

# Mars Ascent Vehicle—Propellant Aging

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## Sponsoring Program(s)

Science Mission Directorate  
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## Project Description

This project is to develop and test a new propellant formulation specifically for the Mars Ascent Vehicle (MAV) for the robotic Mars Sample Return mission. The project was initiated under the Planetary Sciences Division In-Space Propulsion Technology (ISPT) program and is continuing under the Mars Exploration Program.

The two-stage, solid motor-based MAV has been the leading MAV solution for more than a decade. Additional studies show promise for alternative technologies including hybrid and bipropellant options, but the solid motor design has significant propellant density advantages well suited for physical constraints imposed while using the SkyCrane descent stage. The solid motor concept has lower specific impulse ( $I_{sp}$ ) than alternatives, but if the first stage and payload remain sufficiently small, the two-stage solid MAV represents a potential low risk approach to meet the mission needs.

As the need date for the MAV slips, opportunities exist to advance technology with high on-ramp potential. The baseline propellant for the MAV is currently the carboxyl terminated polybutadiene (CTPB) based formulation TP-H-3062 due to its advantageous low temperature mechanical properties and flight heritage. However, the flight heritage is limited and outside the environments, the MAV must endure.

The ISPT program competed a propellant formulation project with industry and selected ATK to develop a new propellant formulation specifically for the MAV application. Working with ATK, a large number of propellant formulations were assessed to either increase performance of a CTPB propellant or improve the low temperature mechanical properties of a hydroxyl terminated polybutadiene (HTPB) propellant. Both propellants demonstrated potential to increase performance over heritage options, but an HTPB propellant formulation, TP-H-3544, was selected for production and testing. The test plan includes propellant aging first at high vacuum conditions, representative of the Mars transit, followed by an additional year at simulated Mars surface conditions. The actual Mars surface environment is based on the igloo design, actively maintains the propellant at or above  $-40\text{ }^{\circ}\text{C}$ , 95% carbon dioxide at Mars surface pressure. The NASA Marshall Space Flight Center (MSFC) Mars environment test facility is shown in figure 1 and located in the East Test area of Redstone Arsenal due to storage of live propellants. The facility consists of a vacuum chamber placed inside a large freezer unit. The facility includes pressure and temperature monitoring equipment in addition to a vacuum quality monitoring system spectrometer to record any outgassing products.

The propellant aging test removed and shipped the first set of samples in the summer of 2014. The results showed  $<0.1\%$  mass loss in all samples, a sign of vacuum compatibility. The initial mechanical property testing did not reach all of the project's stretch goals, but the mechanical properties of TP-H-3062 and TP-H-3544 are nearly identical while the new propellant has both higher  $I_{sp}$  and higher density. Currently, the new propellant is showing positive margins to all requirements and represents an increase in performance over the heritage system. Additionally, the new propellant formulation is the only propellant tested to the relevant environments with significant testing. Note: The project did include control samples at ATK and also one CTPB propellant block. The internal volume after the first samples were removed is shown in figure 2.



Figure 1: Propellant blocks in the MSFC Mars simulation facility.

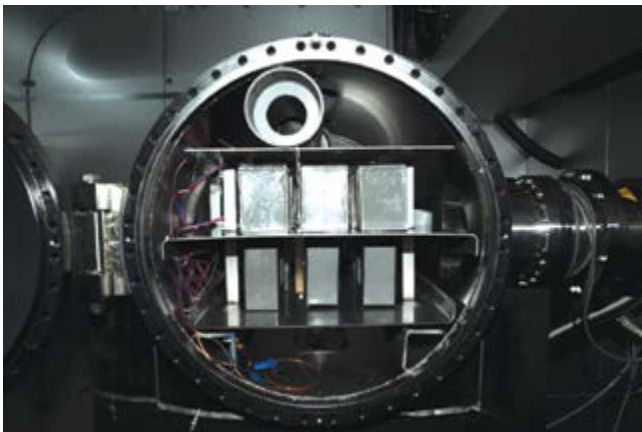


Figure 2: Internal view of the MAV propellant test facility.

### *Anticipated Benefits*

The benefits of the new propellant formulation include high margins for mechanical performance of the propellant, increased  $I_{sp}$  over alternative heritage options, and an overall increase in total impulse of a volume-constrained MAV motor.

### *Potential Applications*

The project's application goals are very focused for the robotic sample return MAV. However, a higher performance solid motor propellant with expanded operating environments is also of interest to non-NASA solid motor applications.

## Notable Accomplishments

This project has completed a large number of propellant formulation trades and developed a database of propellant formulation options and characterized sensitivities for  $I_{sp}$ , burn rate, strain and maximum stress, etc. The project has also completed the first of three phases of propellant aging, validating vacuum compatibility of the new propellant formulation.

## References

Dankanich, J.W.; and Klein, E.: "Mars Ascent Vehicle Development Status," IEEE AC Paper No. 1471, 2012 IEEE Aerospace Conference, Big Sky, MT, March 3–10, 2012.