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Mars Sample Return: Current Architectural Approaches

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International Mars Exploration Working Group

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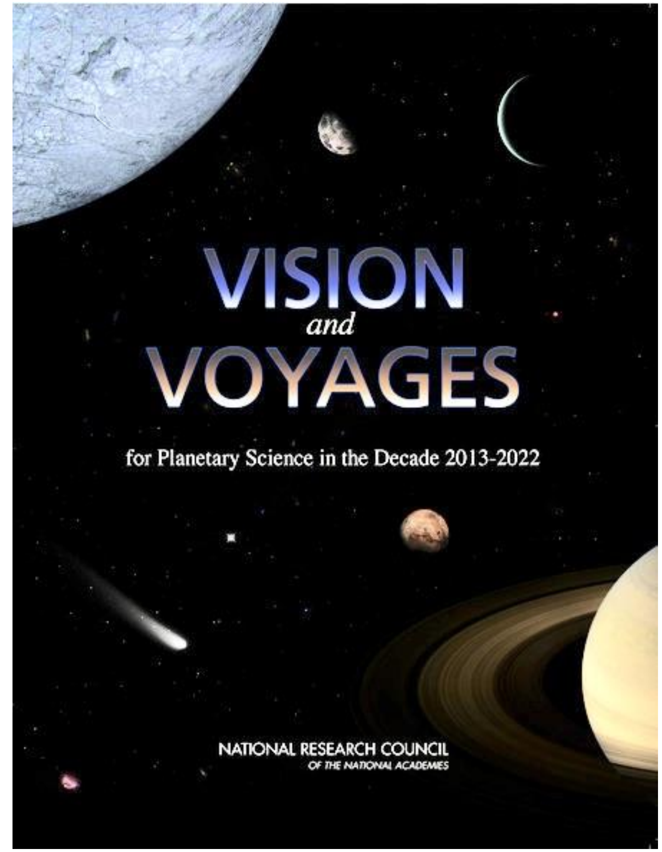
Outline

- Mars Sample Return Science Rationale
- Notional MSR Architecture Overview
- MSR Elements and Key Technologies
  - Mars 2020 (Sample Caching Rover)
  - Sample Retrieval Lander Concept
    - MAV
    - OS
    - Fetch Rover
  - Earth Return Orbiter Concept
    - Rendezvous & Capture
    - Planetary Protection/Containment Assurance
    - Earth Entry Vehicle
  - Mars Returned Sample Handling
- Summary

Mars Sample Return – a Decadal Survey Priority

- ***The NRC Planetary Science Decadal Survey (2011) provided a strong recommendation for MSR***
  - "**The major focus of the next decade will be to initiate a Mars sample-return campaign**, beginning with a rover mission to collect and cache samples, followed by missions to retrieve these samples and return them to Earth."
  - "**A critical next step …. will be provided through the analysis of carefully selected samples** from geologically diverse and well-characterized sites that are returned to Earth for detailed study using a wide diversity of laboratory techniques"
  - "**The highest priority Flagship mission for the decade of 2013-2022 is MAX-C** (Mars astrobiology explorer-cacher)"
  - "During the decade of 2013-2022, **NASA should establish an aggressive, focused technology development and validation initiative** to provide the capabilities required to complete the challenging MSR campaign."



MSR Campaign – Recommended Objectives

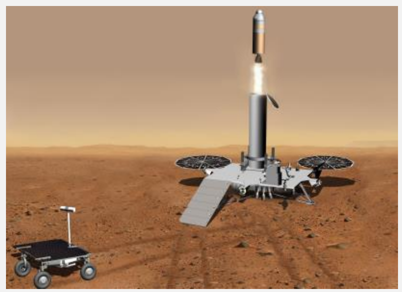
- **Acquire and return to Earth** a rigorously documented set of **Mars samples** for investigation in **terrestrial laboratories**
- Select samples based on their **geologic diversity**, **astrobiological relevance**, and **biosignature preservation** potential
- **Establish the field context** for each sample based on ***in situ* observations**
- Ensure the **scientific integrity** of the returned samples through **contamination control** (including round-trip Earth contamination and sample-to-sample cross-contamination) and **control of environments** experienced by the samples after acquisition
- **Ensure compliance with planetary protection requirements** associated with the return of Mars samples to the Earth biosphere

Notional Mars Sample Return Architecture (1/2)

- Three flight elements plus one ground element
  - Limits the cost, mass/volume, and technical challenges of each flight element

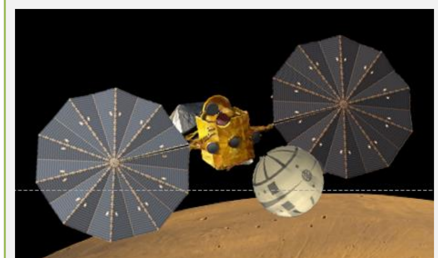
Sample Caching Rover (Mars 2020)

- *Sample acquisition and caching*



Sample Retrieval Lander

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



Earth Return Orbiter

- *Rendezvous and On-Orbit Capture System*
- *Earth Entry Vehicle*

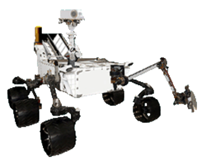
Mars Returned Sample Handling

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

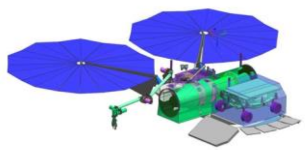
Flight Elements | ***Ground Element***

Notional Mars Sample Return Architecture (2/2)

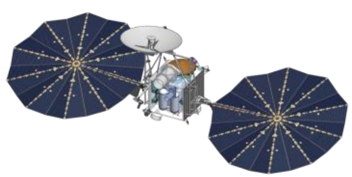
Flight



Sample Caching Rover (Mars 2020)

