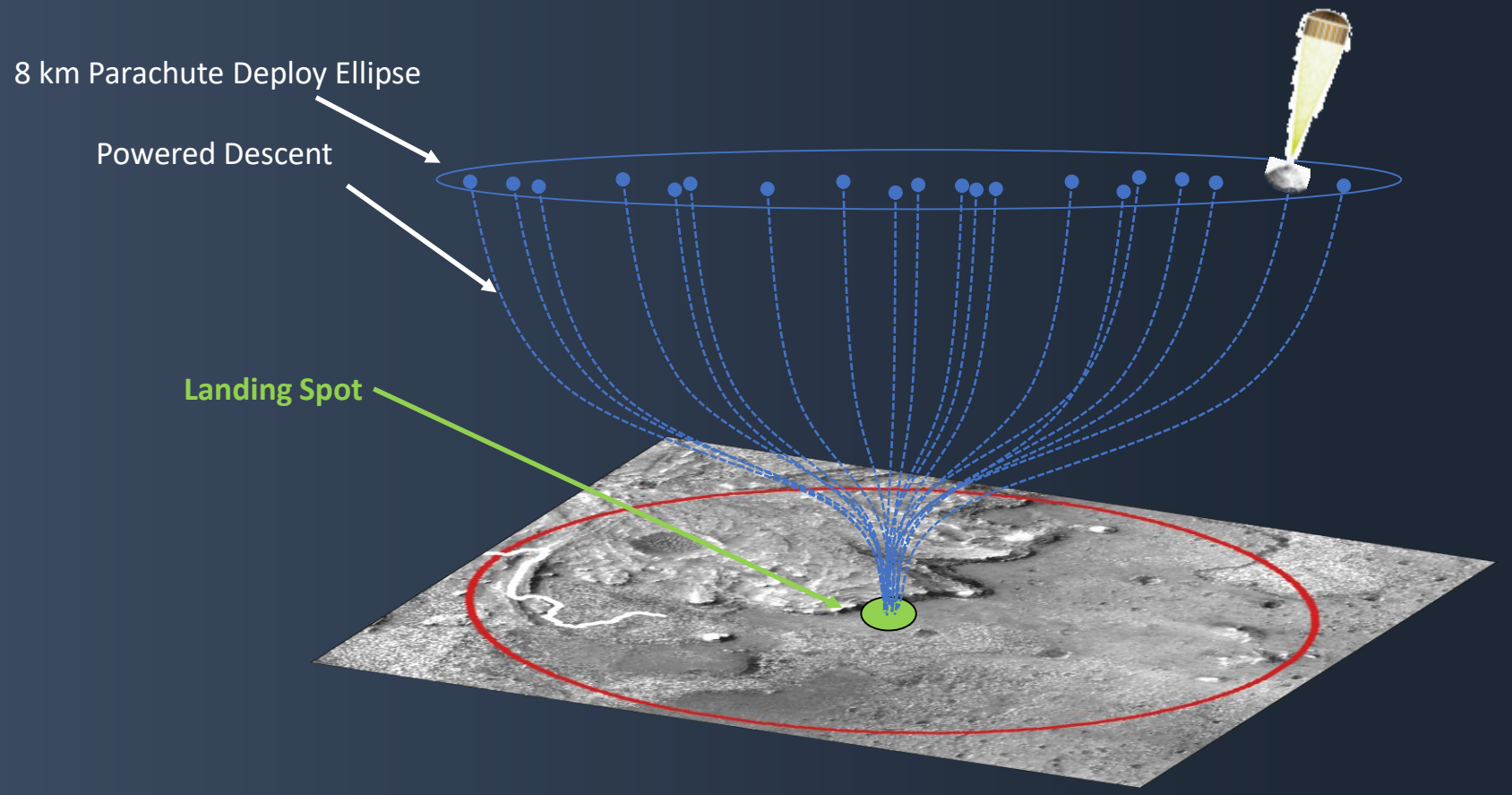
Propulsive Platform Lander (PPL)
- Throttled-Engine Propulsive 4 Leg Platform
- Solar and Secondary Battery Power System
- Thermal Maintenance of the Mars Ascent Vehicle
- SFR Egress, STS and MAS Launch Execution
- 8 Context/Operational Cameras
- UHF Surface Communications



