# High Velocity Impact Performance of a Dual Layer Thermal Protection System for the Mars Sample Return Earth Entry Vehicle.

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## ABSTRACT

The Mars Sample Return (MSR) Earth Entry Vehicle (EEV) is currently planned on being released from its Micro-Meteoroid/Orbital Debris (MM/OD) shielding housing about two days before the Earth entry phase. This leaves the EEV exposed to incoming MM/OD impacts, potentially damaging the heat shield and compromising its Entry, Decent, and Landing (EDL) integrity.

Currently, two materials are proposed to comprise the MSR-EEV heat shield, a dual layer material called Heatshield for Extreme Entry Environment Technology (HEEET) or a single layer Phenolic Impregnated Carbon Ablator (PICA). PICA has been well characterized for OD class impacts, ~7 km/s high mass impacts, from previous testing done in the Orion program, but hasn't undergone extensive MM impact testing. HEEET is a relatively new material with minimal prior testing in regards to Hypervelocity Impacts (HVI). In order to inform the selectability of a material, it is crucial to understand the material performance when faced with an HVI, directly affecting mission success probability.

The current measure of a Thermal Protection System's (TPS) performance against an HVI is evaluating a thermally sized material against its Ballistic Limit Equation (BLE). A BLE is generated empirically from multiple shots of HVI testing and is used as a first order method in evaluating TPS's performance against the expected MM/OD environment. This method has proved useful for previous uniform density TPS materials, but has never been validated against a dual layer recession material such as HEEET.

Testing in the MSR program for FY19 has a requirement to assess the effects of a dual layer TPS by evaluating various thicknesses of HEEET Recession Layer, seen in Figure 1. While flying solely Insulation Layer can theoretically close the system from an aerothermal standpoint, adding a thin stack of Recession Layer has potential to provide a "whipple shield" like effect, increasing the HS robustness. From FY19 test data, BLE's will be derived for the individual thickness ratio samples, as well as the material as a whole to evaluate if a heritage form of the BLE can capture the complex physics associated with a dual layer system. Crater morphology will also be assessed with post-test Non-Destructive Evaluation (NDE) methods such as CT scanning to visualize if a BLE can predict the associated penetration depths, since a BLE assumes full vaporization of the impacting particle and is generally only used to size a spherical crater – disregarding any shrapnel effects from a high density impactor.

To inform this analysis, expected MM environments from the Meteoroid Engineering Model (MEM) and analytical equations for mass flux of incoming MM were evaluated for the notional MSR-EEV trajectory [1]. Using those dispersions, a Monte Carlo simulation was run to determine the most probable particle parameters, as well as those that carry the most risk of bondline penetration. From these probabilities, a test matrix was designed to test against bounding cases for the various parameters of the BLE: projectile density, projectile mass, projectile velocity, and the impact angle.

This presentation will discuss the performance of the dual layer TPS material HEEET against a wide range of impact kinetic energies and densities, as well as the comparison of HEEET to PICA in terms of MM/OD performance and selectability criteria.

**References:** [1] Moorhead, A. V., Koehler, H. M., & Cooke, W. J. (2015). NASA Meteoroid Engineering Model Release 2.0.