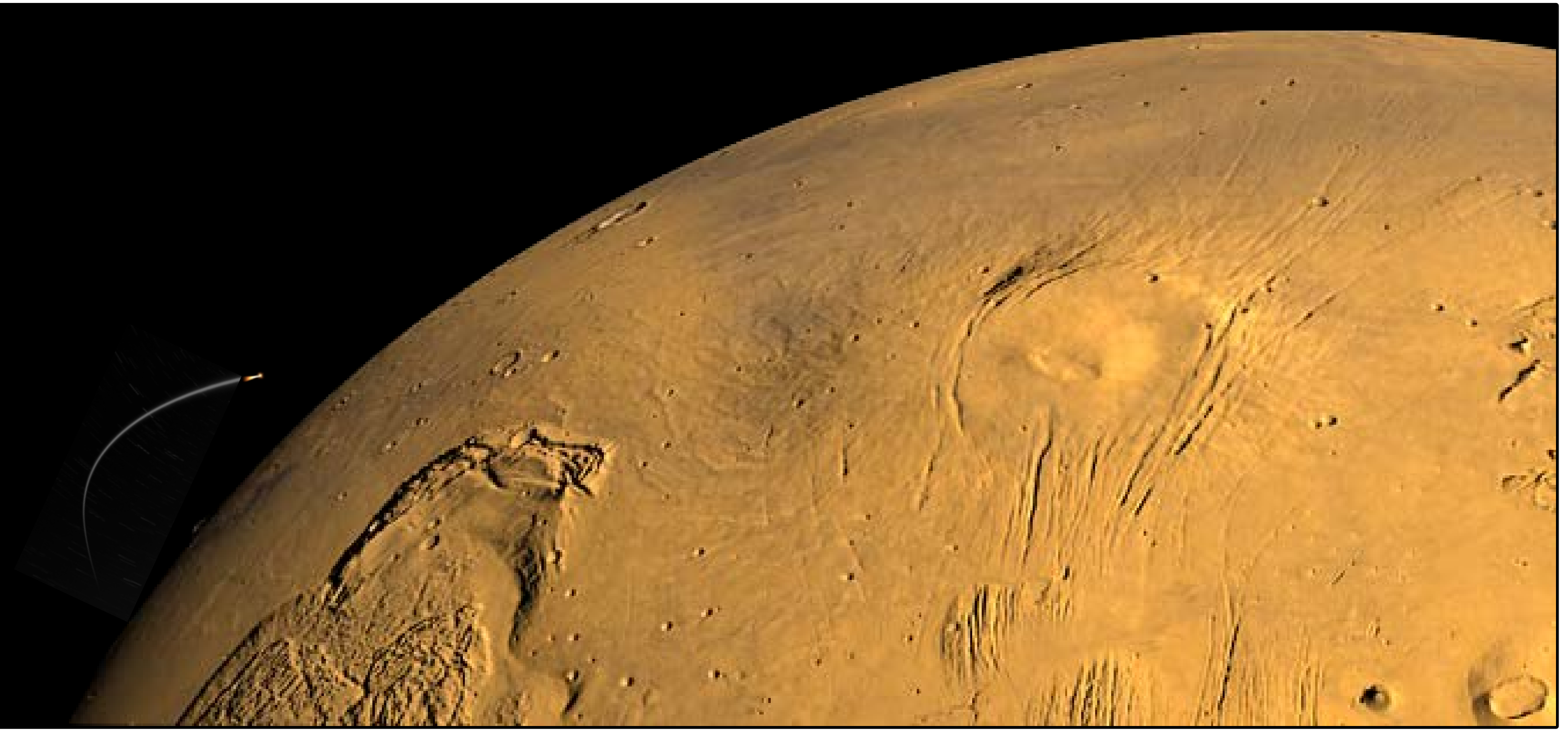
Mars Ascent Vehicle



Jet Propulsion Laboratory
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MARSHALL
SPACE FLIGHT CENTER