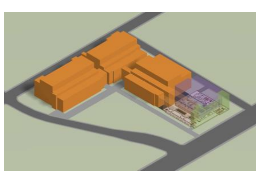


Sample Retrieval Lander

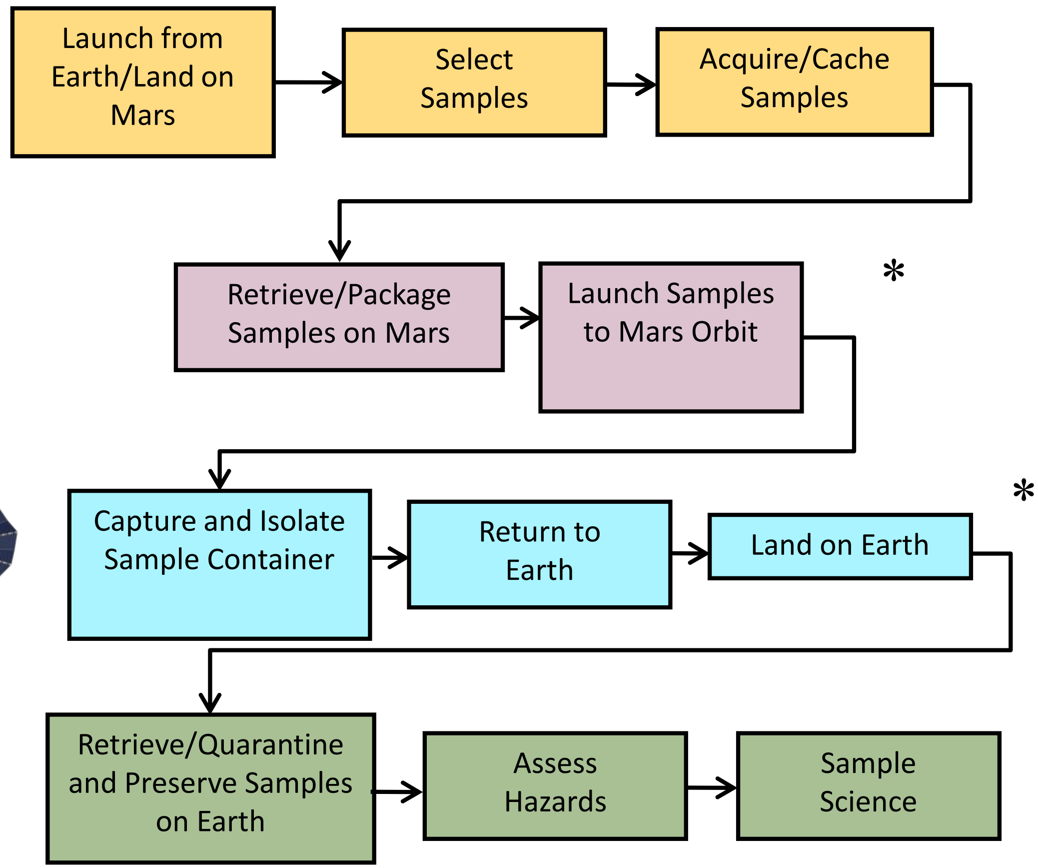


Earth Return Orbiter

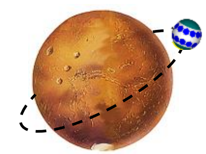
Ground



Mars Returned Sample Handling



Sample Tube on Mars Surface



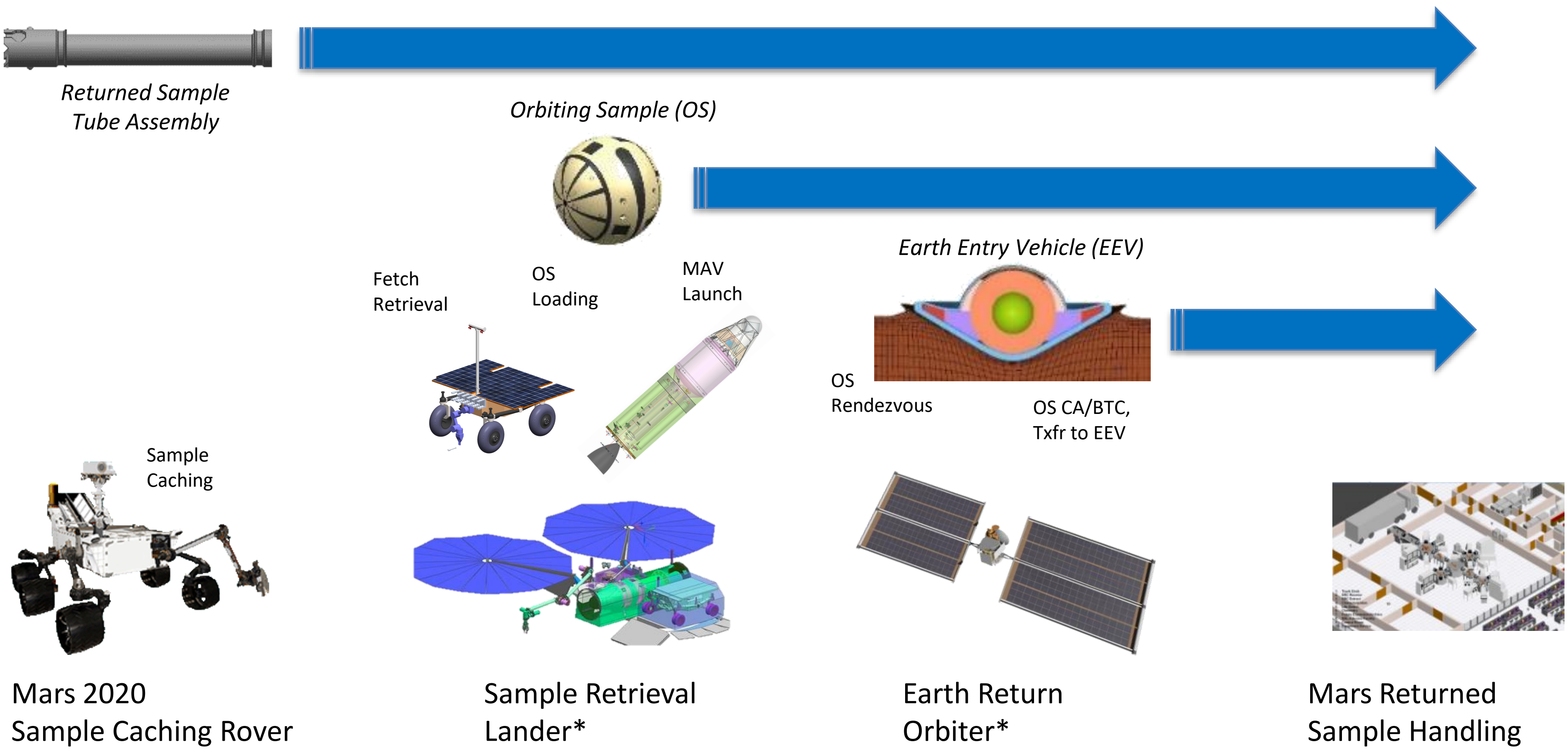
Orbiting Sample (OS) in Mars Orbit

Orbiting Sample (OS) on Earth

Sample Science

*Launching orders of MSR orbiter and lander concepts can be reversed

Key MSR Cross-Element Interfaces

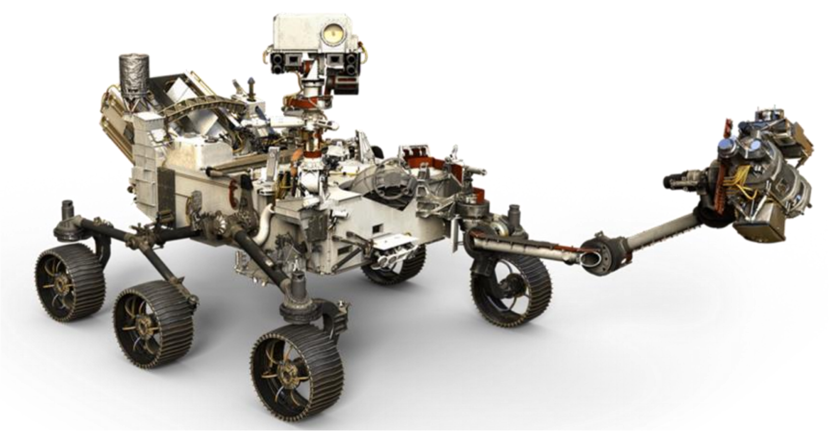


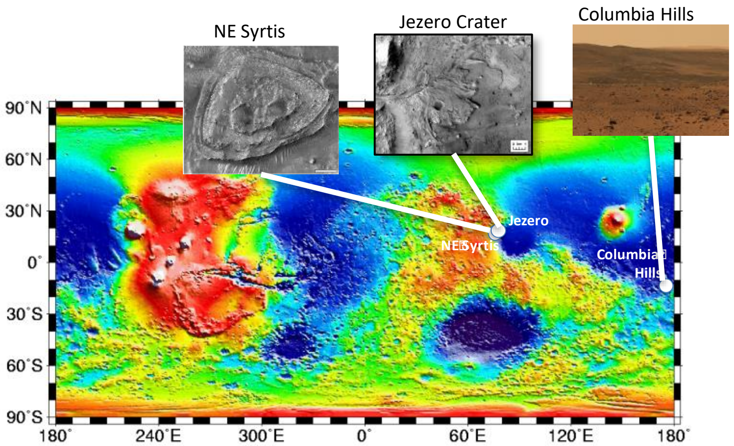
*Concepts

MSR Architectural Elements

Mars 2020

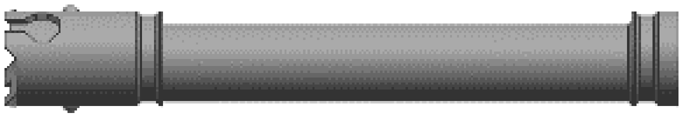
- High heritage from MSL
- EDL improvements
  - Range trigger for parachute deployment
  - Terrain-Relative Navigation for accessing more hazardous (& more scientifically interesting) sites
  - 11x9 km landing ellipse
- Three landing site finalists selected
