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An Overview of Technology Investments in the NASA Entry Systems Modeling Project

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I. Introduction

Current planetary Entry, Descent and Landing (EDL) technologies are fundamentally limited in terms of landed mass and landing accuracy capabilities. Key technology challenges for this mission class were summarized by Braun and Manning.[1] In addition, NASA has conducted several conceptual system and configuration analysis studies of potential human Mars mission architectures. The most recent example was the Mars EDL Systems Study[2] in 2009-2010. The 1970s-era Viking heritage EDL technologies used for all Mars missions to date, including the Mars Science Laboratory,[3] are not extendable to payloads larger than about 1.25 t. The primary limitation is in deceleration of a large payload mass through supersonic speeds in the tenuous Martian atmosphere so that the terminal descent system has time to deploy and ensure a soft landing on the surface. Traditional parachutes, and the low lift over drag blunt aeroshells that deliver the spacecraft to the point of parachute deployment, simply will not scale to large payload mass. In order to enable landing the larger payloads that will be required for large-scale science, in-situ resource utilization, and eventual human exploration, a new generation of innovative entry and descent technologies is required. Although current NASA plans do not call for human Mars exploration until the decade of the 2040's, the magnitude of technology advances that are required necessitate early investment in several (currently) low TRL technologies. There will need to be several flight tests in Earth's atmosphere and possibly at Mars in order to gain sufficient confidence in these systems before relying on them for a human expedition. Tracing back the schedule from human landing on Mars, assuming reasonable development times for the flight tests, and allowing for an occasional failure, it becomes clear that we need to begin such technology developments within the next few years in order to meet the objective of humans on Mars in the 2040's. In addition, while human Mars exploration is certainly the grand challenge for EDL technologies, significant gaps exist for other destinations as well, including Venus, Giant Planets, and high velocity Earth return.

Nearly all EDL related technology development efforts within NASA at the current time are contained within the Space Technology Mission Directorate (STMD). Investments in this Directorate range from system level architectures to component technologies, primarily at mid-TRL, with an expected maturity timeline of 2-3 years. Examples include the Low Density Supersonic Decelerator Project (LDSD), the Advanced Entry Placement Technology (ADEPT) Project, the Hypersonic Inflatable Aerodynamic Decelerator Project (HIAD), and the Heatshield

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for Extreme Entry Environment Technology Project (HEEET). In addition, a single Project, Entry Systems Modeling (ESM), has a focus on lower TRL investments, primarily in the areas of Aerosciences and Thermal Protection Materials. The proposed paper will discuss the background, requirements, and the status of current technology investments in ESM, which is currently in its second year of execution.

II. Technology Investment Summary

ESM was created with two primary technical areas: Aerosciences and Materials. One of the first project deliverables, in both technology areas, was the development of Key Performance Parameters (KPP's), which are used to gauge the rate of progress in technology maturation, and to inform eventual technology downselects. In addition, the project was tasked to identify stakeholders or customers for proposed technology investments. While pull technologies are permitted within STMD, those capabilities that have strong customer support and a clear infusion plan are given higher priority. The current investment portfolio and achievements will be summarized in this section. At the current time more than 30 conference papers and journal articles have been published based on the research conducted in ESM.

III. Materials

The goal of the Materials area is to develop thermal protection system (TPS) materials and corresponding high fidelity models. Given the funding level of the project, the focus is on lower TRL concepts that can be matured to TRL 4 within 2-3 years and transitioned to another project for further maturation to TRL 6 and eventual mission infusion. Initial ESM materials investments include conformal ablators, flexible TPS, high-fidelity ablation response models, and coupling of computational fluid dynamics to ablation response. The current status of each of these tasks will be summarized in the final paper.

IV. Aerosciences

Entry modeling and simulation capabilities, including experimental validation, are a lynchpin of modern EDL design. Ground test limitations preclude a "test as you fly" approach to EDL systems, and flight tests are prohibitively expensive in most cases. As a consequence, validated high-fidelity models are used to extrapolate ground test results to predict flight performance. The aerosciences technical area includes investments in three key thrust areas: improved CFD/DSMC capability, shock layer radiation modeling, and aerothermal experimental validation. Some select results from the first two years of the project will be highlighted in the final paper.

References

[1]Braun, R.D. ad Manning, R.M., "Mars Exploration Entry, Descent and Landing Challenges," *Journal of Spacecraft and Rockets*, Vol. 44, No. 2, 2007.

[2]Cianciolo, A.M. et al. "Entry Descent and Landing System Analysis Study: Phase 1 Report," NASA TM-2010-21620, July 2010.

[3]Steltzner, A., "Mars Science Laboratory Entry, Descent and Landing System," IEEE Paper 2006-1497, Mar. 2006.