

OVERVIEW OF MICROMETEOROID AND ORBITAL DEBRIS ANALYSIS PROCESS FOR MARS SAMPLE RETURN EARTH ENTRY SYSTEM

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Brief Presenter Biography: Quincy McKown is a systems engineer at AMA based out of Ames Research Center with a background in aerodynamics and blunt body stability characterization.

Introduction: Micrometeoroid and orbital debris (MMOD) risk analyses for the Mars Sample Return (MSR) Earth Entry System (EES) have been significantly more rigorous than previously flown missions because of its categorization as a Class V restricted return mission. This means the returned samples present significant concern for biogenic contamination. These analyses seek to determine if a micrometeoroid or orbital debris strike would result in loss of containment assurance and are summarized in the flowchart in Fig. 1.

Methodology: The mission is considered in two MMOD phases: a pre-release phase where the EES is protected by a Micrometeoroid Protection System (MMPS) and a post-release phase called “free-flight” where the EES is exposed directly to the MMOD environment. These phases correspond to interplanetary cruise and imminent re-entry, respectively. To inform the MMPS design, a 30-shot high velocity impact testing (HVIT) series on candidate configurations at NASA White Sands Test Facility was completed in the summer of 2022. Sample post-shot images are shown in Fig 2 [1]. These data are used to baseline the MMPS design and to tune the hydrocode simulations.

ALE3D, CTH, and SPHC are the hydrocodes that simulate physics of high-speed impacts [2]. Results generated with these populate a penetration depth versus energy space beyond the testable velocity regime of HVIT (~7 km/s). The penetration depth versus energy space data are used to define a critical projectile diameter function called a Ballistic Limit Equation (BLE), where the projectile “criticality” is determined by zone dependent failure criteria defined a-priori [3]. For example, the nose of the heatshield has a failure criterion of 50% TPS penetration,

assigned because the landing loads are concentrated on that region and no substructure damage is permitted.

The BLEs for each vehicle material zone are input into the BUMPER 3 code, along with the vehicle surface mesh and the corresponding space environment model, to calculate a probability of penetration or number of penetrations. The environment models, MEM3 for MM and ORDEM 3.2 for OD, simulate the meteoroid environment from 0.2 to 2 au based on the Grün flux equation, and the debris environment up to 40,000 km altitude from Earth surface, respectively [4,5].

Presentation Focus: The presentation or poster will present the results to-date focusing on the full risk analysis process flow seen in Fig. 1. Details on the derivation of the failure criteria will be discussed, along with HVIT results and how these influenced the MMPS configuration baseline decision. Further, results of hydrocode simulations will be presented and the tuning to HVIT outputs will be described. Finally, the strategies that direct the BLE formulation will be reviewed, specifically, for the EES elements that are most exposed to the MMOD environment.

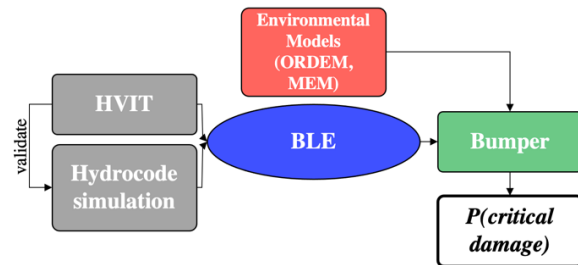
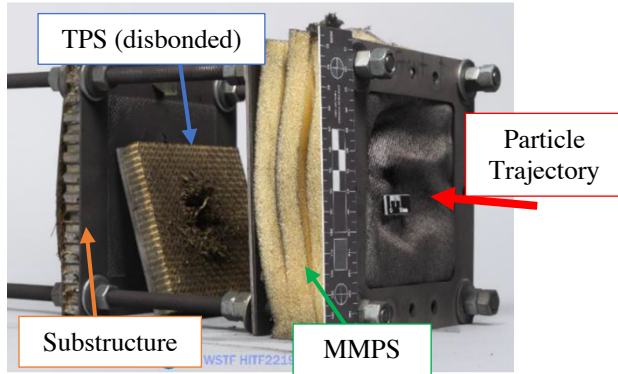
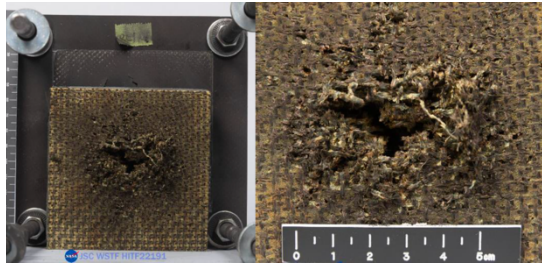


Figure 1: Process Flow for MMOD Risk Analysis



(a) MMPS in front of TPS, isometric view



(b) TPS surface, front view

Figure 2: Images of damage to TPS behind candidate MMPS configuration post-HVIT 12kJ shot [HITF22191, Test 18]

References

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- [4] Moorhead, A., Kingery, A., and Ehlert, S. (2020) *Journal of Spacecraft and Rockets*, vol. 57, no. 1, pp. 160-176.
- [5] Matney, M., Manis, A., et. al. (2019) *First International Orbital Debris Conference*.