IAF SPACE EXPLORATION SYMPOSIUM (A3)
Mars Exploration – Science, Instruments and Technologies (3B)

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DESIGN CONSIDERATIONS AND DEVELOPMENT STATUS FOR ATMOSPHERIC POWERED DESCENT OF HIGH-MASS PAYLOADS AT MARS

Abstract

The entry, descent, and landing (EDL) systems for NASA's eight successful Mars landers have all relied on extensions of technology developed for the Viking missions of the mid-1970s. The most ambitious mission, the Mars Science Laboratory, delivered a rover the size of a small automobile (1t payload) to the surface of Mars on August 6, 2012. While incremental improvements to EDL technologies, namely rigid aeroshells, supersonic parachutes, and subsonic propulsive terminal descent, have increased payload mass capability, new approaches to EDL are necessary to support the delivery of larger human exploration payloads (20t) to the Mars surface. NASA has identified and initiated development of a number of those technologies. This paper is focused on the design considerations and development status of one such technology: powered descent, or extended, free-flight retropropulsion.

Atmospheric powered descent challenges traditional processes and dependencies in system design. Changes to a design by one discipline have the potential to affect overall vehicle performance in a more exaggerated manner than in the case of powered descent with no atmosphere. The interdependence is due to the fact that propulsive-aerodynamic interference effects can be very sensitive to small changes in configuration or operational environment. Flight mechanics, aerosciences, propulsion, and mechanical design, along with other disciplines, must iterate and integrate at the conceptual design level to produce a closed design satisfying mission requirements with reasonable confidence. As examples, aerosciences may provide limitations on engine operating conditions or engine configuration to avoid interference effects that could potentially impact vehicle controllability. Likewise, aerodynamics models directly impact propellant usage.

Within this context, a summary of the current assumptions for the human-scale powered descent phase of EDL at Mars, an overview of relevant physics, and an assessment of the present baseline concepts are presented. Additionally, the interdependencies of traditionally 'black box' disciplines in the integrated vehicle design and execution of the powered descent phase are discussed. The emphasis is on impacts of the interactions between the atmosphere and retropropulsion exhaust plumes on system performance and the work required to develop and fly such a powered descent system at Mars. Finally, this paper will discuss the relationship between ground testing, computational analysis, and flight testing for a human-scale mission implementation of powered descent, focusing on the evolution of the state-of-the-art in wind tunnel testing and high-fidelity computational fluid dynamics simulation capabilities.