  - Jezero Crater
  - NE Syrtis
  - Columbia Hills
- Adaptive caching strategy
- Sample tube design
  - Length: 144.3 mm
  - Mass: ~80 g (empty); ~100-120 g (w/ 10 cc sample)





M2020 Landing site candidates

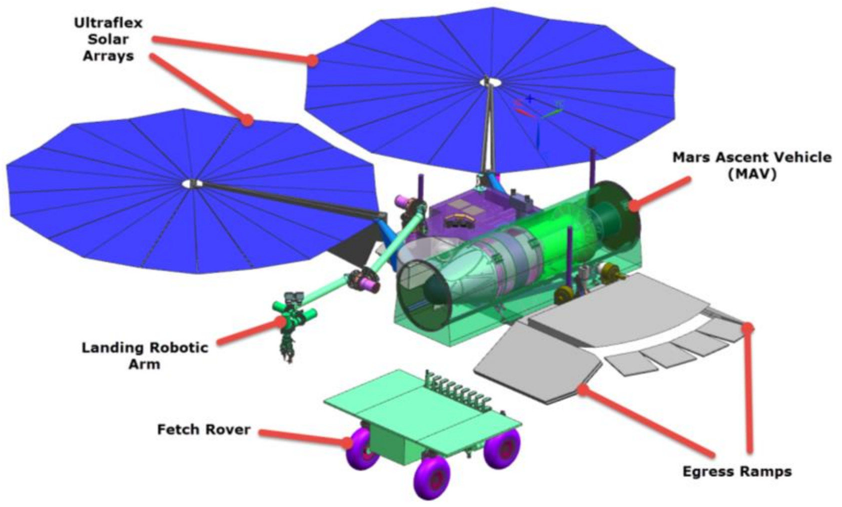
Site	ID	Latitude	Altitude
Jezero	JEZ	18.4 N	-2.64 km
NE Syrtis	NES	17.9 N	-2.04 km
Columbia Hills	CLH	14.5 S	-1.93 km

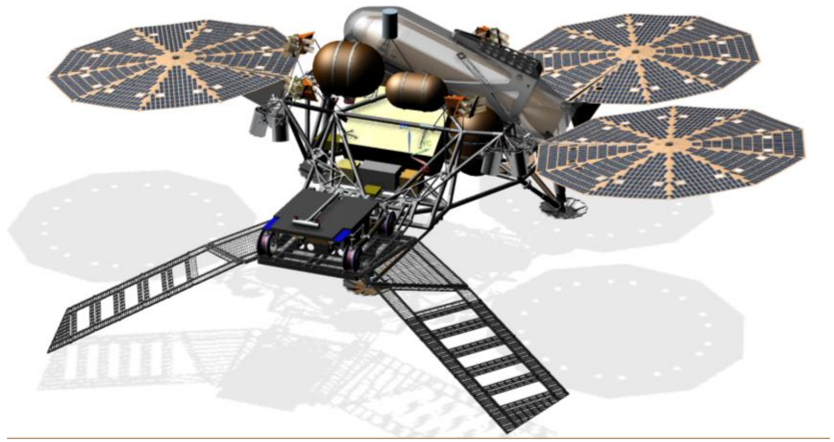


M2020 Returned Sample Tube Assembly

Notional Sample Retrieval Lander

- Key Functions:
  - Deliver Fetch Rover and MAV to appropriate landing site to achieve sample tube pick up and transfer to the OS
  - Launch MAV into >350 km orbit, >25 deg inclination with dispersion of <1 deg
- Payload
  - MAV + Fetch Rover (500 kg)
- Flight system
  - Pallet Lander deployed by MSL/M2020-heritage Skycrane *or* Propulsive Platform Lander (Phoenix/InSight/Viking heritage)
  - Solar powered (16 m^2 active area)





