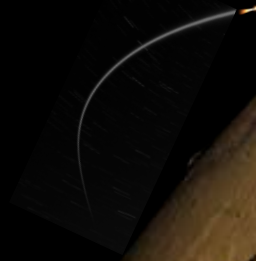


# Mars Ascent Vehicle



Qualification of a Hybrid Propulsion System  
for the Mars Ascent Vehicle  
Britt Oglesby / MSFC Solid Propulsion

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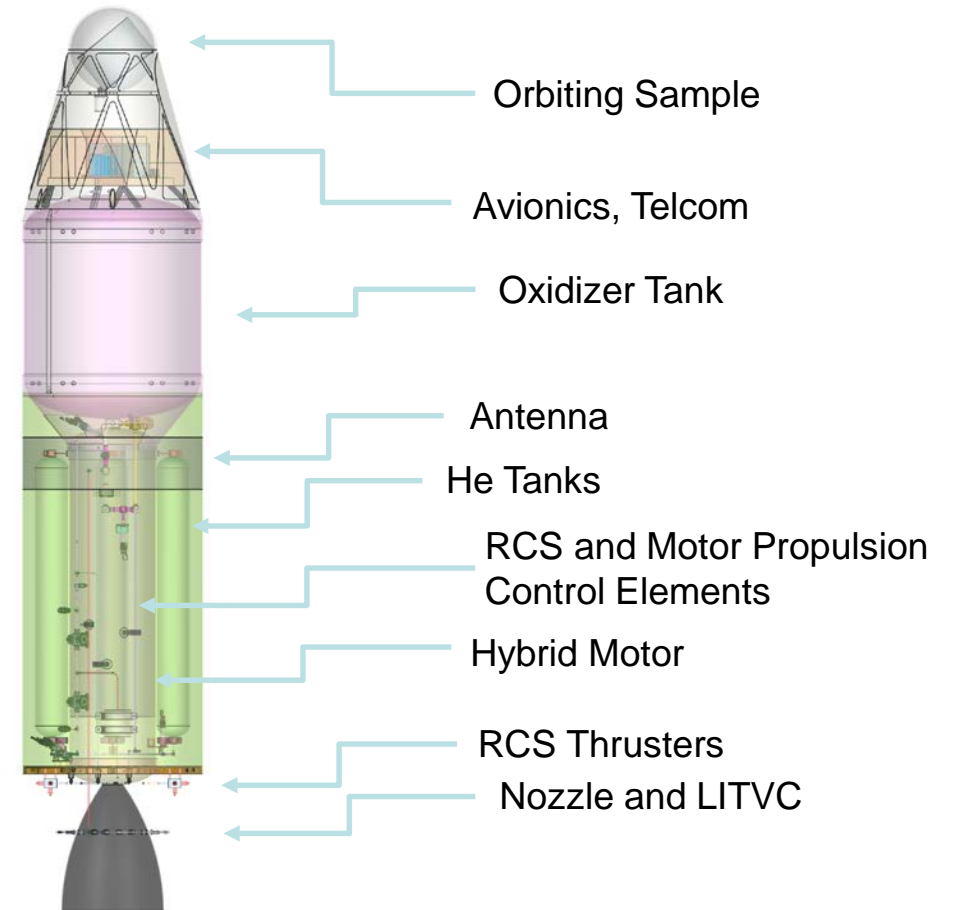


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## Hybrid MAV Overview

- Mars Ascent Vehicle (MAV)
- The system may be launched as early as 2026.
- A hybrid motor is the currently being traded for the propulsion system.
  - Oxidizer: MON-25
  - Fuel: SP7
- The current Technical Readiness Level (TRL 5) needs to be advanced to a qualified system.
- A focus on development and qualification challenges for the hybrid motor system.



