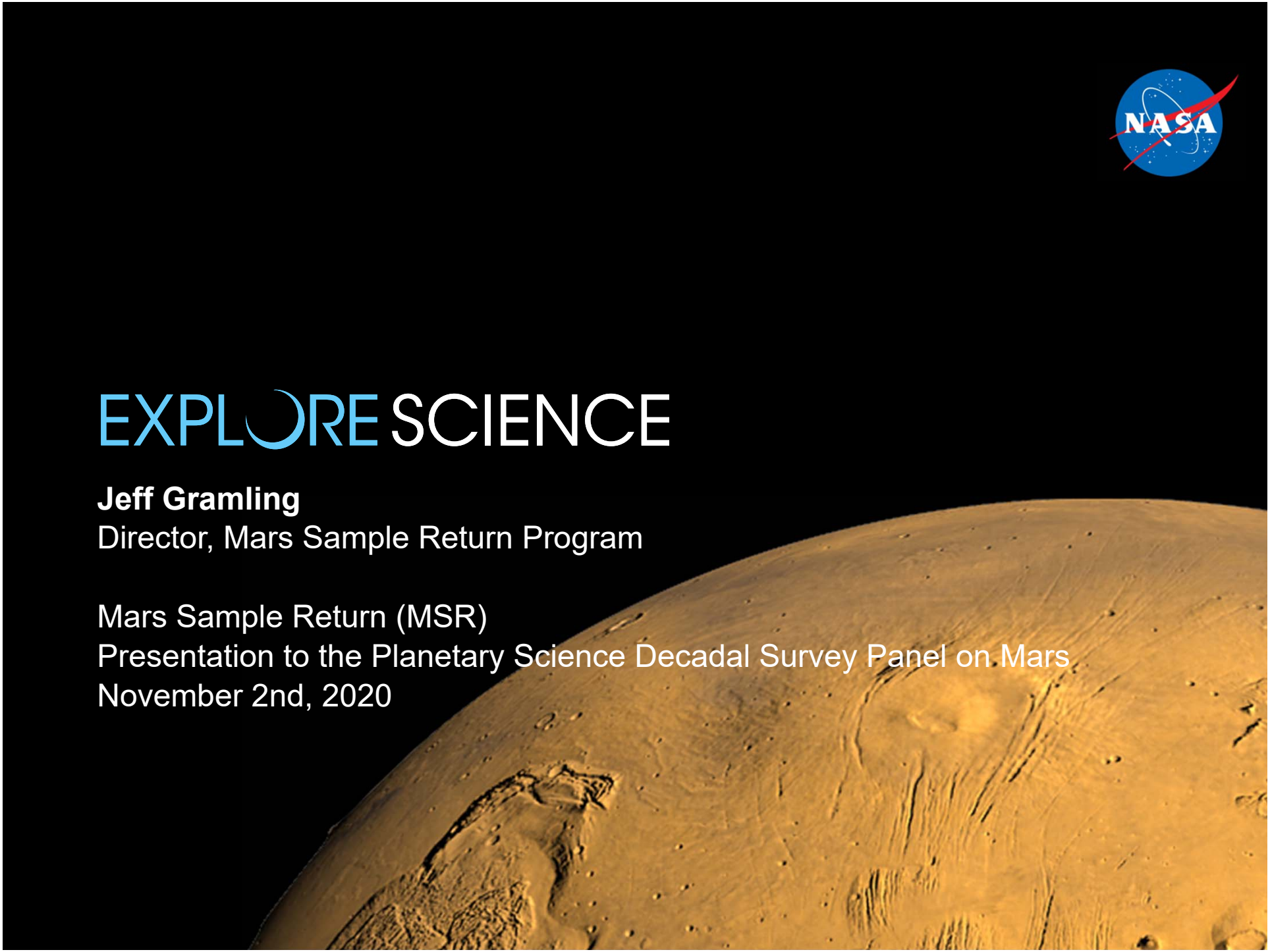


EXPLORE SCIENCE

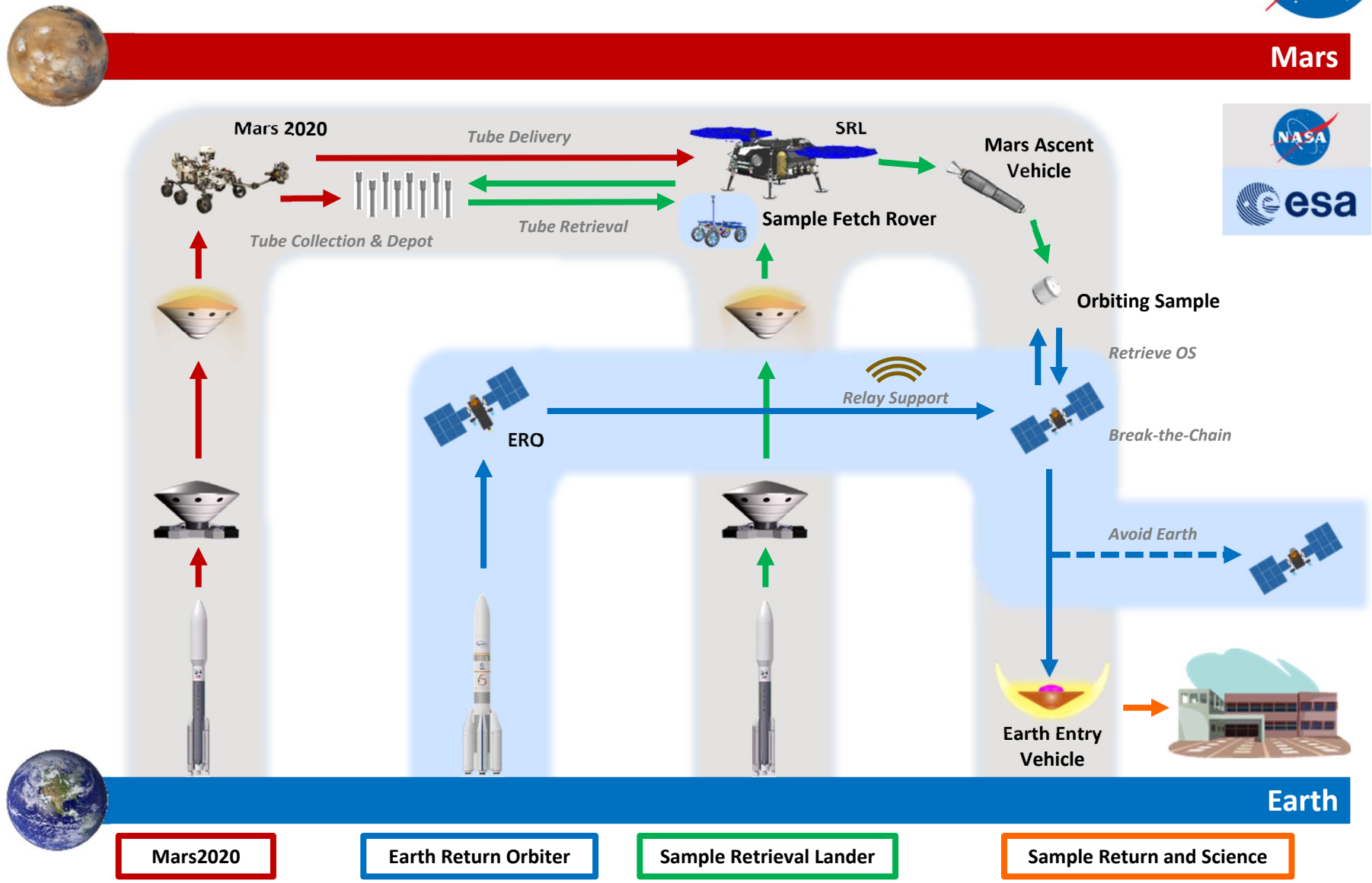
Jeff Gramling
Director, Mars Sample Return Program

Mars Sample Return (MSR)
Presentation to the Planetary Science Decadal Survey Panel on Mars
November 2nd, 2020

Mars Sample Return

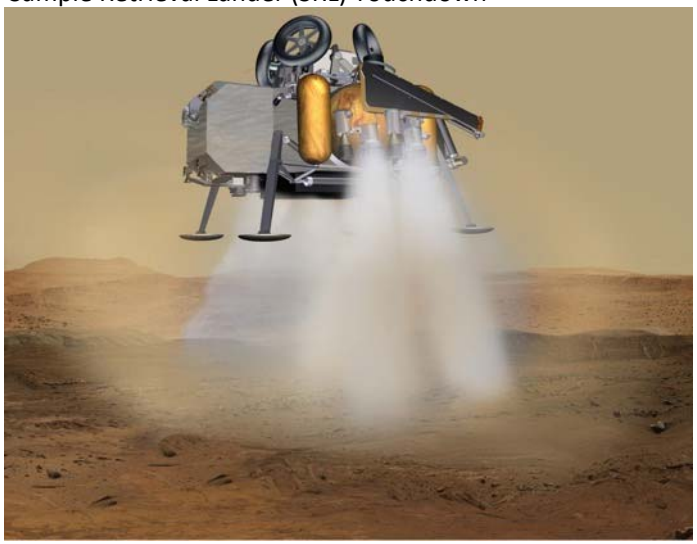
- Mars Sample Return (MSR) is the robotic science campaign the Mars community has been building towards for multiple decades
  - Number one Planetary Science community priority in the last Decadal Survey
- Mars Sample Return requires a set of capabilities that were not demonstrated 20, or even 10, years 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
- A MOU establishing an ESA/NASA program partnership was signed on October 5th, 2020
- The Mars Sample Return “Program” is not the full/total effort required for success
  - The Mars Sample Return “Campaign” includes M2020 for sample collection and the MSR Sample Receiving Facility