SRL 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



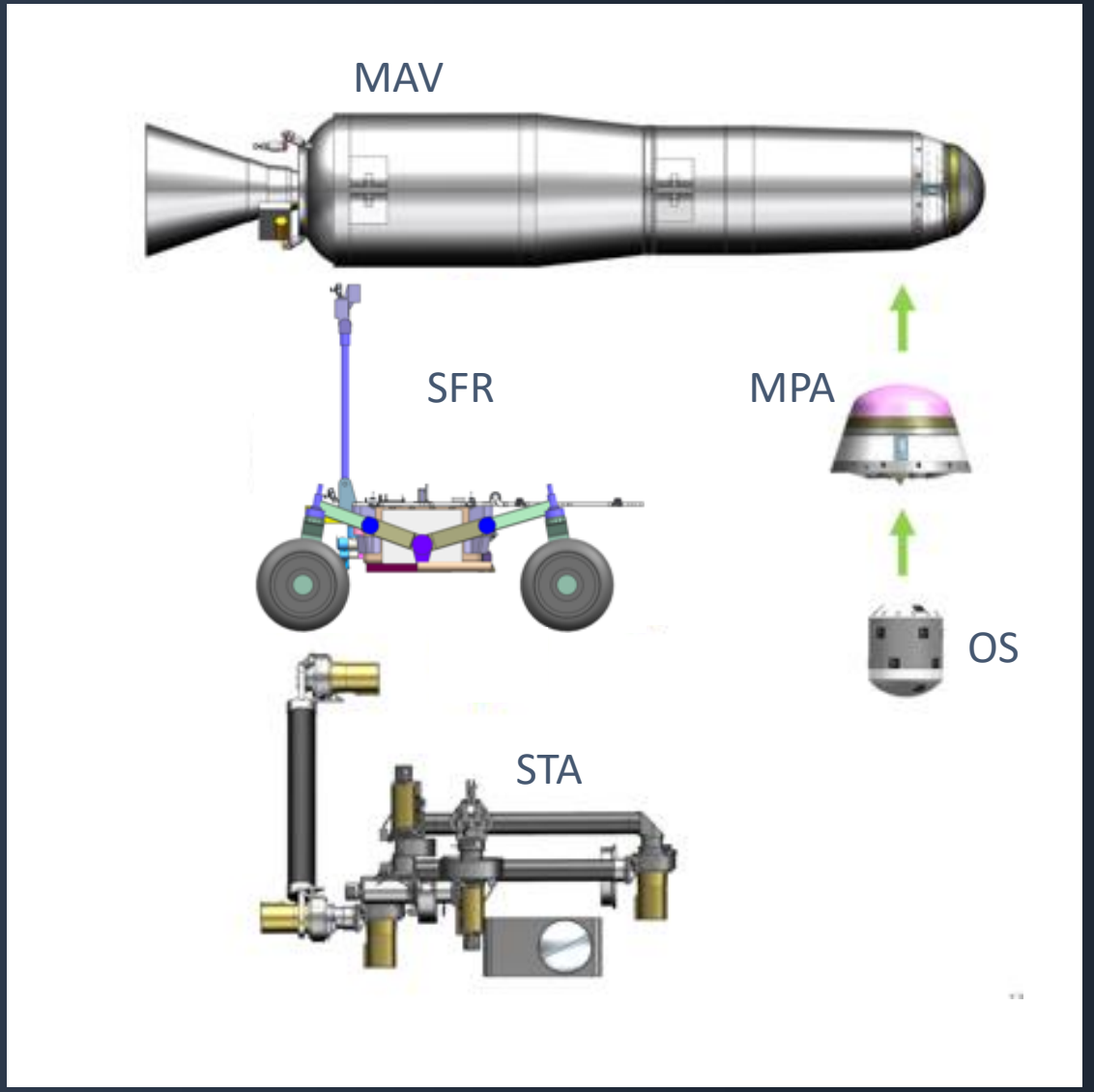
SRL Payloads

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

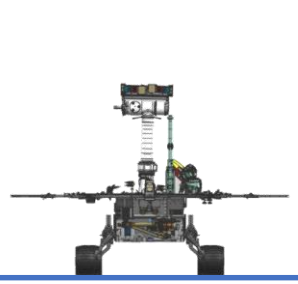
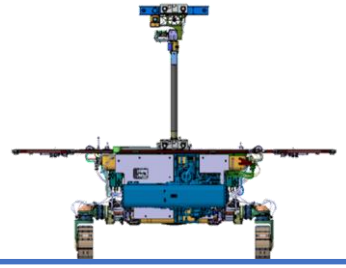
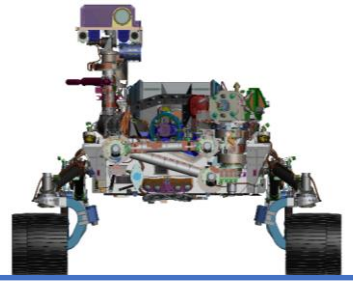
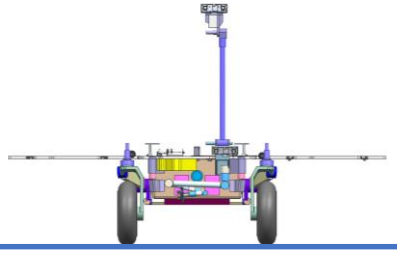
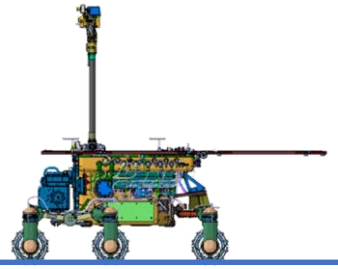
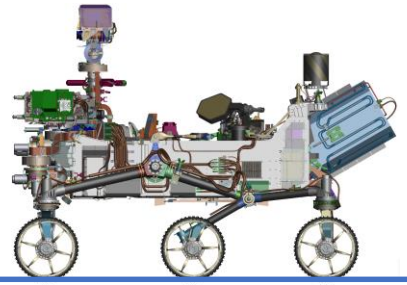
