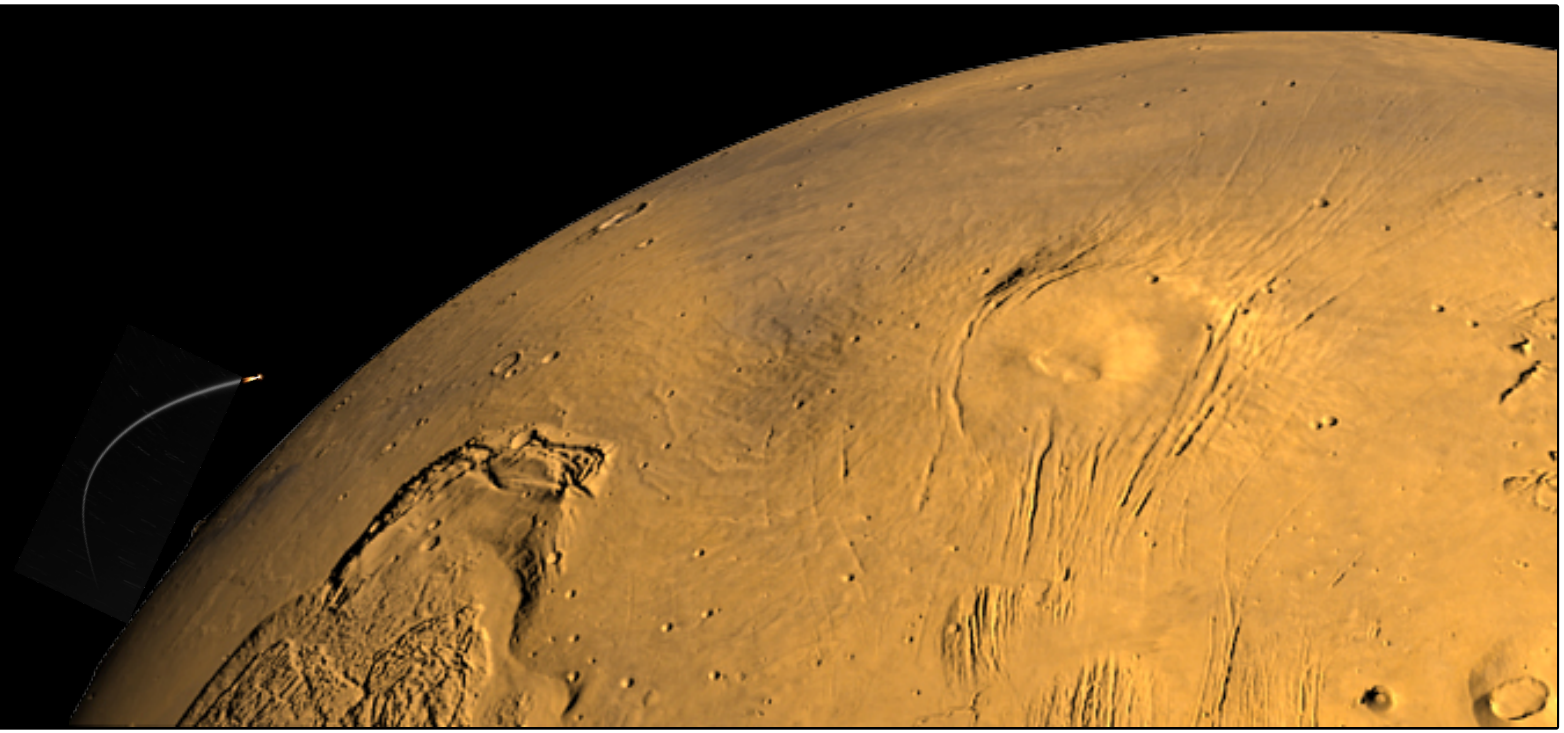
Mars Ascent Vehicle



Jet Propulsion Laboratory
California Institute of Technology

MARSHALL
SPACE FLIGHT CENTER

Mars Ascent Vehicle – Payload?, Spacecraft?, Launch Vehicle? – A Systems Approach to MAV

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MSR-MAV PAA Study Objective

To support a potential Mars Sample Return Lander mission, by maturing designs for two Mars Ascent Vehicle concepts: the MAV-Hybrid and MAV-Solid, so that an informed decision can be made between the two.