MSR Architectural Overview

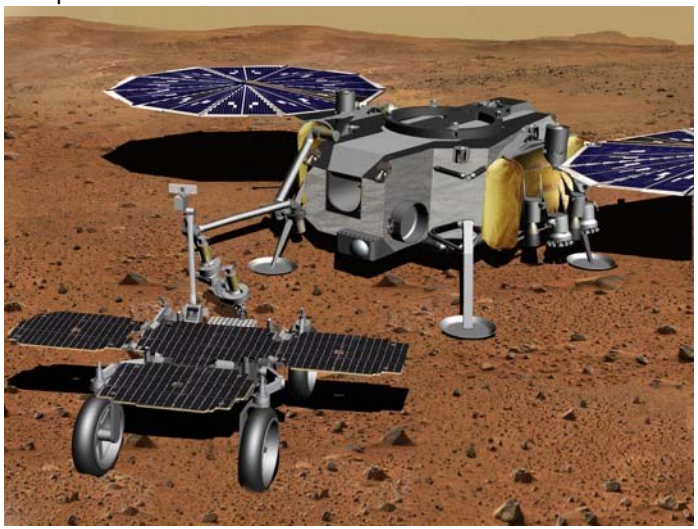


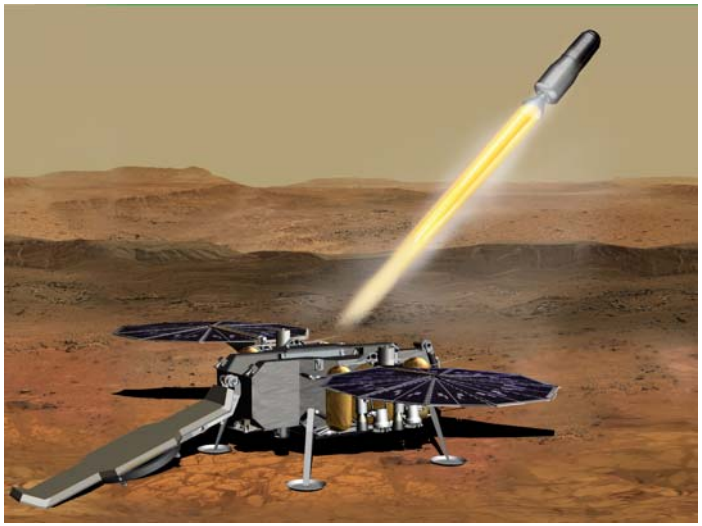
MSR Program Elements

Sample Retrieval Lander (SRL) Touchdown

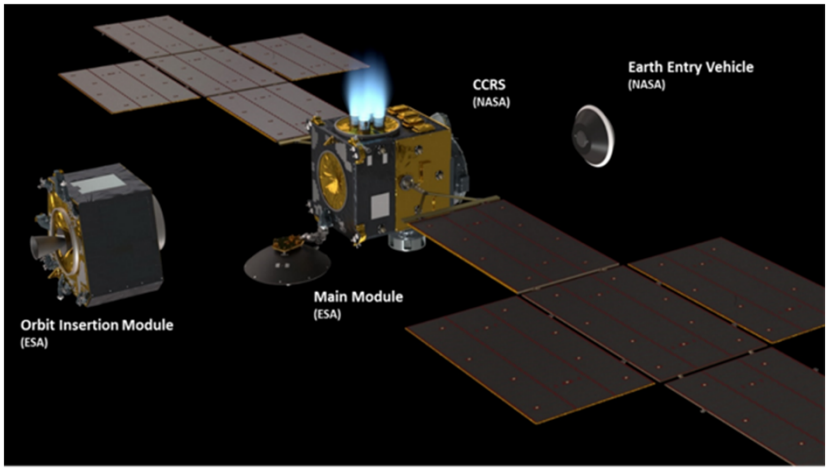


Sample Transfer





Mars Ascent Vehicle (MAV) Launch

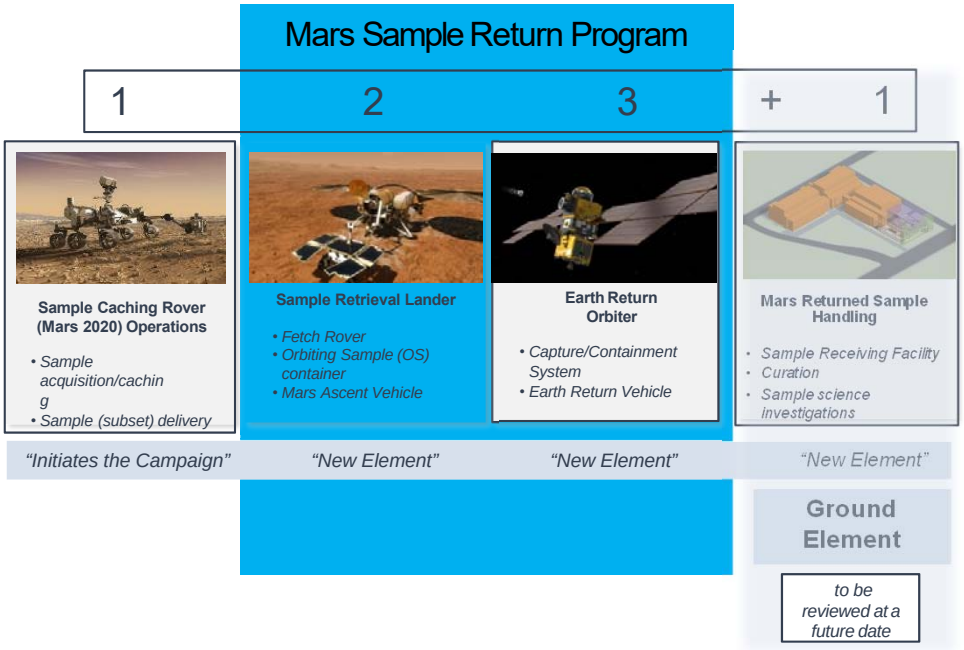


Earth Return Orbiter (ERO)

Mission Concept Review (MCR) Reference Baseline

- 2026 Launch Readiness Dates for ERO (ESA) and SRL (NASA), with sample return in 2031
  - Alternate mission opportunities identified
  - Mars surface operations with timeline margin
- SEP (Solar Electric Power) /Bi-Prop ERO that provides performance/timeline flexibility
  - Two-module CCRS (Capture, Containment, and Return System) (NASA) aligned with Capture/Contain and Earth Return functionality with sufficient technical margins
  - High-stability Earth Entry Vehicle (EEV) with robust heatshield to ensure containment through Earth atmospheric flight, landing and recovery
- Single propulsive, solar-powered Lander with sufficient technical margins
  - MAV (NASA)- SSGU (solid guided first-stage, solid unguided second stage)
  - Sample Fetch Rover (SFR) (ESA)- wheels sized for Green Pathway operations
- Early year funding planned to mature engineering developments

