Overview of Initial Development of Flexible Ablators for Mars EDL

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Abstract

The Vision for the EDL Technology Development Project (EDL TDP) is to develop world class Entry, Descent, and Landing (EDL) technologies for Exploration Class Missions. The objective of the EDL Exploration Class Missions Project is the development of applicable technologies to a readiness level of TRL (Technology Readiness Level) six for specific Exploration Class Missions. The NASA Exploration roadmap calls for human exploration of Mars beginning in the decade of the 2030s, with precursor missions to the Low Earth Orbit and the Moon in preceding decades. While the technologies for LEO and Lunar return to Earth are reasonably mature and are under further development within NASA, the necessary technologies for landing astronauts and exploration class payloads (> 40 metric ton) on the surface of Mars do not exist today. The only proven EDL architecture for Mars entry is based on Viking heritage, with extensions for Mars Science Laboratory (MSL). However, this architecture is fundamentally limited to landed masses of about 2 metric tons, and cannot meet landed elevation and landing precision requirements for larger class exploration missions.

The Design Reference Mission as defined by the Entry Descent Landing Systems Analysis for Mars Missions Requiring Large Surface Payloads document (EDLSA-001) is to deliver multiple 40 metric ton payloads to the surface of Mars in order to support human exploration, in-situ resource utilization, and large scale exploration. Previous technology roadmaps have demonstrated that the current TRL of the necessary EDL components is so low that immediate technology development is required to support this timeline. Even if the need date of the technologies were to slip, low to mid TRL technology development is still a high priority, because of the long lead times of the required elements. In both the hypersonic and supersonic stages of EDL there are only two proposed technology candidates, and at the current level of fidelity it is not known whether either will be scalable to exploration class missions.

During it's first year, the EDL TDP was divided into three elements: Thermal Protection Systems (TPS); Aeroshell Modeling and Tool Development (MAT); and Supersonic Retro-Propulsion (SRP). Now, in it's second year, the EDL TDP has further divided the TPS element into two separate elements: Rigid TPS (R-TPS); and Flexible TPS (F-TPS) This paper will describe the steps being taken in pursuit of advanced ablative flexible TPS materials and systems with performance which support Exploration Class Systems. The Flexible TPS element will focus on developing material concepts for a 23-m deployable entry system to survive dual pulse heating (peak ~120W/cm^2), as shown in Figure 1. Because the peak heat flux exceeds 50 W/cm2, ablative materials will be required for the TPS. The Flexible TPS Element will define, develop, and model the ablative thermal material protection system concepts required to allow for the human exploration of Mars via aerocapture followed by planetary entry.

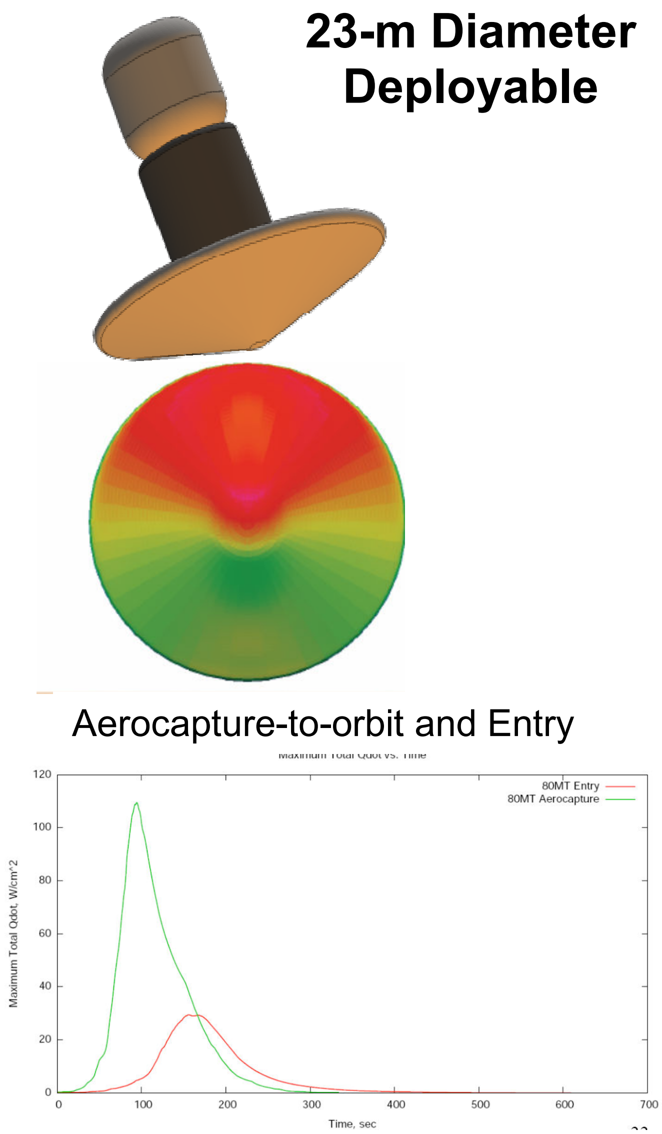

Figure 2. 23-m diameter deployable heatshield shape, heating distribution, and heating histories

For the initial project year, the focus of the deployable materials tasks was on evaluating the wide breath of possible TPS concepts selecting an initial set of concepts for thermal and structural screening and evaluation. NASA scientists developed flexible versions of known rigid ablative materials by replacing the rigid reinforcements with flexible equivalent materials and exploring with various resin compounds for impregnation into the reinforcements. In addition, organic flexible materials were also impregnated with resins and included. Evaluation criteria were developed for relevant materials comparisons and ranking. Existing materials properties were used to develop low fidelity models used to determine the design the proper screening test facilities and conditions therein and specimen geometries. Folding tests, radiation transparency tests and thermal evaluation tests in a radiant environment and an aerothermal environment were performed on each of the screening materials. Results of the screening tests were ranked according to the evaluation criteria and the first round of down-selections for further development were made.

This paper will present the results an overview of the initial development and evaluation of a new class of materials: ablative flexible materials.