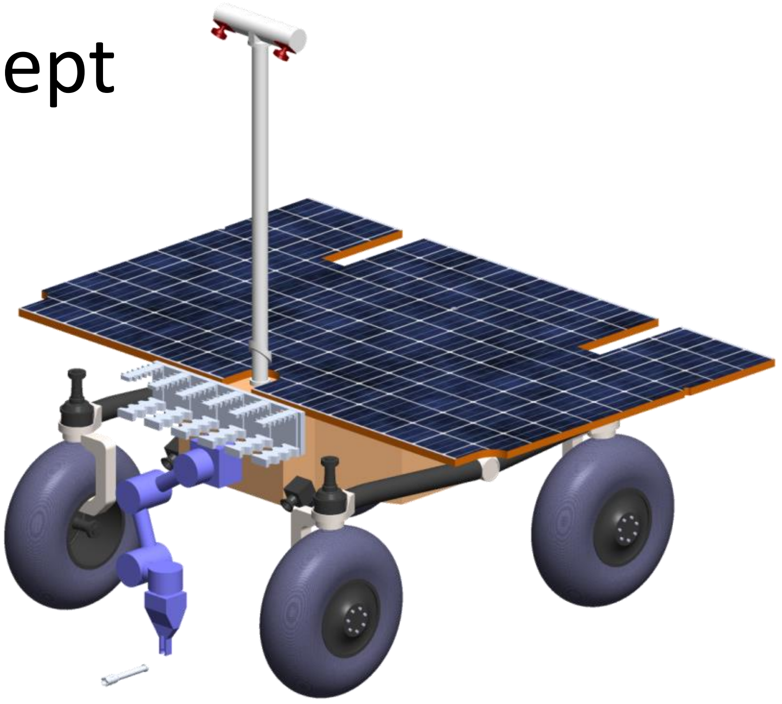
Notional SRL Options

Two Lander options:

- Common to both:
  - EDL through backshell separation, avionics, engines, use of terrain relative navigation (TRN)
  - Will need augmented EDL capabilities over MSL/M2020 capabilities due to poor Mars opportunity and need for greater landing mass

Sample Fetch Rover Concept

- Key functional requirements
  - Able to drive out SRL landing dispersion
  - Compatible with M2020 candidate sites
    - Jezero Crater
    - NE Syrtis
    - Columbia Hills
  - ~30 km drive (wheel odometry)
  - ~200-sol surface fetch mission
  - Capable of retrieving up to 31 sample tubes



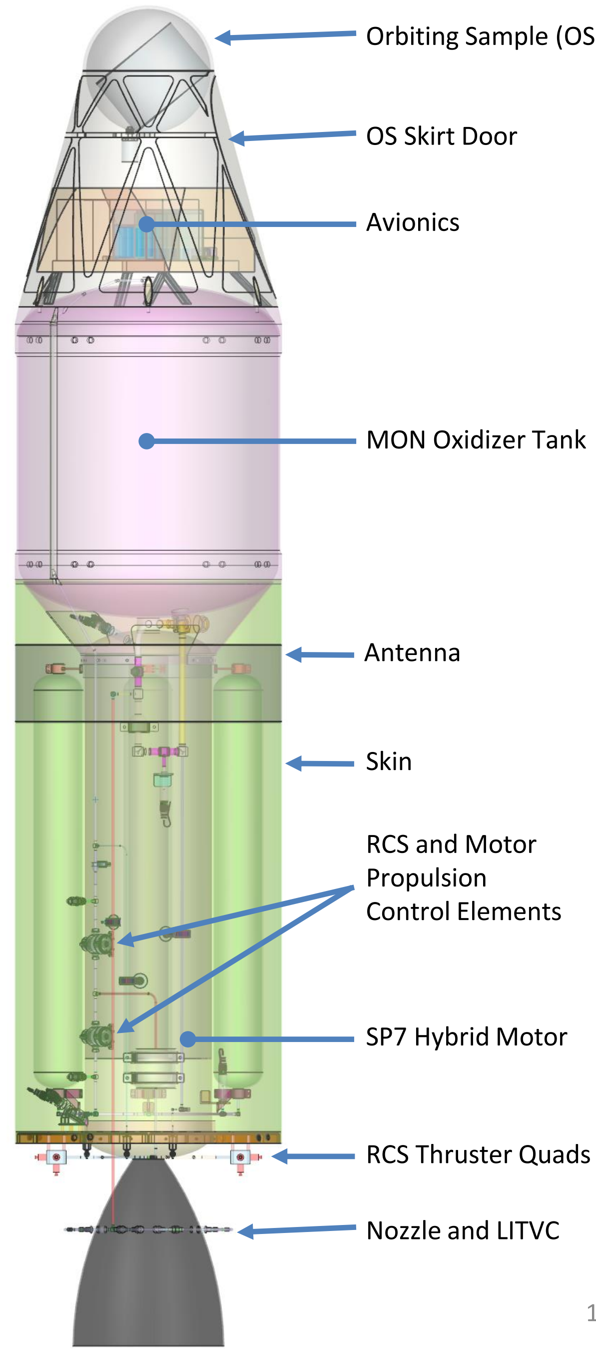
Key Specifications

Rover Mass: 120 kg (NTE)
Stowed Volume: 0.96m^3
Required Peak Power: 140 W
Power Architecture: Solar Arrays (1.5m^2)
Mobility System: 4 wheel bogie (4 drive / 4 steer, sideways driveable)
Robotic Arm Degrees of Freedom: 4
Flight Computer: RAD750 + VCE
Navigation: VCE + 3U MSL repackage + Miniature IMU + M2020 EECAMs
Telecom: Electra-Lite radio + UHF Antenna

MAV Reference Design

- Continued Study from 2015…
  - Added Subsystem Maturity and Fidelity
  - Validated Single-Stage-To-Orbit Design
    - Target Orbit 350 km @ 18º Inclination
    - 12 kg OS Capability (31-Tubes)
  - Length: 2.4 m x Diameter: 0.57 m
  - GLOM Range: 290-305 kg (w/ 50% margin)
    - Varies with launch uncertainties
  - Mass Fractions
    - Propulsion Dry Mass : 10%
    - Non-propulsion Dry Mass : 12%
    - Oxidizer Mass: 63%
    - Fuel Core Mass: 14%
    - Helium Mass: <1%