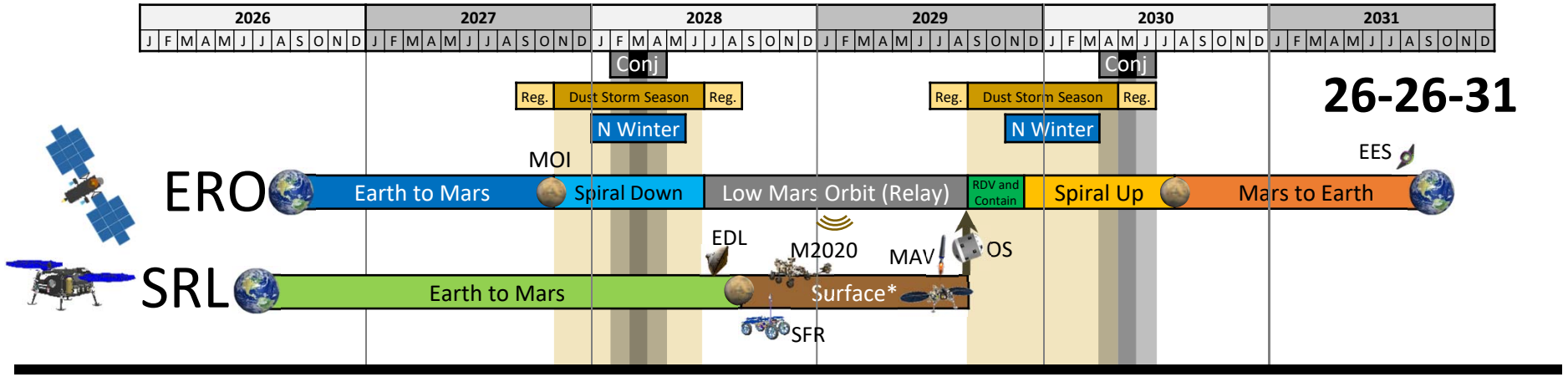
Mars Sample Return Campaign



- 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 OS for transfer to SRF
- The MEP Program manages M2020 Phase E operations & will be the home of the future SRF Project