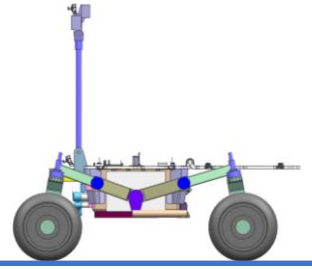
SFR
- 230kg NTE mass with specified volume envelope
- 4 wheels with 55cm diameter
- Umbilical power until power positive on surface

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

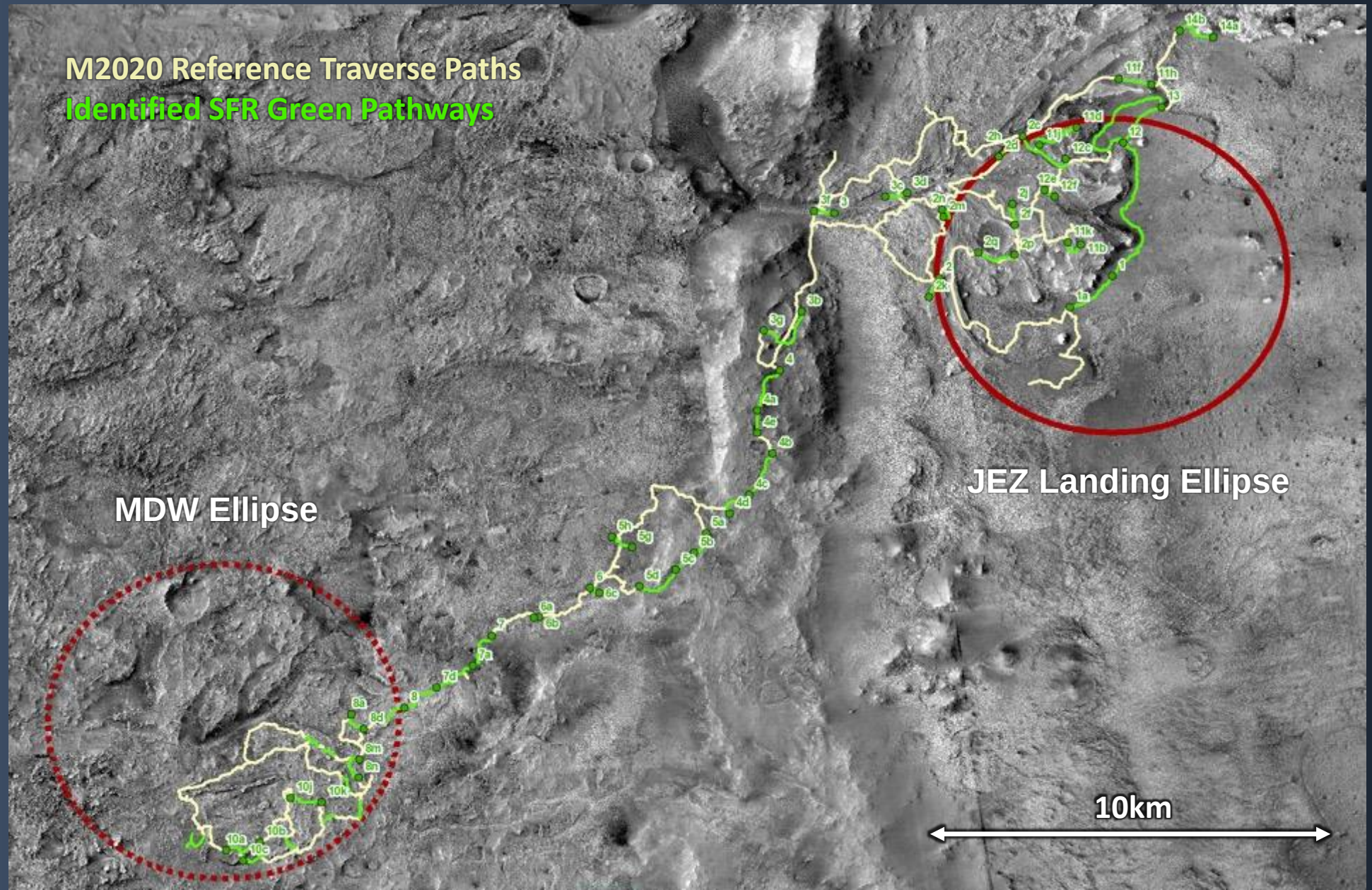
Orbiting Sample (OS)
- Accommodates 30 sample tubes
- OS and MPA each have 8 kg maximum mass (51% and 88% margin, respectively)