Development Concepts for Mars Ascent Vehicle (MAV)
Solid and Hybrid Vehicle Systems
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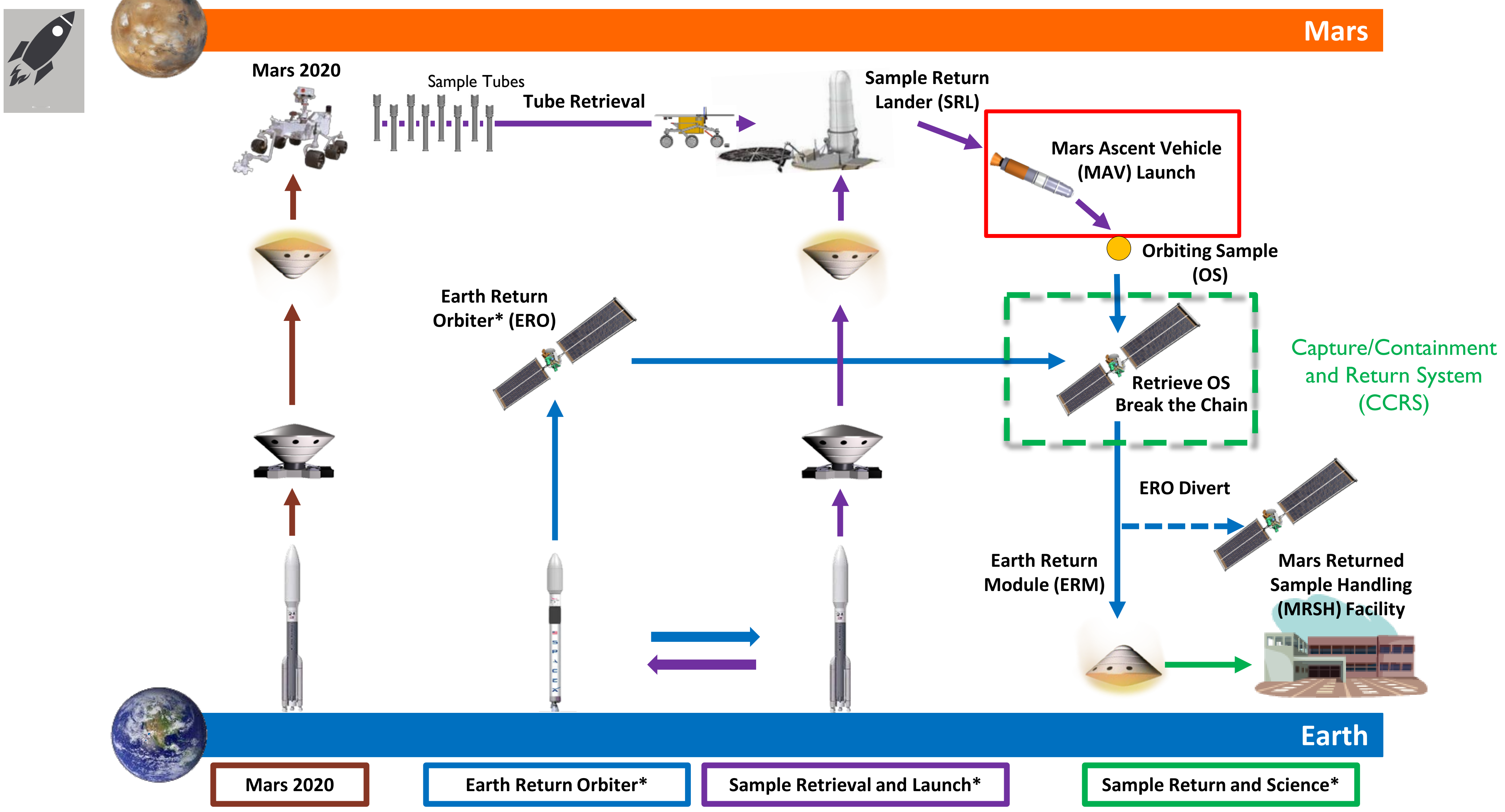