Campaign Timeline Overview

*Illustrates an example scenario



26 – 26 – 31

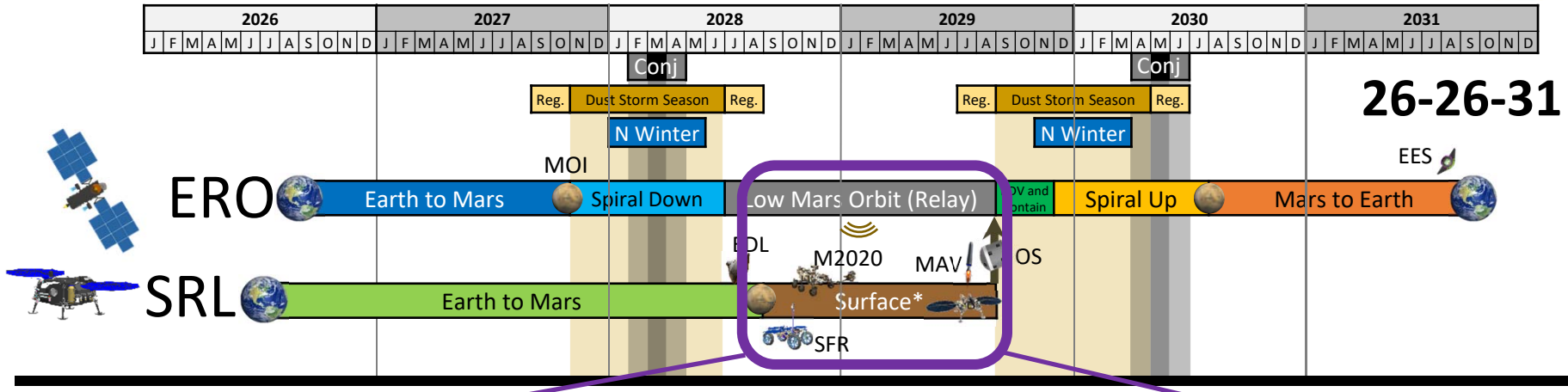
SRL Launches in 2026

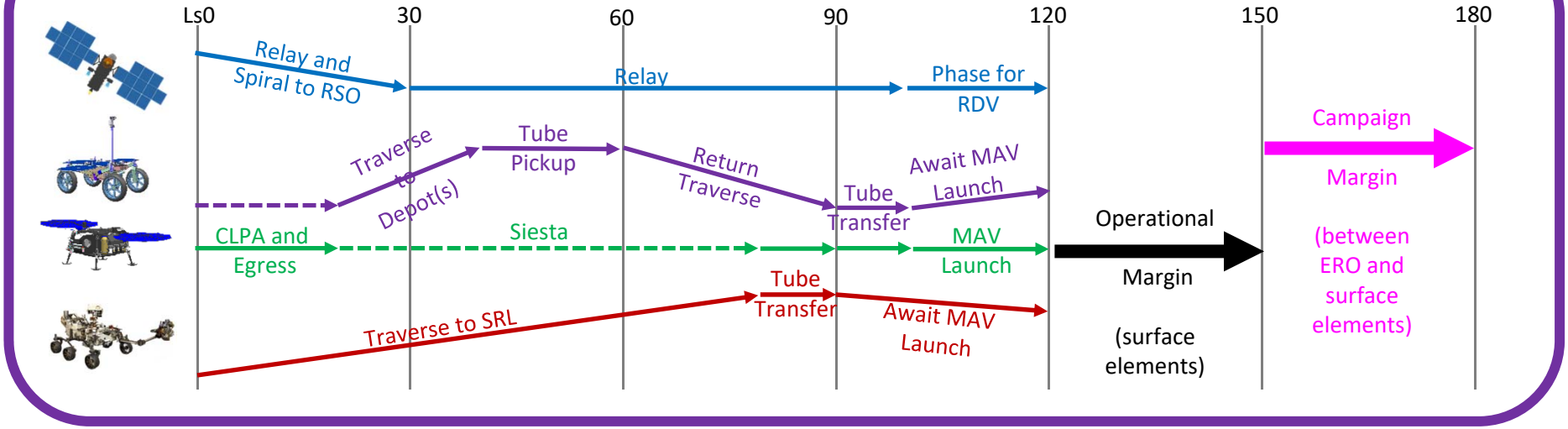
ERO launches in 2026

Samples are returned in 2031

- SRL avoids winter and global dust storm season, enabling all-solar SRL/SFR
- SRL Entry, Descent and Landing (EDL) occurs in a favorable season, maximizing landed mass
- ERO can provide all relay services needed for MSR (SRL, SFR, M2020, MAV)
- SRL and ERO fit on available launch vehicles and trajectories are feasible