GLOM	Gross Liftoff Mass
LITVC	Liquid Injection Thrust Vector Control
OS	Orbiting Sample
RCS	Reaction Control System
TPS	Thermal Protection System



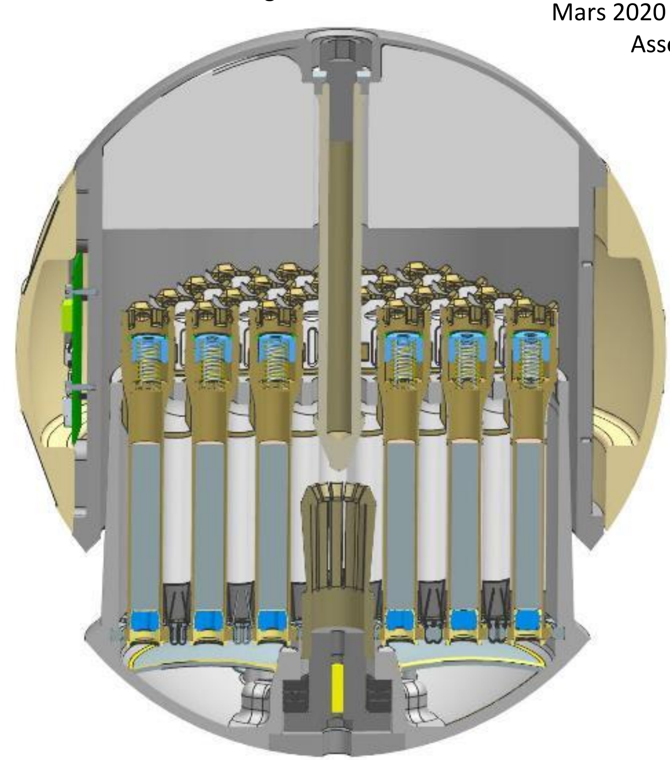
MAV Technology Development Status

Orbiting Sample (OS) Concept Overview

- OS Concept
  - 31 tube slots, central rod for load support
  - 2 chambers for atmospheric samples
- Surface
  - Sandblasted gold meets thermal, albedo, & specular reflectance requirements
- Mass & diameter
  - Mass ≤ 12 kg
  - Diameter ≤ 28 cm
- The OS with Sample Tubes must withstand environments imposed by SRL, SRO, EEV
- Orbital Sample (OS) interfaces directly with both SRL/MAV and ERO elements of MSR