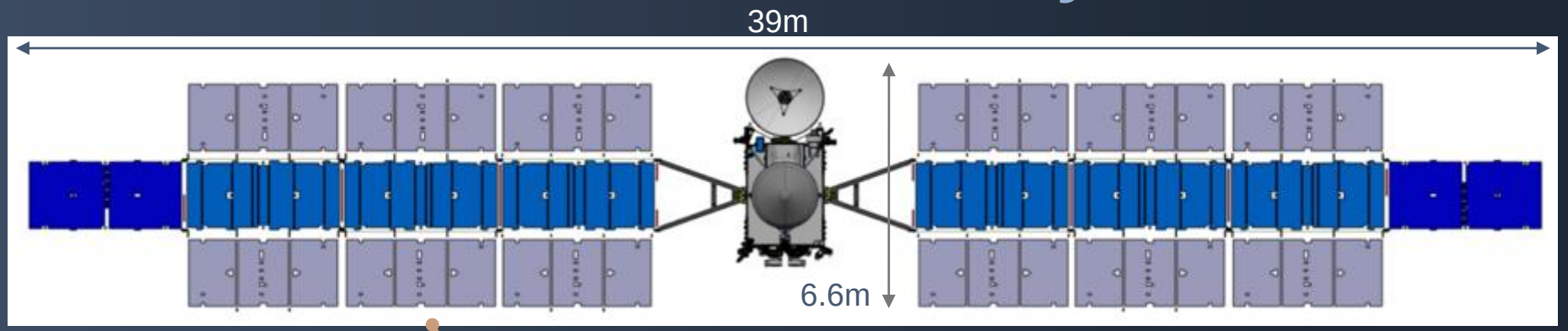
Rover Size Comparison

MER	ExoMars	M2020	SFR
			
			
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	**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	**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	**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