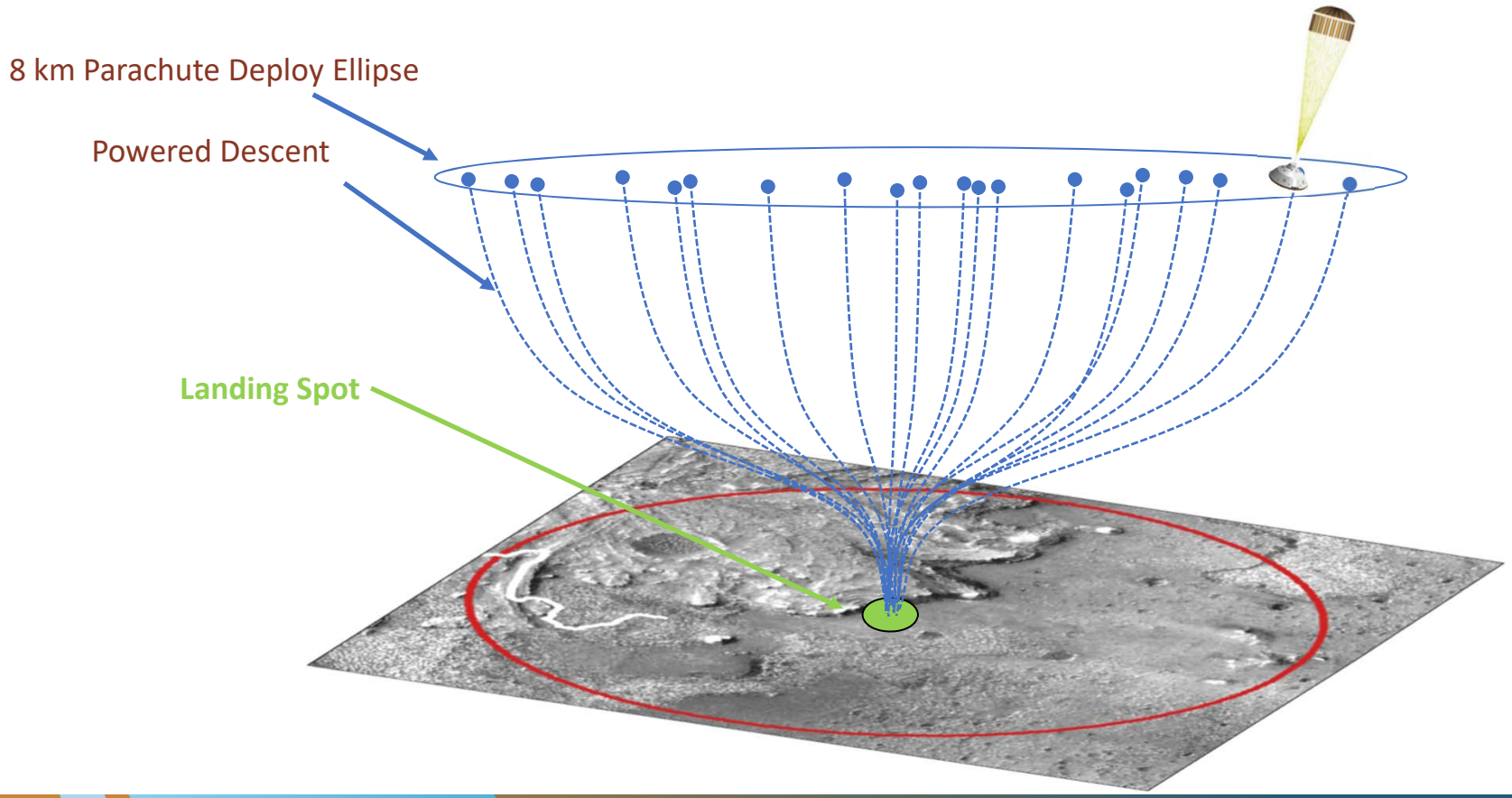
Campaign Timeline Overview



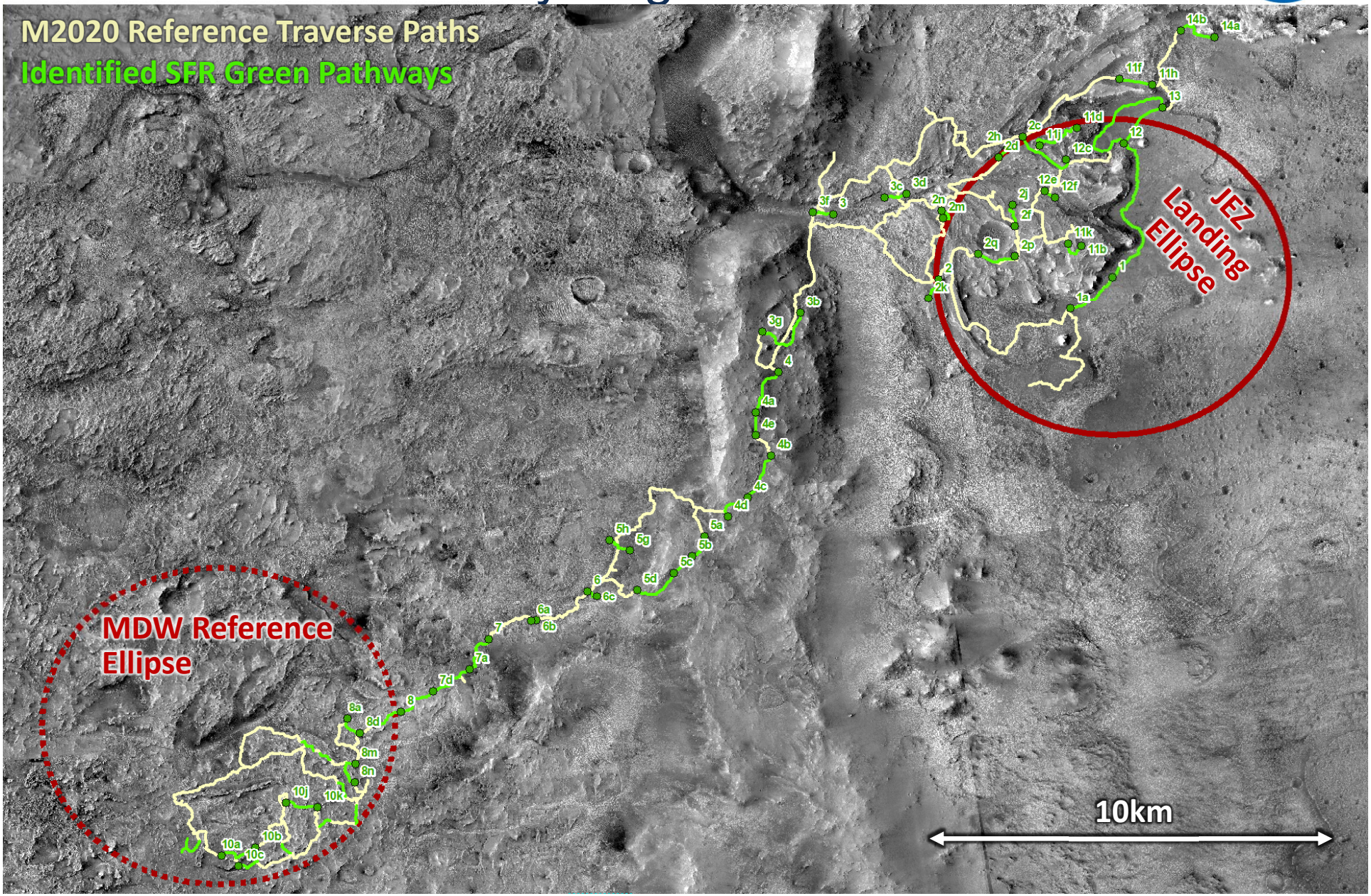


SRL EDL - Extended Divert

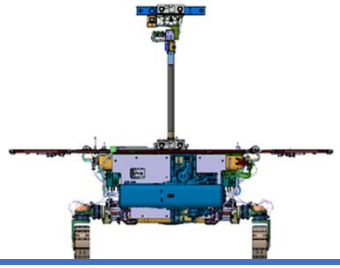
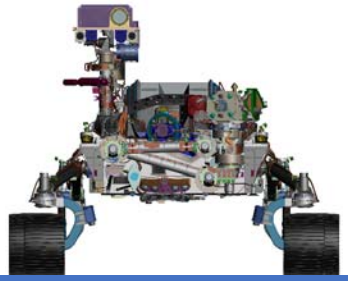
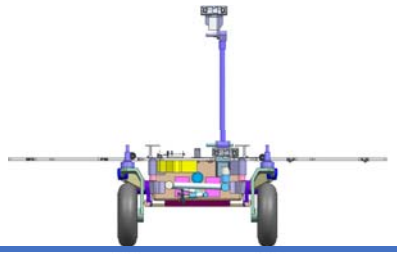
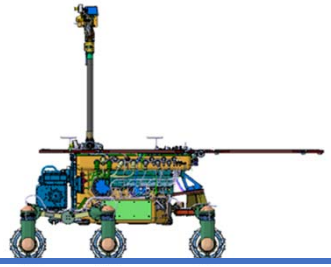
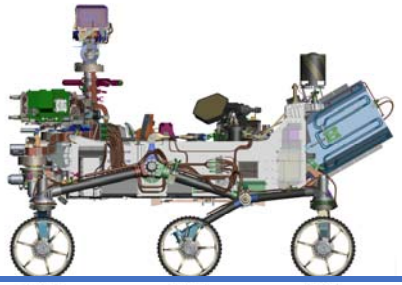
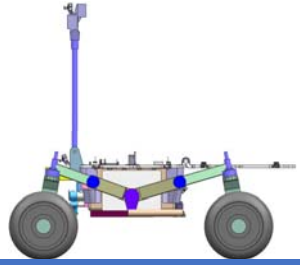
- SRL will carry enough propellant to fly out the backshell separation ellipse (8 x 8 km) and land at a specific spot (~±20m accuracy)
- Enables new capability of landing at a specific site scouted by Mars 2020