What's a PAA Study?

- Preliminary Architecture Assessment (PAA) – a conceptual design activity meant to design, analyze, and compare multiple design configurations in parallel to meet a set of common engineering requirements.
  - Identifying potential bottlenecks and design issues for each configuration
  - Identifying potential programmatic design issues, regardless of configuration
  - Assembling a cross-Agency team and preparing them for Design Analysis Cycle (DAC) 0
- We couldn't find anything else in the NASA Systems Engineering literature that described this type of effort
- All the other acronyms were taken

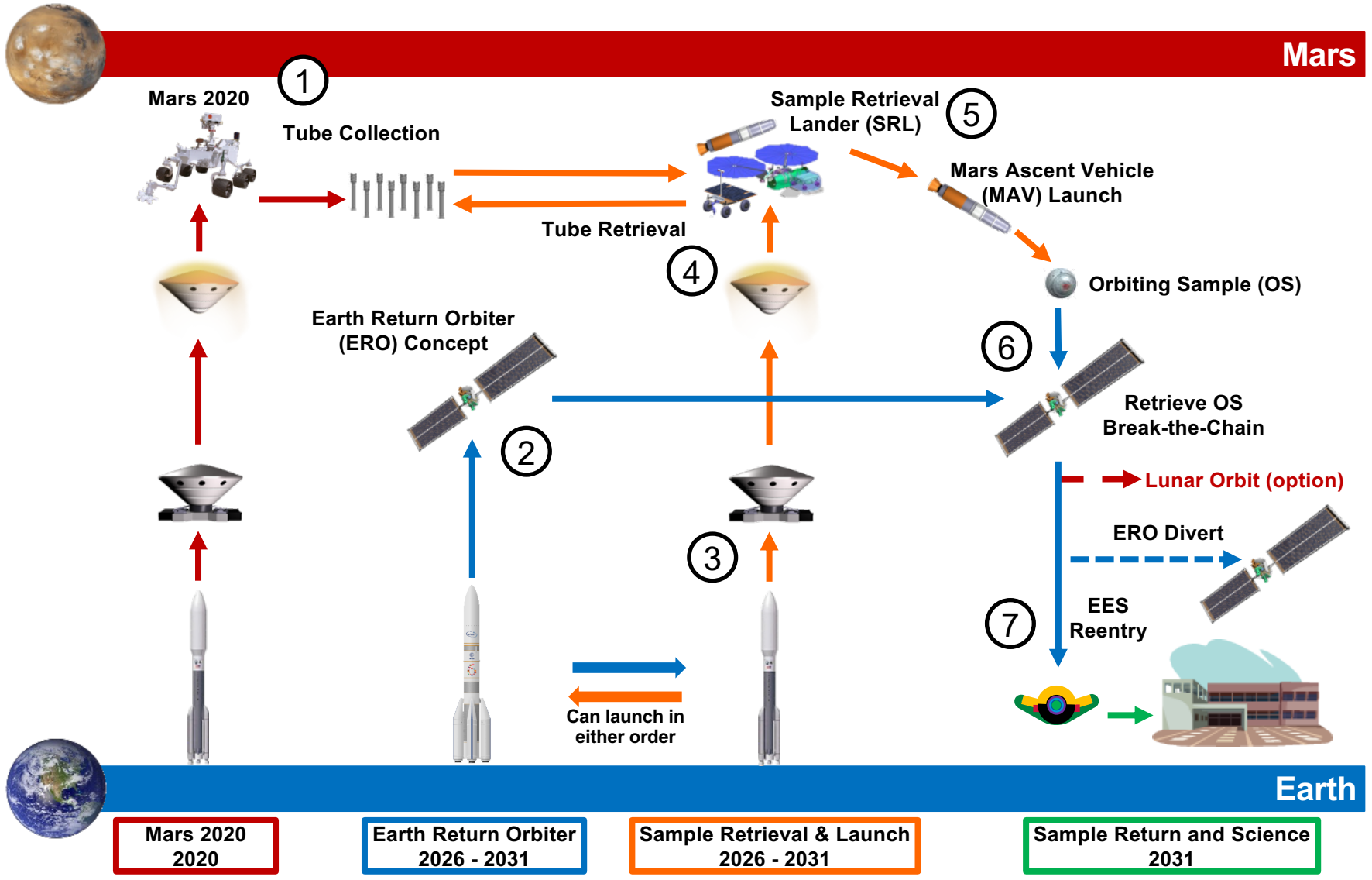
MSR Mission Overview

National Aeronautics and Space Administration
Jet Propulsion Laboratory / Marshall Space Flight Center
Mars Ascent Vehicle Study

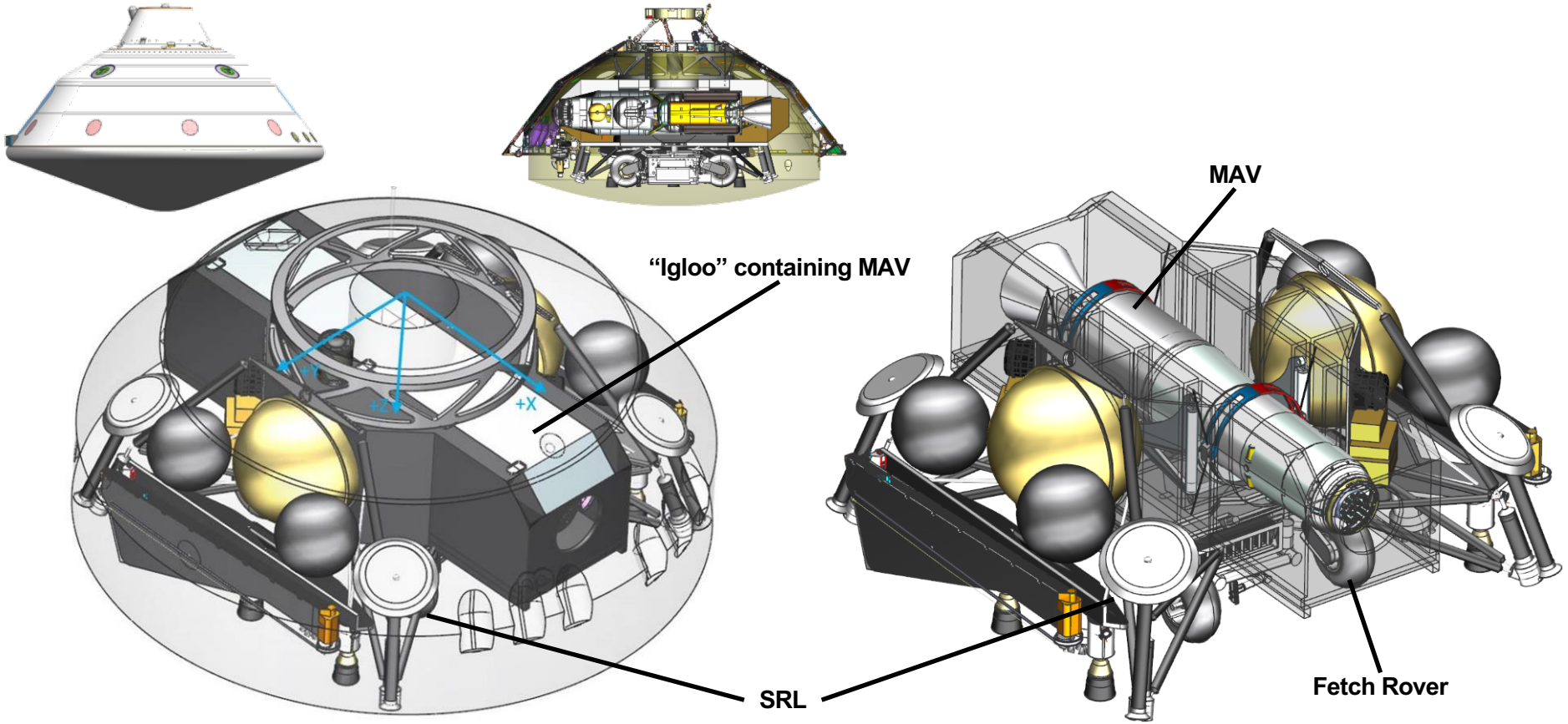
MSR Mission Objective:

Collect Mars samples and return to Earth.