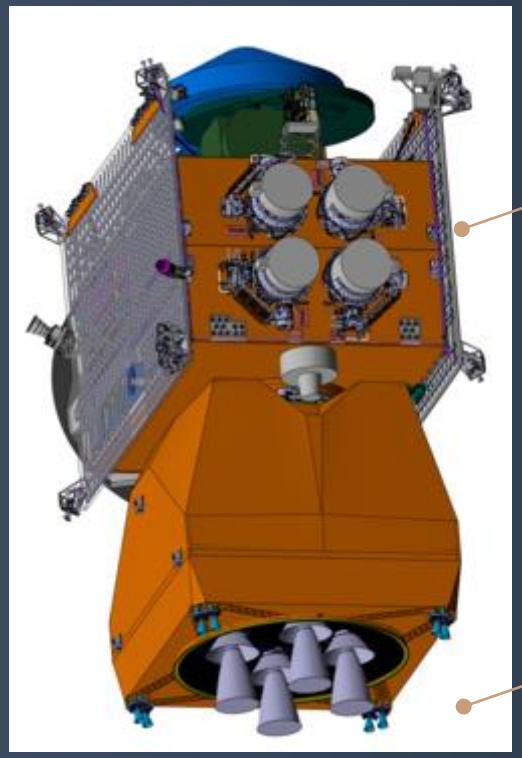
Overview of Green Pathways Across Jezero-Midway Region



ERO Anatomy



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

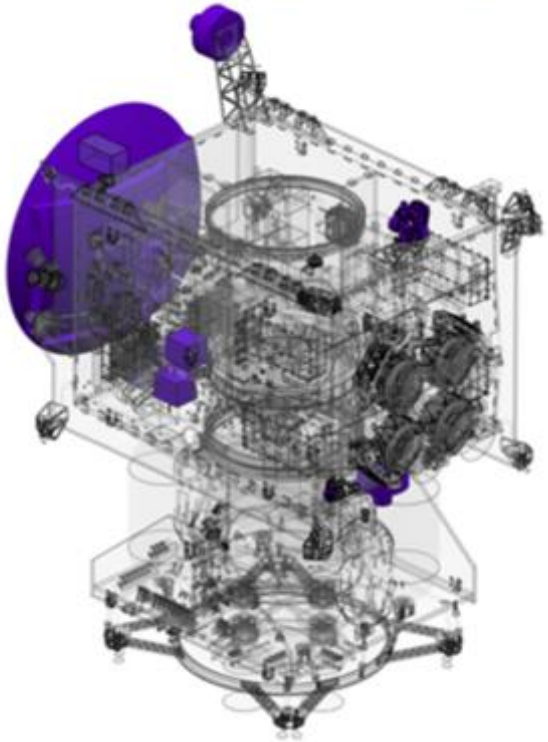


Electric Propulsion:
3 + 1 (spare)
Isp of 4000s, DeltaV ~10 km/s

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

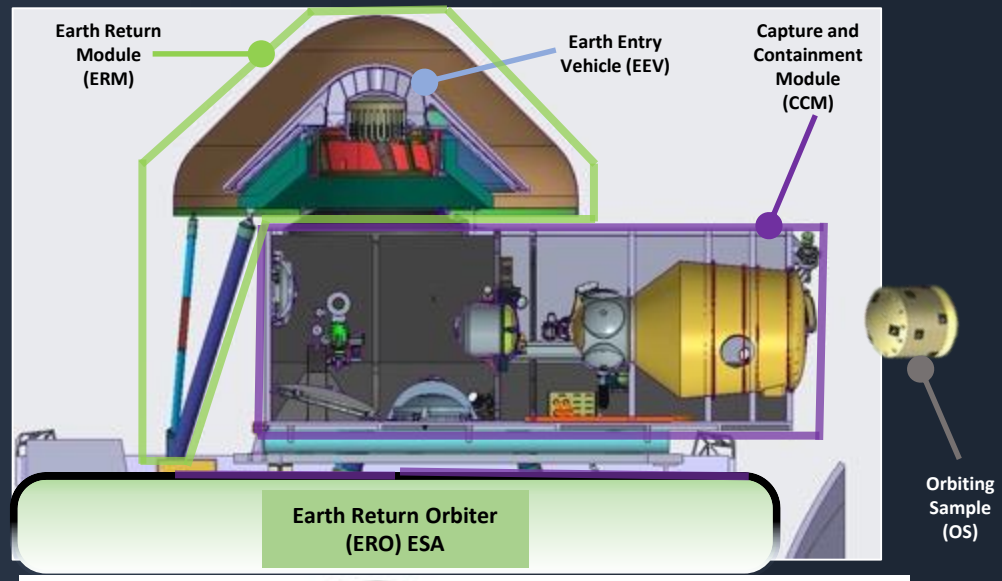
Bi-Prop Transit Stage:
Isp = 320 s

Communication system (X band and UHF)



