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Mars Ascent Vehicle—First Stage Motor

Project Manager(s)/Lead(s)

John Dankanich/ZP30
(256) 544–3441

Scott Doudrick/Jet Propulsion Laboratory

Jacob Williams/ATK, Elkton
(410) 392–1388

Sponsoring Program(s)

Science Mission Directorate
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Project Description

This project is development effort of a first stage solid motor based on a two-stage solid motor Mars Ascent Vehicle (MAV) design for the robotic Mars Sample Return (MSR) mission (fig. 1). The MSR MAV has been studied for decades and multiple concepts have been shown to meet the mission objectives as posed.[1] However, there remains significant uncertainty with the MAV requirements. The sample container and sample cache itself is immature. Additionally, MAV-specific requirements ranging from full three-axis controlled and strict communication requirements to minimal capability concepts are still under consideration. Given the maturity of the overall mission requirements, the MAV has been limited to a large number of parametric analyses and paper studies.

Recently, a Jet Propulsion Laboratory study highlighted the flexibility of a two-stage solid motor concept. The MAV itself is driven by the constraints of the Entry, Decent, and Landing (EDL) system. Within the EDL constraints, there is a range of MAV options ranging in complexity from simple spun upper stage options to higher capability three-axis controlled solutions. There are also options to trade the ratio of mission ΔV between the first and second stage. Finally, sensitivity studies also indicated that solid motors with a high percentage of off-load flexability only had minor impact on the total system mass over a single point design optimized motor. This flexibility in the first stage motor has allowed NASA to mature the design of the motor beyond parametric analyses and start to address known design challenges of the motor.

Figure 1: Two-stage solid motor MAV concept design.

The project included system design trades for case materials, grain design, nozzle options, actuators, etc. In addition to the ATK effort, the NASA Marshall Space Flight Center (MSFC) team also included igniter design support, igniter modeling plume analysis, thermal analysis, thermal-structural analysis, nozzle design, nozzle modeling, motor ballistics, combustion instability assessment, etc. A concept design for the first stage motor is shown in figure 2. Figure 3 illustrates some of the ignition gas dynamics.

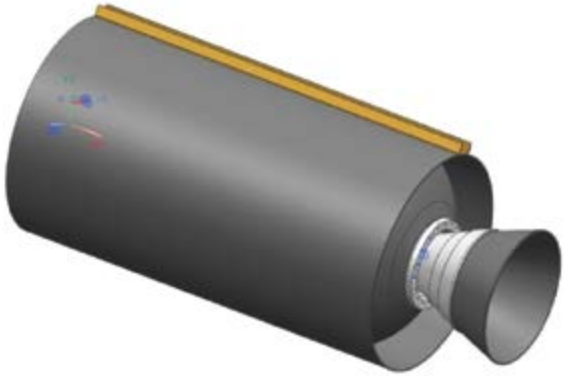

Figure 2: First stage solid motor concept design.

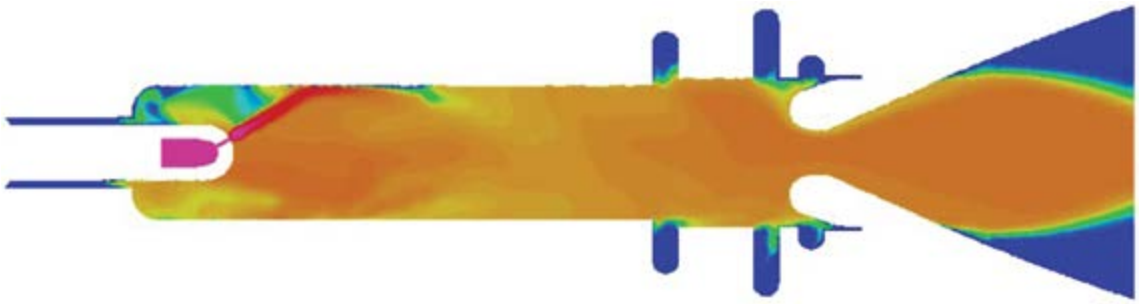

Figure 3: MSFC ignition gas dynamics modeling image.

Anticipated Benefits

The benefits of the first stage motor work included significant progress towards an engineering solution to the MAV propulsion. The MAV has been studied for decades and is listed in the Planetary Sciences Division Decadal Survey as one of the highest priority technology investments and has a high perceived risk.[2] This project is the highest fidelity design of a MAV propulsion system ever completed and provides the first preliminary analysis of a potential path forward. If successful, the MAV propulsion system development may evolve into an engineering development project rather than a higher risk technology development effort.

Potential Applications

The application for the first stage MAV motor is specific to the MSR MAV.

Notable Accomplishments

This project will complete three design and analysis cycles of preliminary design fidelity to identify a first stage solid motor solution that meets all requirements of the MAV. The project includes all thermal, mechanical, ballistics, etc. modeling of the integrated motor assembly and operation. The project also included both contractor and NASA independent validation of preliminary design and analyses. The project confirms a feasible approach to meet the objectives of the MAV first stage motor.

References

1. 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.

2. Squyres, S.; et al.: "Vision and Voyages for Planetary Science in the Decade 2013–2022," NASA Research Council of the National Academies Final Report, 2011.