1. Mars 2020 rover collects Mars samples and leaves tubes in place.
2. Earth Return Orbiter (ERO) sent to Mars orbit.
3. Sample Retrieval Lander (SRL) with Mars Ascent Vehicle (MAV) sent to Mars.
4. Fetch rover tasked with retrieving sample tubes on Mars surface. MAV dwell time in SRL on Mars ~9 months.
5. Tubes loaded into the Orbiting Sample (OS) in the MAV. MAV carries the OS to Mars orbit.
6. ERO rendezvous with OS. Captures, contains and transfers it to the Earth Entry System (EES).
7. EES returns OS to Earth.



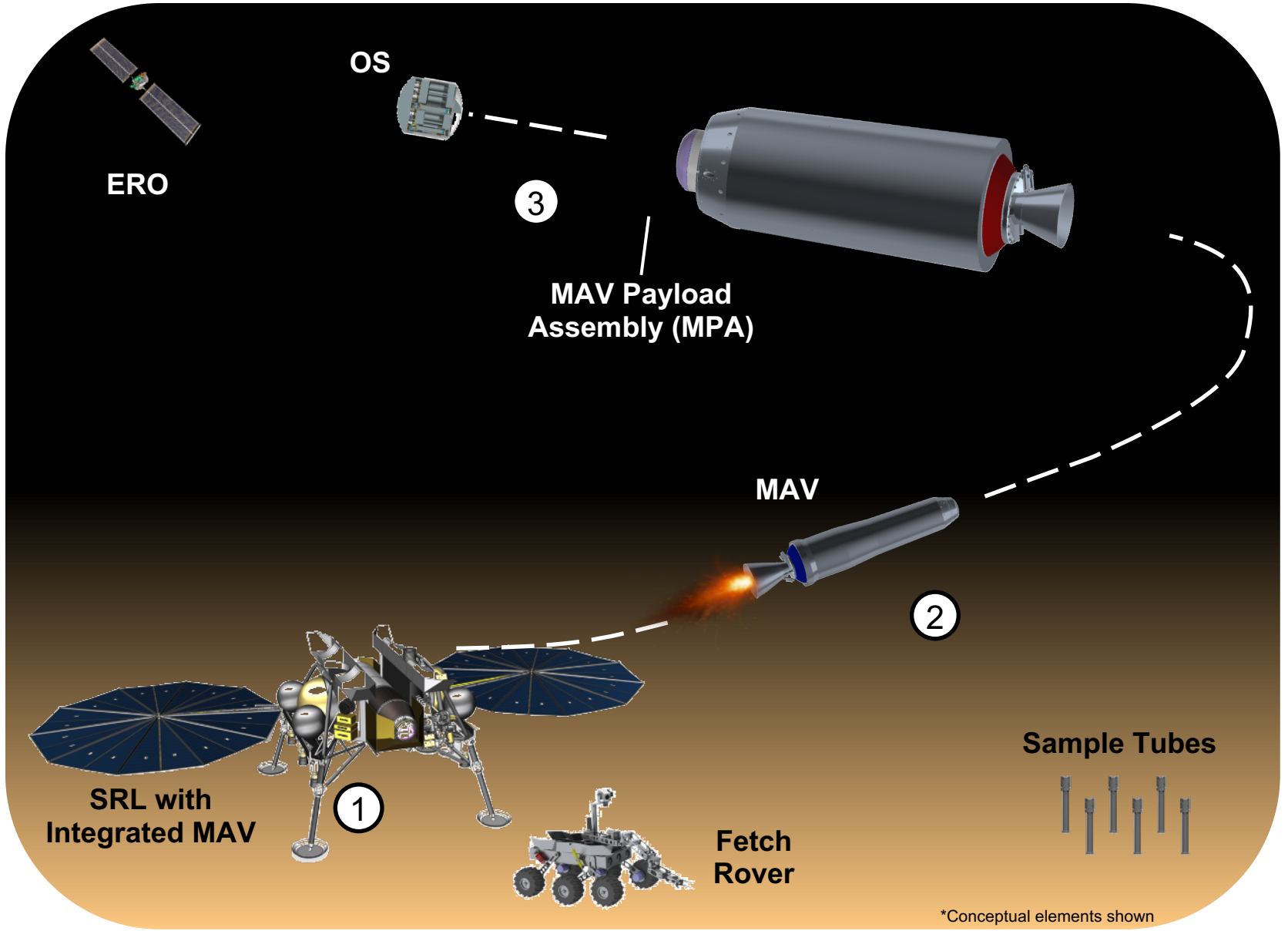
Sample Return Lander (SRL) and MAV: Stowed Configuration