Overview of Green Pathways Across Jezero-Midway Region



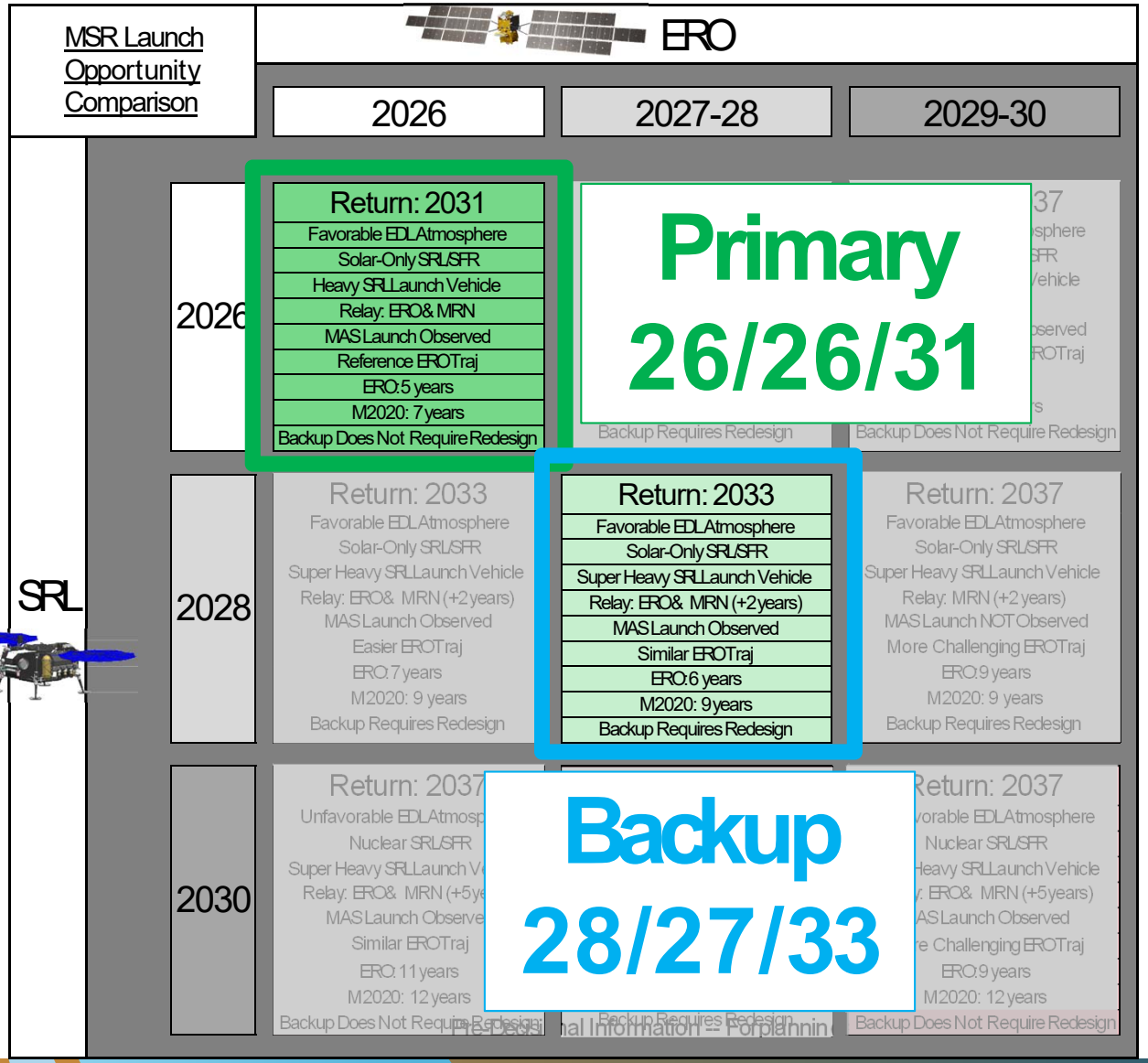
Rover Size Comparison

MER	ExoMars	M2020	SFR
			
			
Mass = 173 kg	**Mass** = 310 kg	**Mass** = 1030 kg	**Mass** = < 230 kg
Number of wheels = 6 **Wheel Diameter** = 230 mm **Wheel Type** = Rigid	**Number of wheels** = 6 **Wheel Diameter** = 285 mm **Wheel Type** = Compliant	**Number of wheels** = 6 **Wheel Diameter** = 526 mm **Wheel Type** = Rigid	**Number of wheels** = 4 **Wheel Diameter** = 550 mm **Wheel Type** = Compliant, Mesh
	Wheelbase = 1260 mm	**Wheelbase** = 2260 mm	**Wheelbase** = 1550 mm
Susp Type = Rocker-Bogie w/ internal diff	**Susp Type** = 3x Bogie	**Susp Type** = Rocker-Bogie w/ external diff	**Susp Type** = 4 wheel w/ external diff
Ground Clearance = 300 mm	**Ground Clearance** = est 250 mm	**Ground Clearance** = 584 mm	**Ground Clearance** = 350 mm

Resiliency Decisions and Sample Safe States

- Through architecture design, created numerous sample-safe states and decision events
  - Sample(s) are designed to survive on the Mars surface for a minimum of 10 years
  - Functionally redundant paths for delivering samples to SRL (M2020 and SFR)
  - OS orbit is designed to be stable for a minimum of 10 years
  - OS designed to be capable of returning as many as 30 samples
- In Phase A, team will look carefully at each Phase for additional resiliency
- MSR is using resiliency to guide decision making
  - Testing and V&V programs will be detailed with focus on high risk areas
  - A risk-based sparing program will be developed in Phase A
  - Probabilistic risk assessment will be used as part of the SE&I function to quantify risk as part of the Program decision-making process