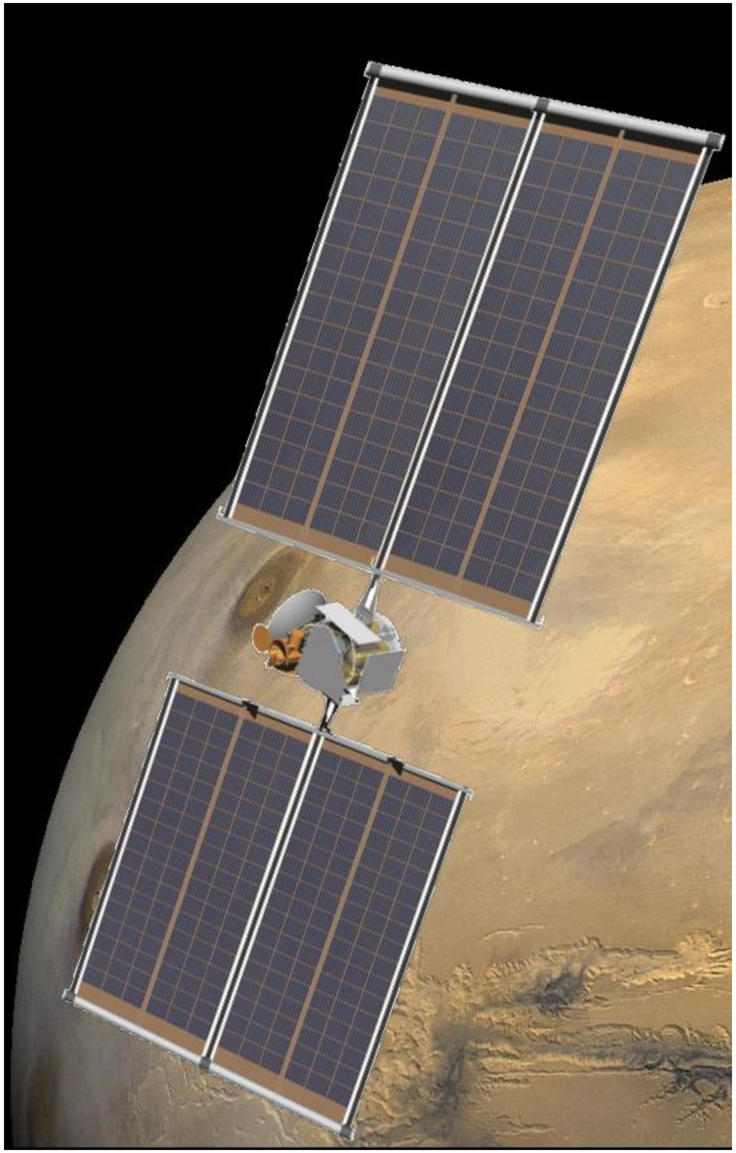
Current OS Reference Design

Mars 2020 Sample Tube Assembly



Notional Sample Return Orbiter

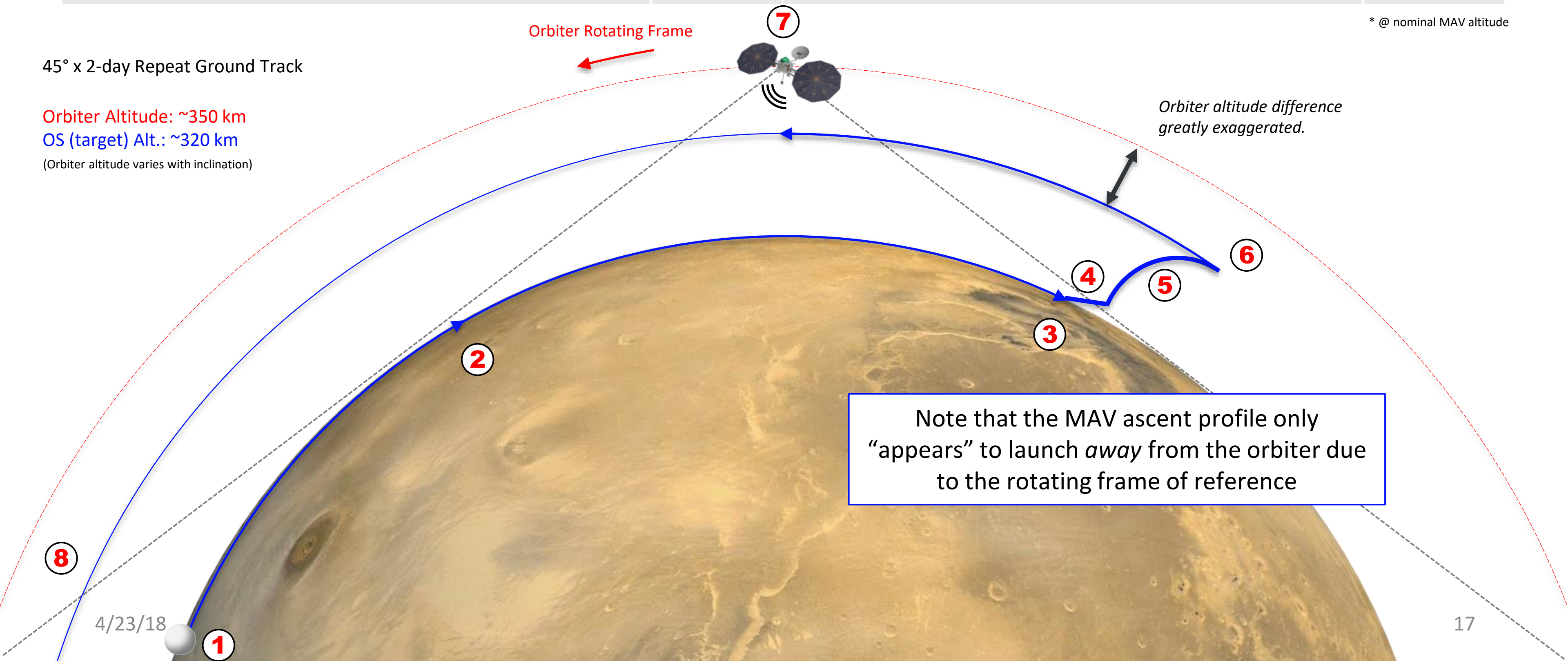
- Key functions
  - Rendezvous & Capture of on-orbit OS
  - Containment and Earth Planetary Protection
  - Communication telemetry and tracking during MAV launch
  - Return to Earth
    - Release of Earth Entry Vehicle on direct entry trajectory
    - Delivery of contained samples to cis-lunar space for human-assisted return
- Payload
  - Rendezvous and OS Capture System (ROCS)
- Flight System
  - Currently assessing Chemical and Electric Propulsion options for this high-ΔV mission
  - Staging (jettison of orbiter elements prior to Earth return) likely required



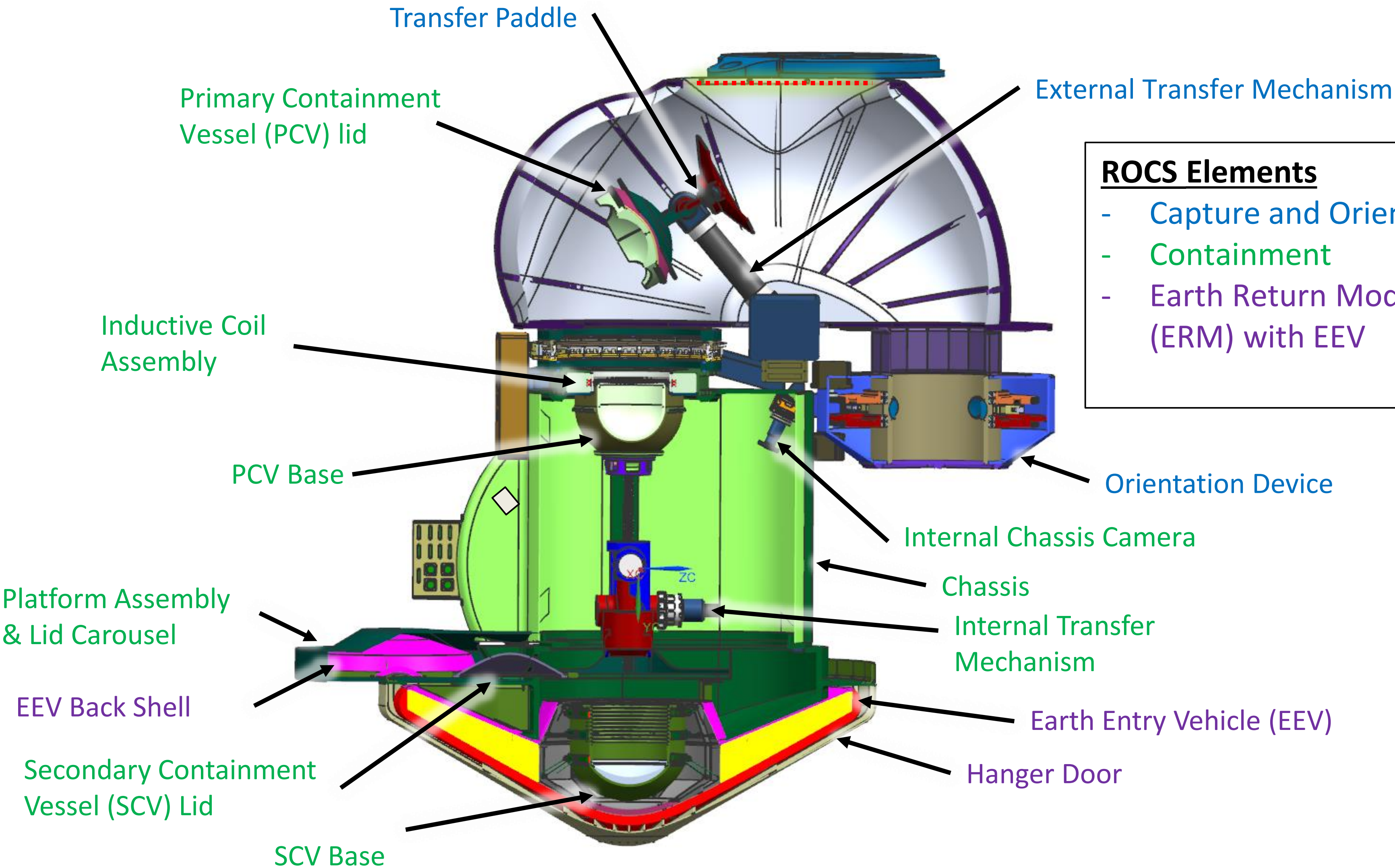
Notional MAV Launch Sequence

Event	Time	Event	Time
(1) MAV Ready for Launch	L-2d	(5) Ascent Coast Phase	L+15m
(2) MAV-Orbiter In-View (Go / No Go)	L-20m	(6) 2nd Burn / OS Separation	L+16m
(3) MAV Launch	L-0	(7) OS Passes under Orbiter	L+15h*
(4) Ascent 1st Burn	L+2m	(8) OS Occulted by Mars	L+39h*