*Conceptual elements shown

MAV Mission Objectives

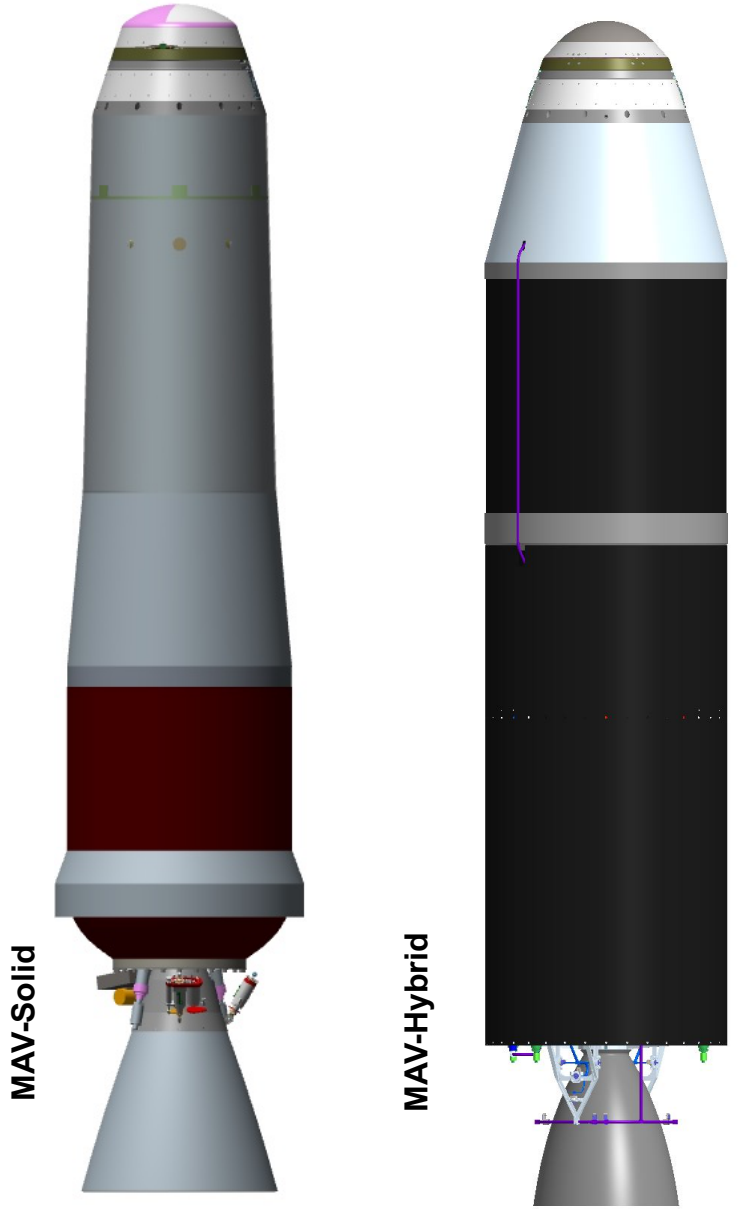
1. Receive sample tubes inside OS on Mars surface.
2. Launch OS to predefined Mars orbit.
3. Release OS in Mars orbit.