*Concepts under study

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Introduction

- ***Previous Studies***
  - Solid, liquid and hybrid rocket propulsion feasibility studies since 2011
  - Focus on hybrid rocket propulsion since 2016
- ***Reassessing Propulsion Systems for Risk Reduction***
  - Liquid propulsion vehicle found to not be feasible
- ***Challenges***
  - An autonomous return mission has never been done
  - Mars surface environments
  - Platform packaging limitations
  - Performance and trajectory requirements
- ***Study Team***
  - MSFC’s Advanced Concepts Office (ACO)
  - MSFC propulsion and vehicle design engineering expertise
  - JPL MAV team

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Concept Design Methodology for Solid Propulsion MAV

- *Common ground rules, assumptions and constraints with hybrid MAV concept*
- *ACO's iterative design methodology*
  - Performance needs
  - Structures sizing estimation
  - Reaction control system and vehicle stability
  - Avionics and power sizing
- *Analysis prioritized for subsystems which presented the most uncertainty or risk to safety and mass.*
- *Ongoing updates as concepts mature*

Parameter	***Assumption/Constraint***
Orbital Insertion Height	343 km
Orbital Insertion Inclin.	25˚
Payload Mass	18 kg
Vehicle Mass	400 kg (max)
Vehicle Length	3 m (max)
Vehicle Diameter	0.57 m (max)
Non-Operational Temp.	-70 ˚C to +40 ˚C
Operational Temp.	-20 ˚C
Entry Accel. Loads	15 g (lateral)
Post-Insert Divert	No divert maneuver
RCS Location	Fwd of 2nd stage / within OML
Avionics/Power Hardware	Maximum similarity to hybrid
Performance Margin	Additional 5 kg payload
Other Margin	AIAA margins / 25% for unknown

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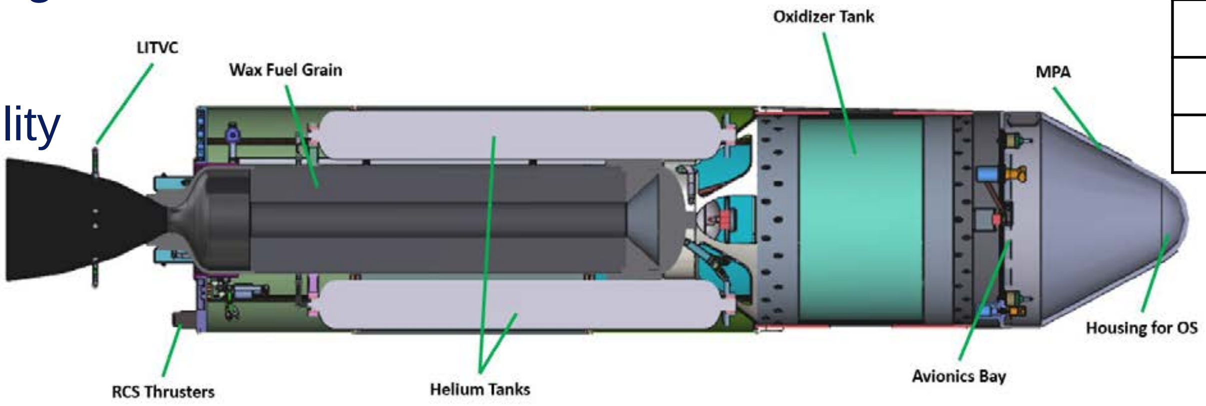
Hybrid MAV Concept Design Overview

- *Single stage to orbit vehicle*
- *SP7 wax and high percentage mixed oxide of nitrogen (MON)*
- *Liquid Injection TVC*
  - MON oxidizer
- *Reaction Control System (RCS) Concept*
  - Helium pressurant
- *Hybrid MAV Challenges*
  - MON percentage
  - Aerodynamic Stability
  - Hypergolic Ignition