Capture, Containment and Return System (CCRS) Overview

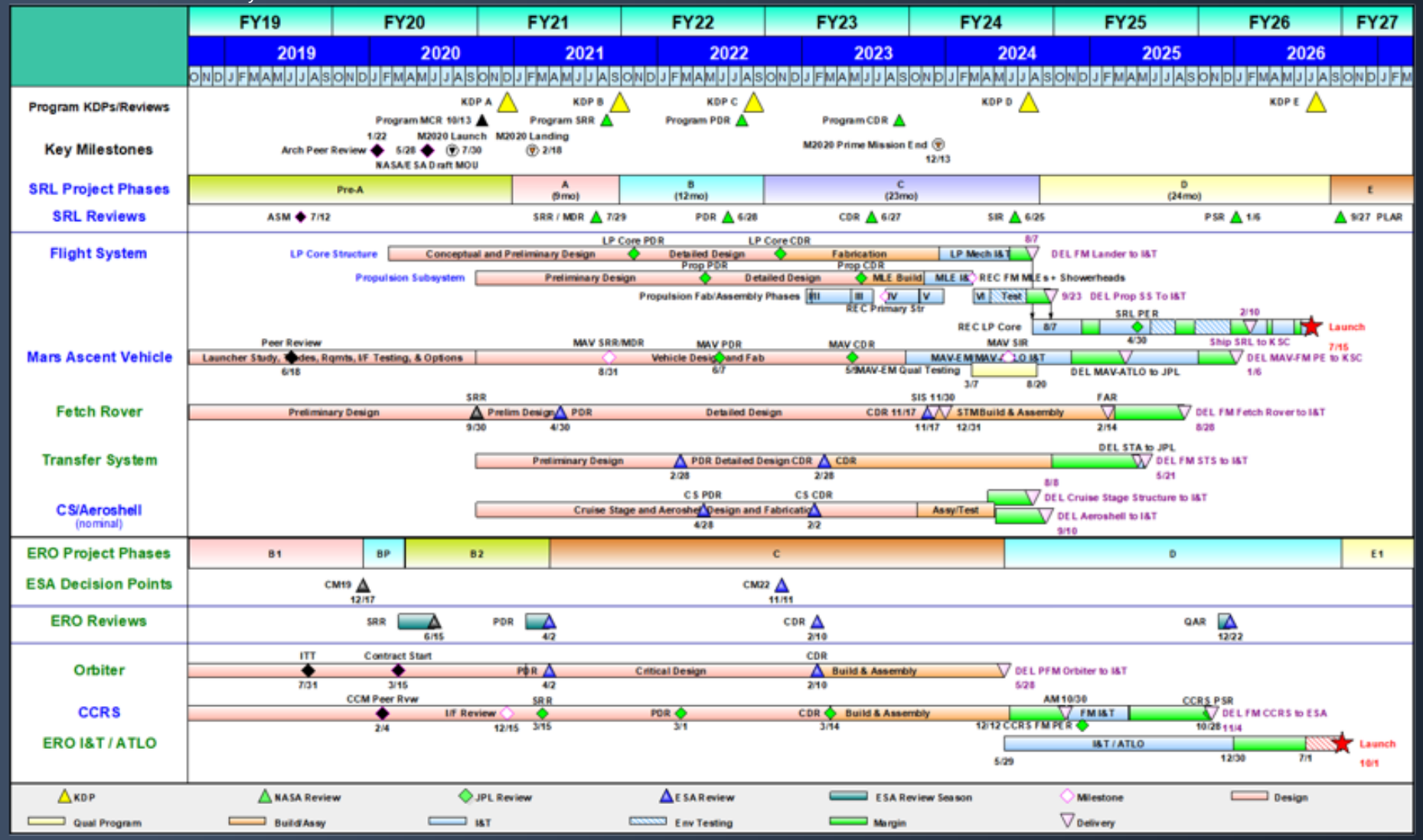
- CCRS is the payload on the ESA ERO
  - Capture the OS
  - Break-the-Chain and assure Containment
  - Deliver EES to UTTR while meeting BPP requirements
- Capture and Containment Module
  - Captures, constrains, and orients the OS
  - Transfers contained OS to the CCRS clean zone
  - Maintain clean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