Driving Requirements for PAA

- The ‘quality’ of the final orbit of OS
  - Lower bound 300 km (hard value)
  - Upper bound 375 km (soft value)
  - Target orbit 343x343km ± 25 deg inclination
  - Semi-major Axis ± 9km
  - Eccentricity < 0.006
  - RAAN* ± 0.08°

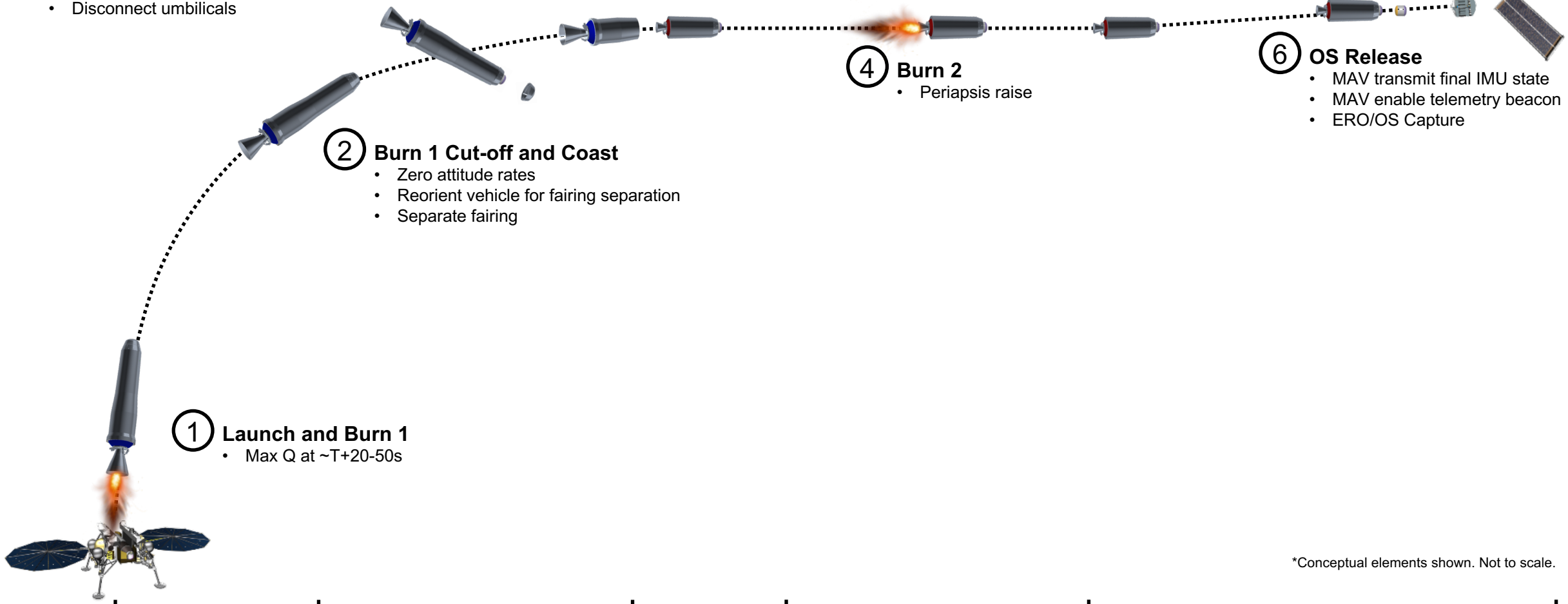
- The MAV concept must meet volume and mass requirements to fit onto the Sample Return Lander
  - Target GLOM 400kg
  - Height was originally not to exceed 3.0m, changed to 2.8m.
  - Diameter 0.57m



*Right Ascension Ascending Node

MAV Flight Operations Overview

National Aeronautics and Space Administration
Jet Propulsion Laboratory / Marshall Space Flight Center
Mars Ascent Vehicle Study