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## Hybrid Fuel

- Wax based fuel designated SP7 (formulated by Space Propulsion Group).
- After full scale testing it was decided to modify the formulation to lower the regression rate (SP7A).
- Various manufacturing challenges have been tackled throughout development.
  - Residual stress due to the large Coefficient of Thermal Expansion (CTE) and phase change volume differences leads to fuel grain segments cracking.
- 3 to 4 large fuel segments are used to create one motor.
- Physical properties study underway by Southern Research Inc.

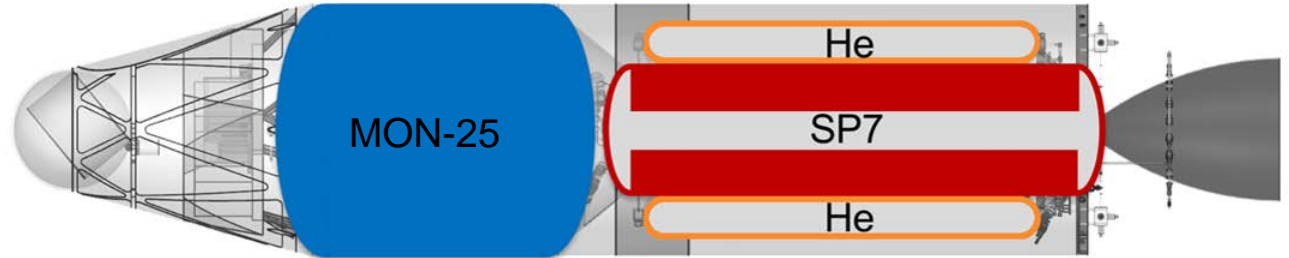


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## Hybrid Liquid Systems

- The hybrid motor liquid systems will be a significant driver of cost and schedule.
- Design, development, and hardware selection will require a significant lead time.
  - Oxidizer tank (≈24 months)
  - Oxidizer Valve (≈27 months)
  - Regulators (≈27 months)
  - Fill and Drain valve (≈16 months)
  - Pressurant tanks, pyro valves, LITVC valves, etc
- Utilize heritage hardware and testing when possible
- There will be unique loads on the vehicle during Earth launch and EDL on Mars depending on the final orientation vehicle.
- The oxidizer valve will be critical for a quick ignition and release from the lander





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## Hybrid Fuel Qualification

- The effect of ingredient production variation will need to be studied.
- SP7 ingredients are commercially available.
  - Able to buy in bulk for all qualification and flight motors
- Detailed, repeatable fuel grain casting process in a controlled environment will need to be defined.
- Solid propellant burn rate motor equivalents is a possibility to test hybrid fuel at a subscale level.
  - Previous subscale testing has been completed SPG, MSFC and Purdue
  - Small burn rate motors can be cast in parallel



Unprocessed SP7



SPG



Purdue



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## *Liquid System Component Qualification*

- Possibility of several newly designed components that will need to be qualified for the first time.
- COTS components may need additional testing/qualification due to unique environment.
- Oxidizer tank will be a long lead item with unique structural requirements.
- Component level tests will take place before moving to subsystem level testing.
  - Main oxidizer feed system, LITVC system, RCS system



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**Hybrid Motors**

- Planned hybrid motors from TRL5 to flight
- The number of motors is driven by cost and schedule.
- Currently baselining 4 static test motors per year leading to qualification.
  - Development motors currently being tested at Whittinghill Aerospace.
- Flight motor and spare will be manufactured alongside qualification motors.