MSR Program Summary Schedule

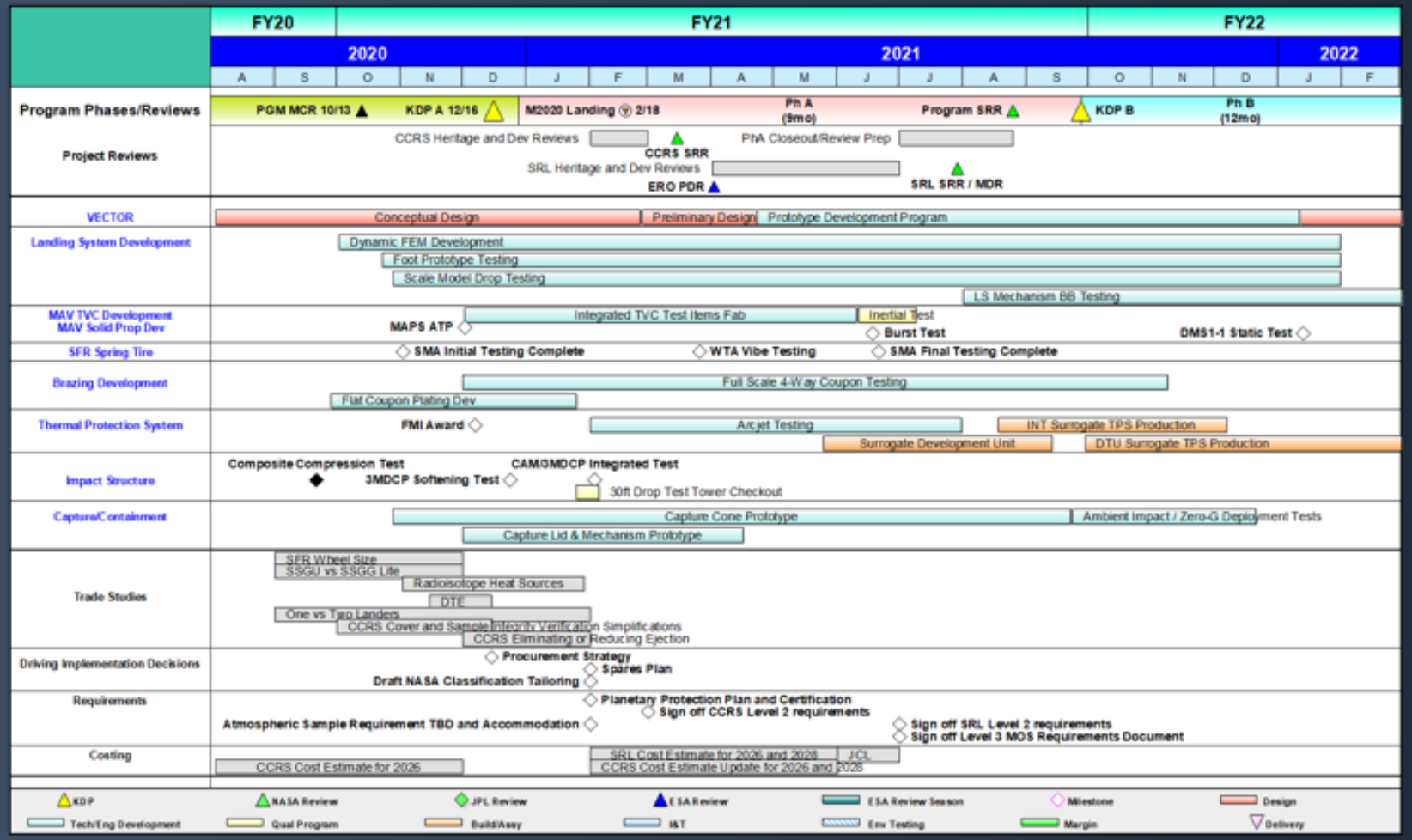
BLUE: Work Performed by NASA
GREEN: Work Performed by ESA



- 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

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)

Summary

- With launch 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; we can't do this without them
- Through the pre-phase A effort, the team has 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 MEP investments and technology advances
- Team is ready to mature design and solidify baseline 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

The MSR team has been approved for Phase A


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