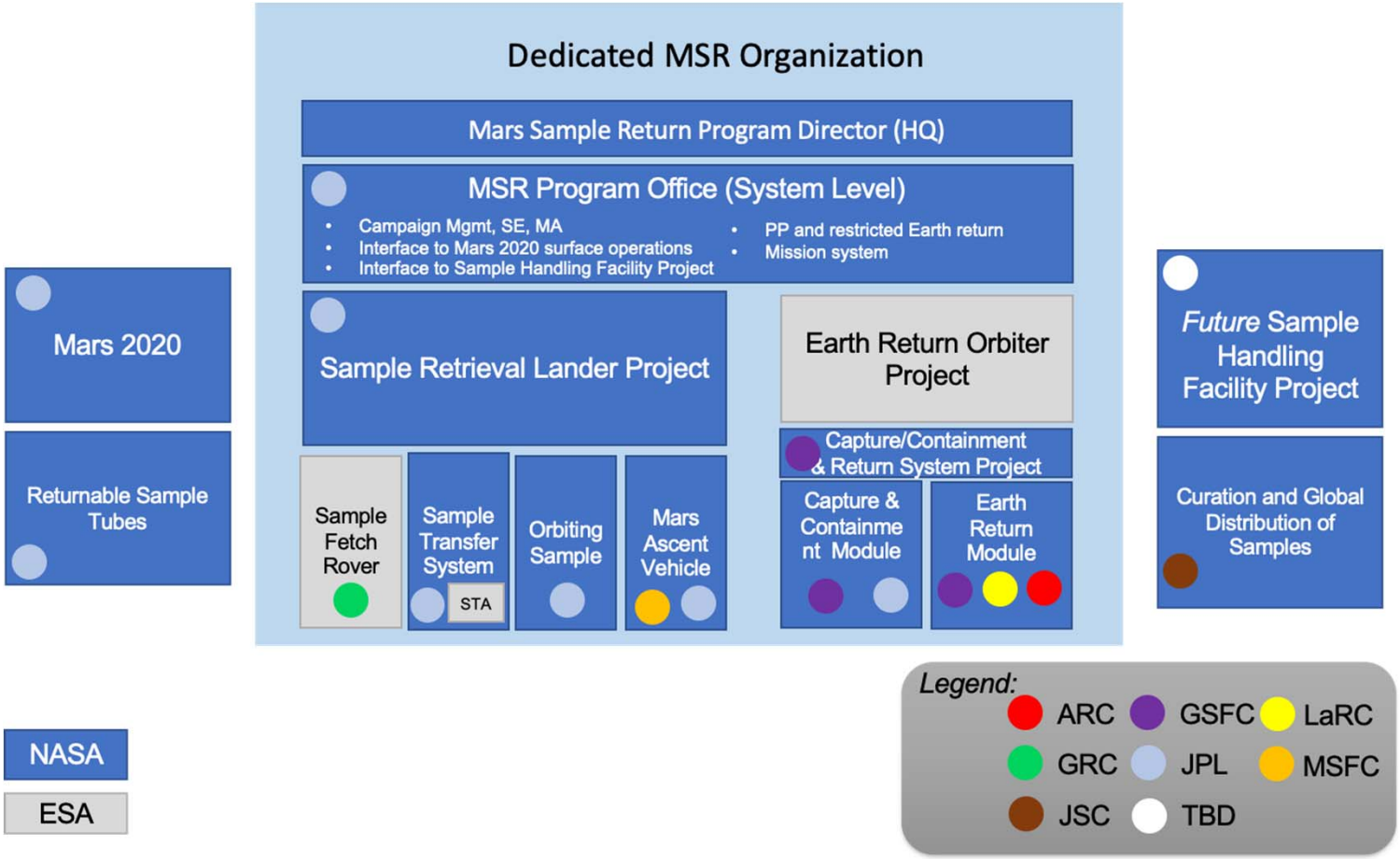
MSR Launch Opportunities



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

- Each opportunity is evaluated based upon SRL and ERO designed specifically for that opportunity
- MRN = Mars Relay Network
  - MRO, MAVEN, TGO
- Nomenclature: “28/27/33”
  - SRL Launches in 2028
  - ERO Launches in 2027
  - ERO Returns in 2033
- "2027-28” covers the potential for ERO to launch one year earlier and use an Earth flyby prior to utilizing a 2028 Earth - Mars transfer. These options are architecturally similar.

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)

Lessons Learned/SMD Flagship Model

- During Formulation, MSR team has reviewed and attempted to apply Agency lessons learned from past flagship missions
- Mars Science Lab (MSL)
  - Perform independent cost assessments prior to MCR
    - *Aerospace and CTS performing independent cost assessments*
  - Conduct Non-Advocate review prior to MCR
    - *SMD commissioned MSR Independent Review Board*
- JWST & WFIRST
  - Streamlined lines of authority to SMD AA
    - MSR has dedicated Program Director in SMD reporting to AA/SMD and a dedicated MSR Program Office at JPL
- M2020
  - MSR will follow development of M2020 lessons learned
- SMD “Agency Flagship” Mission Model Implementation
  - Program Director at HQ
    - *Augmented with staff to maintain understanding of program performance and status*
  - MCR conducted by an Agency SRB

Looking Forward

- With launch of M2020, the MSR Campaign is underway
- MSR is drawing upon the best talent from across NASA and ESA
- MOU signed; Pre-Phase A work complete
- This team has developed a feasible baseline and broad set of options in preparation for the MCR
- The time is now to leverage MEP investments and technology advancements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