Parameter	
GLOM	372 kg
Reserve Mass	5 kg
Payload	18 kg
Avionics & Telecom	4 kg
Power	0.4 kg
Vehicle Structure & Thermal	12 kg
Propellant	296 kg
Prop. Dry Mass	36 kg
ΔV	Appx. 4000 m/s
Total Impulse	824,300 Ns
Specific Impulse	308 s
Average Thrust	6830 N

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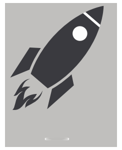
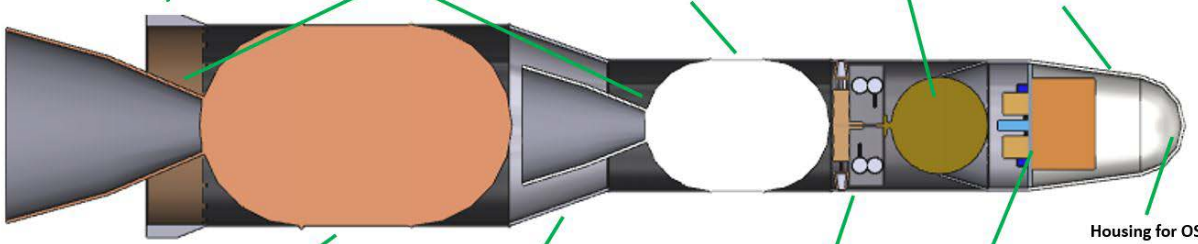


Solid MAV Concept Design Overview

- *2-Stage vehicle with “frangibolt” separation system*
- *Derived from heritage space and tactical motors*
- *Electro-mechanical TVC*
- *Reaction Control System (RCS) Concept*
  - Monopropellant hydrazine
- *Solid MAV Challenges*
  - Extreme cold environments
  - Lander interface

Parameter	***1st Stage / 2nd Stage***
GLOM	374 kg
Reserve Mass	5 kg
Payload	18 kg
Avionics & Telecom	10 kg
Power	0.5 kg
Vehicle Structure & Thermal	31 kg
Propellant	263 kg
Prop. Dry Mass	47 kg
ΔV	Appx. 4000 m/s
Total Impulse	620,730 Ns / 113,230 Ns
Specific Impulse	291 s
Average Thrust	13,794 / 4,355 N



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MAV Concept Comparison

- *Hybrid and Solid concepts show similar Gross Lift-off Mass (GLOM)*
- *Structures estimates are preliminary*
- *Further characterization of cold performance needed*
  - Hybrid potentially stores and performs better
- *Hybrid concept shows higher efficiency*
- *Solid shows higher TRL*
  - Extensive heritage in tactical systems and space missions

Parameter	***Hybrid MAV***	***Solid MAV***
GLOM	372 kg	374 kg
Reserve Mass	5 kg	5 kg
Payload	18 kg	18 kg
Avionics & Telecom	4 kg	10 kg
Power	0.4 kg	0.5 kg
Vehicle Structure & Thermal	12 kg	31 kg
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Interface Challenges and Mission Architecture Considerations

- *Interface with lander must continue to be studied and negotiated*
  - Structural supports and launch guides
  - Mass and volume constraints
  - Power constraints
- *Interface with Orbiting Sample (OS) and MAV Payload Assembly (MPA) still being studied*
- *Clarification of mission timelines*
  - Narrow expected storage and operational environments
- *Further integration of MAV study team into larger Mars Sample Retrieval study to stay abreast of changes to lander design, constraints, and assumptions*

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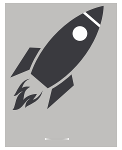

Ongoing and Future Studies

- *Propulsion system selection is expected to be made in 2019*
- *MSFC is currently running a preliminary architecture assessment in support of the propulsion system selection*
    - Concepts for MAV using each propulsion system are being developed in parallel
    - Mass, power, and cost estimates will be developed, and provided to the decision makers

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