

ORION ARTEMIS I AS FLOWN MMOD ANALYSIS

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ABSTRACT

Introduction

The Lockheed Martin Orion spacecraft conducted the Artemis I flight around the Moon from November 16 through December 11, 2022. After the flight, an engineer from the NASA Johnson Space Center (JSC) Hypervelocity Impact Technology (HVIT) Group performed a Micrometeoroid and Orbital Debris MMOD analysis using the Bumper 3 risk assessment tool to predict the number of small impacts that would likely have occurred during the mission. Separately, a team from the same group inspected the Orion capsule for hypervelocity impact damage features. The results of the inspection were compared to those of the analysis to aid in improving the analysis, including the environment models.

Scope of Work

The spacecraft geometry model was created by Lockheed Martin during construction of the Artemis I Orion vehicle based on Computer Aided Design (CAD) models of the vehicle. New hypervelocity impact testing was performed to verify Ballistic Limit Equations (BLEs) used in the analysis to link impactor size and damage to the Thermal Protection System (TPS).

The exact trajectory flown was recorded during the flight, including vehicle attitude. This data was used in conjunction with the ORDEM 3.2 and MEM 3 environment modeling tools to create models of particle flux impacting the spacecraft throughout the mission. Meteoroid shower forecast information was also included to account for additional particle flux associated with meteoroid showers.

Inspection of the Orion capsule included the Backshell thermal tiles and the tape covering it, windows, fabric thermal materials, and small areas of other materials. Potential MMOD damage found was characterized using various techniques, including optical microscopy, computed tomography scanning, and X-ray spectroscopy.

Findings

The number of craters found in the Backshell tile, and their size distribution, matches well with the Bumper analysis prediction. Tape, window, and other material impacts recorded similarly align to Bumper analysis predictions.

Conclusions and Recommendations

This comparison of analysis with inspection of the hardware provides valuable insight into the MMOD environment and how accurately analysis tools assess the impact risk to spacecraft. As this was the first large, non-ablative returned surface from a lunar mission, this analysis extends the MMOD community's insight beyond low Earth orbit into cis-lunar space.