0 Pre-Launch
- Thermally-condition motor(s)
- Pressurize working fluid(s)
- Release launch locks
- Disconnect umbilicals

1 Launch and Burn 1
- Max Q at ~T+20-50s

2 Burn 1 Cut-off and Coast
- Zero attitude rates
- Reorient vehicle for fairing separation
- Separate fairing

3 Stage Separation/Settling
- Reorient vehicle prior to burn 2
- Settle ullage and/or separate stage prior to burn 2

4 Burn 2
- Periapsis raise

5 Burn 2 Cut-off
- Zero attitude rates
- Reorient vehicle for OS release

6 OS Release
- MAV transmit final IMU state
- MAV enable telemetry beacon
- ERO/OS Capture

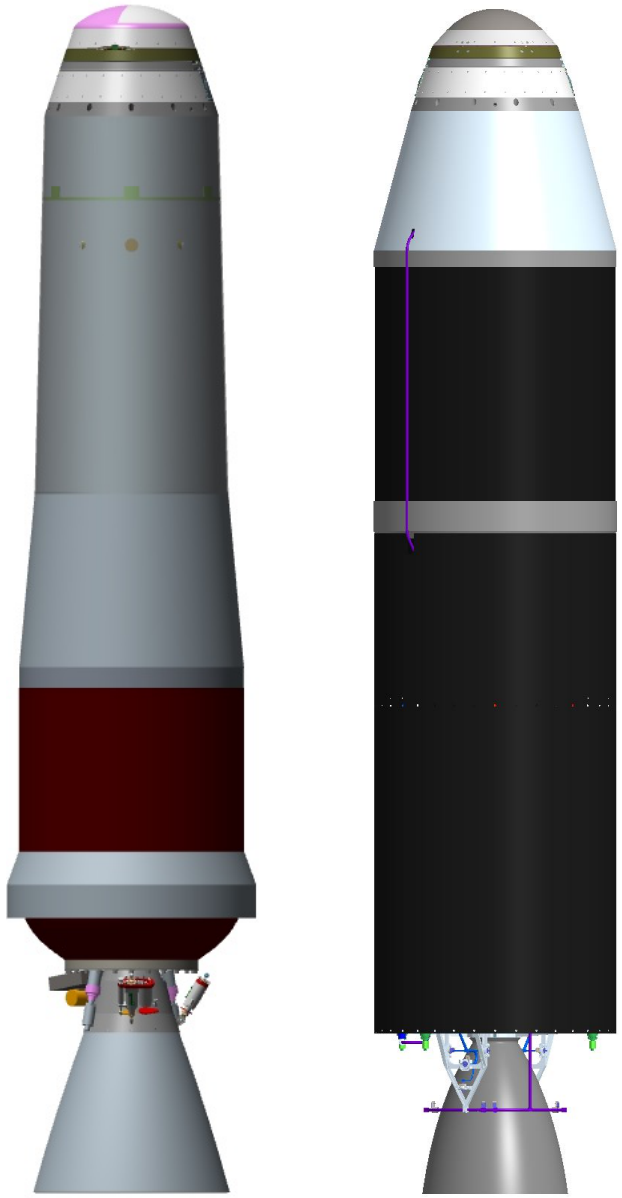
*Conceptual elements shown. Not to scale.

Burn 1	Coast	Burn 2	Prep for OS Separation	Loiter
70 – 90s	500 – 540s	20 – 30s	~Minutes	~Hours

MAV Architecture Concepts

Two-Stage Solid Motor Vehicle

- Solid motors for both stages
- Pyrotechnic stage separation
- Electrical-mechanical Thrust Vector Control (TVC)
- Monopropellant RCS
- Solid igniters



Single-Stage Hybrid Motor Vehicle

- Storable, pressure-fed liquid oxidizer
- Solid fuel
- Liquid Injection Thrust Vector Control (LITVC)
- Cold-gas Roll Control System (RCS)
- Hypergolic ignition

PAA Result Summary

- Both configurations successfully deliver their payload to orbit under nominal conditions, meeting size and mass constraints.
- Initial 6DOF dispersions featuring off-nominal scenarios showed that some orbit constraints were exceeded with the solid configuration.
- Although a number of options exist to mitigate constraint violations, these needed to be investigated in detail.
- Following PAA, MAV GNC team tasked with further analyzing MAV-Solid orbital parameters.
  - Dispersed Parameters
  - Sensitivities
  - Monte Carlo simulations
  - Extensive V&V with independent JPL team