* @ nominal MAV altitude



ROCS Containment System Concept

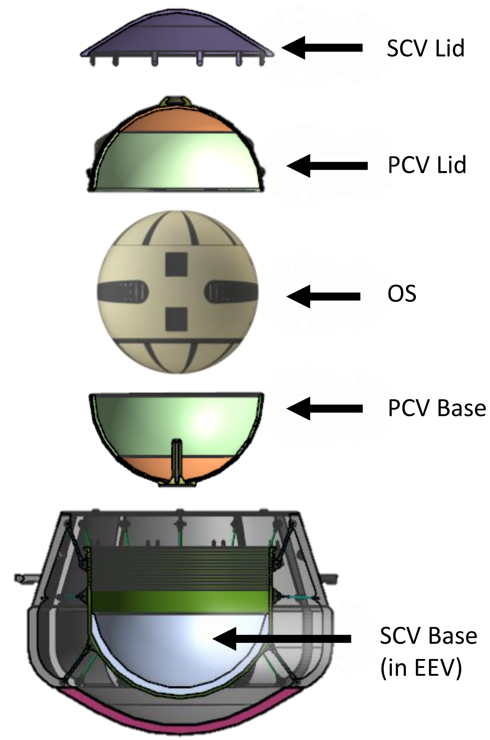


ROCS Elements

- Capture and Orientation
- Containment
- Earth Return Module (ERM) with EEV

Biocontainment Concept Overview

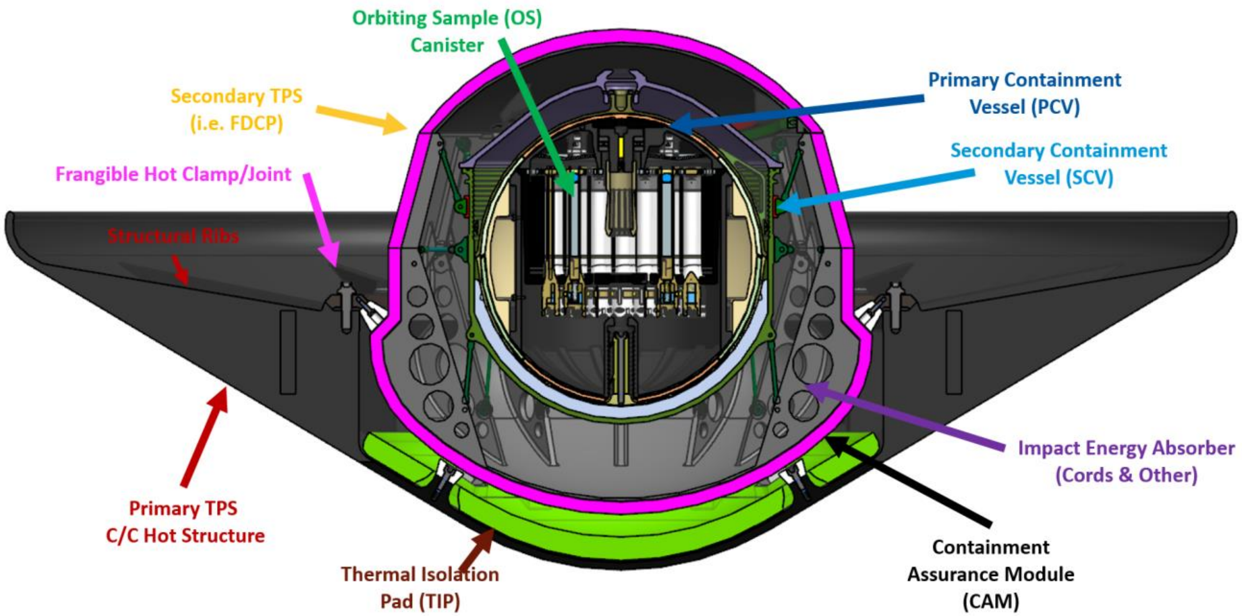
- Biosealing represents a key sub-element of the Rendezvous and OS Capture System (ROCS):
  - Breaking-the-chain of contact with Mars (BTC)
  - Sealing a primary containment vessel (PCV)
  - Sealing a redundant secondary containment vessel (SCV)
  - Transferring the Contained-OS to the EEV (ERC)
- Currently developing brazing technology for PCV to simultaneously seal the containment vessel and sterilize the seal itself