Solid Motor Qualification Examples	
Motor	Tests
Apollo Jettison	21
Apollo Abort	20
Apollo Pitch Motor	17
Booster Sep Motor	16
Standard Missile IVA	15
Patriot	13
Orbus-21 (IUS-1)	6
Atlas V SRM	6
Ares Abort	6
Ares ACM	6
Ares Jettison	6
Castor IVA	5
GEM 40	4
Star 30B	4
Star 63D	4
SRTMU	4
GEM 60	3
Orion 50	1

Hybrid Motors																			
Motor	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Development	1	2	3	4	5	6	7	8											
Motor Qualification									1	2	3	4	5	6					
System Qualification															1				
Flight Test																1			
Dynamic Test Model																	1		
Flight Deliverable																		1	2



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## Qualification Motors

- Motor qualification will consist of the flight motor and LITVC.
- Flight oxidizer and helium tanks will only be used in fully integrated system tests.
- A range of environments and operational scenarios will characterize the motor performance.
- Planetary protection methods are currently being studied.
- Six motor qualification tests are currently scheduled.
  - The number of tests is a function of time and cost.
- Currently scheduling one fully integrated system test.

Hybrid Motors							
Motor Qualification	1	2	3	4	5	6	
System Qualification							1
Flight Liquid System							X
Planetary Protection	X	X	X	X	X	X	X
Thermal Cycling	X	X	X	X	X	X	X
Shock and Vibe		X	X	X	X	X	X
Altitude Start	X	X	X	X	X	X	X
Operating Temperature	NOM	NOM	HIGH	LOW	LOW	HIGH	NOM
1st Ignition Flow Rate	NOM	NOM	LOW	HIGH	LOW	HIGH	NOM
Oxidizer Flow Rate	NOM	NOM	HIGH	LOW	HIGH	LOW	NOM
Fuel Utilization	NOM	NOM	LOW	HIGH	HIGH	LOW	NOM
Coast Time	NOM	NOM	HIGH	LOW	HIGH	LOW	NOM
2nd Burn Altitude Start	X	X	X	X	X	X	X
2nd Ignition Flow Rate	NOM	NOM	HIGH	LOW	LOW	HIGH	NOM
2nd Burn Oxidizer Flow Rate	NOM	NOM	LOW	HIGH	LOW	HIGH	NOM
LITVC Function	X	X	X	X	X	X	X



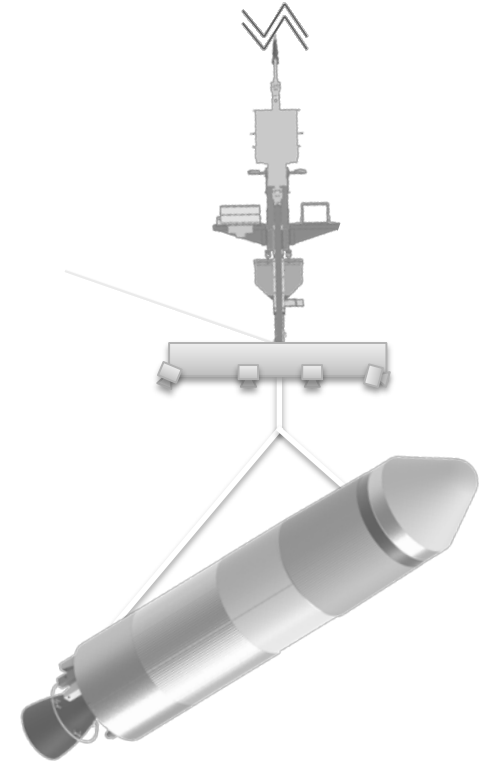


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## *Vehicle Level Flight Tests*

- Testing at altitude is the best way to simulate Mars conditions.
  - Temperature, Pressure
- Balloon launch will support as flight-like MAV as possible.
- The flight test will enable key operational tests such as:
  - Remaining SP7 behavior during coast
  - 2<sup>nd</sup> ignition at altitude
  - LITVC during both motor firings
  - RCS
  - Avionics
- One flight test is currently being scheduled.





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## Summary

- MAV hybrid motor continuing to be under development.
- Collaboration between Ames, JPL, MSFC, Space Propulsion Group and Whittinghill Aerospace.
- Qualification plans are still preliminary.
- Qualification completed through a series of components tests, static tests, and a flight test.



***Mars Ascent Vehicle Study***



***Questions***