¼-scale Brazing Prototype

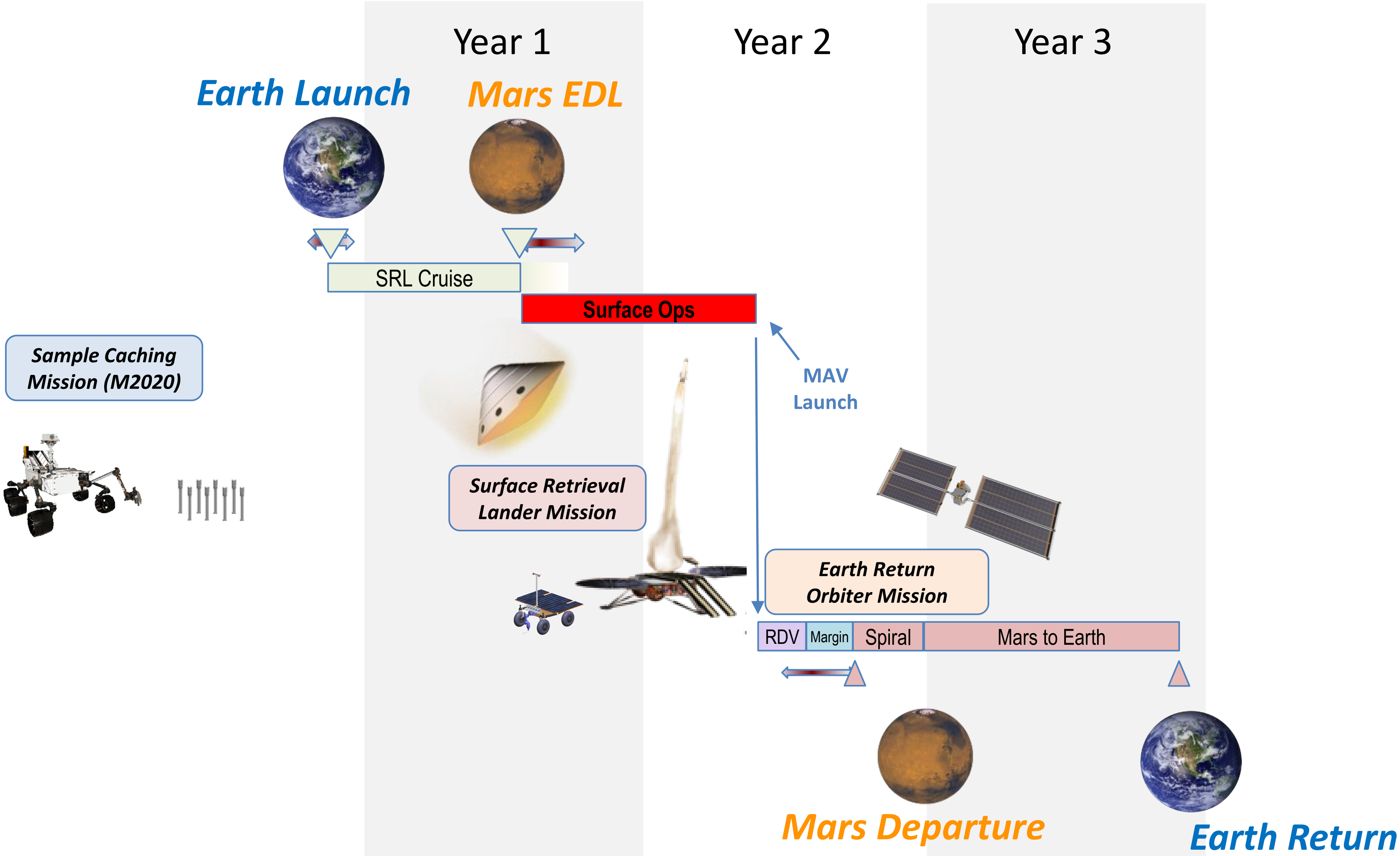
Earth Entry Vehicle Concept

- Driving Requirements
  - Assured containment (MMOD impact tolerance, off-nominal landing scenarios up to 300 g peak)
  - Science integrity (1300 g nominal peak landing load)
  - High entry velicity (up to 13.5 km/s)



Candidate EEV concept (1.25 m dia., 60˚ sphere-cone, 96 kg (margined landed mass, including 12 kg NTE OS mass)

Notional "Fast" MSR Timeline



Fast timeline could return samples to Earth ~3 yrs after SRL launch

Summary

- Mars Sample Return represents the next logical step in advancing our understanding of the Red Planet
- Mars 2020 – in flight implementation – is on track to acquire a set of scientifically selected samples for potential return to Earth
- Mission concepts have been established for the follow-on Sample Retrieval Lander and Earth Return Orbiter missions required to return those samples
- Key technology development activities are underway for critical MSR capabilities (MAV, Containment Assurance)

We are ready to move forward with a campaign to return samples from Mars

Backup

Key Campaign-level Technical Trades

M2020 Sample Caching Strategy
- Depot(s)
- Add'l M2020 Extended Mission Caching?
- # Tubes
- M2020 Sample Tube Delivery?

SRL/ERO Joint Mission Timelines
- SRL/ERO Launch Dates
  - ERO chem vs. SEP propulsion
- SRL Surface Mission Timeline
- ERO Orbital RDV timeline
- ERO Relay Support to SRL?
- Earth return date

MAV
- Targeted Orbit (Altitude, Inclination)
- Delivered Orbit Accuracy

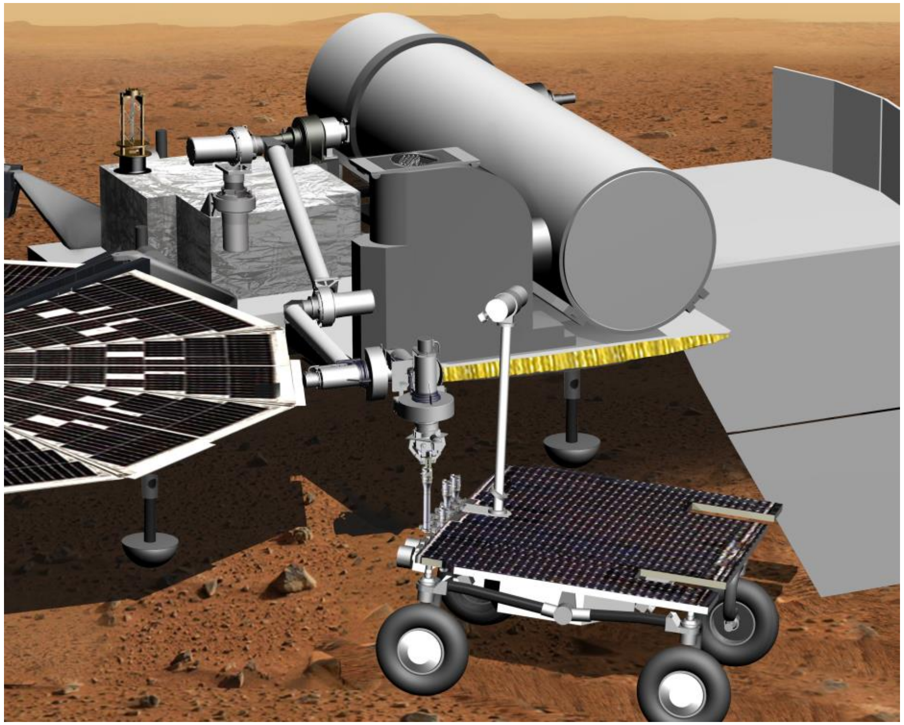
OS
- RF Beacon?
- # Tubes
- Air Samples?

Containment Assurance
- BTC on surface and/or in orbit
- CA method(s)

Earth Return Strategy
- Direct Earth Return
- Cis-Lunar Delivery w/ Crewed Return

Tube transfer with Lander Robotic Arm

- For either M2020 or Fetch Rover sample delivery, SRL incorporates a Lander Robotic Arm to transfer tubes to the Orbiting Sample container
    - Arm is currently 2m long and 7 DOF
    - Will likely utilize force control and vision system for precision operations
- Robotic Arm could potentially be an item for partner contribution



(Artist's Concept)

Mars Returned Sample Handling (MRSH)

Notional 3-Component Architecture