THE BEHAVIOR OF HIGH-VELOCITY DUST GENERATED BY LANDER PLUMES IN THE LUNAR ENVIRONMENT

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Lunar lander plumes have been determined to generate fine ejecta at speeds exceeding 2 km/s [1], and recent work [2] has shown that Escape Velocity Domain (EVD) ejecta may remain in orbit for extended periods of time. By confining this study to expected near-term lunar activity and the known cone of dust generated by lunar landings, the behavior of high-velocity dust is characterized in an effort to understand its impact on orbiting lunar infrastructure such as the Gateway as well as the footprint of reimpacting dust on the lunar surface. In addition to the regular 3-body gravitation effects, the effects of Solar Radiation Pressure and charge are both quantified and modeled.

INTRODUCTION

The impact of dust on lunar missions has long been a concern to spacecraft functionality, astronaut health, and general mission success. With the upcoming Artemis program and the return of humans to the moon, there has been renewed interest in lunar dust. However, little attention has been paid to high-velocity dust and its ultimate destination. Previous work [2] has shown that predicting the destination of any given high velocity (v > 2.35 km/s) particles is nontrivial in the 3-body system. This problem is further complicated when one considers the increased role of Solar Radiation Pressure (SRP) and charge effects on very small particles (diameter < 1μm). It is also worth considering what the lifetime impact of regular landings on the surface, and the dust those landings generate, will be on orbiting infrastructure such as the Gateway.

METHOD

Using the approach taken by [2] as a starting point, the trajectories of the particulates are simulated at the range of expected angles from the impingement point. Because of the small mass relative to the area of the particles, SRP is expected to play a greater role in their expected trajectories, and thus close attention will be played to this consideration. Furthermore, the charge of the particles is also expected to play a much more significant role than it would for larger impact

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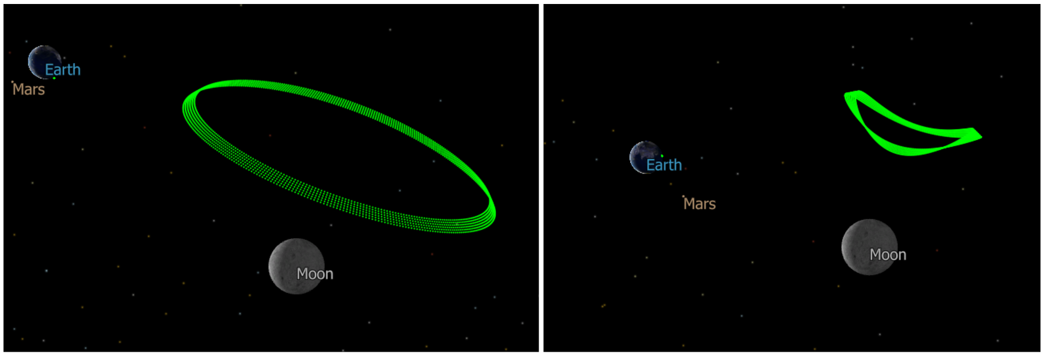

Figure 1. Dust was modeled with an initial position at the south pole landing site and initial velocity range near the EVD with a direction of between 1 and 3 degrees from horizontal at the impingement point.

debris. This is due to the greater cross-sectional area of the particle relative to its mass. Therefore, a time-dependent vector field is used to simulate the electromagnetic field of Earth and how it drives particle destinations. Once the expected flight paths of the particles have been determined, their reimpact distribution on the surface of the moon and the chances of impacting or interacting with Gateway and other lunar infrastructure will be determined. Depending on the relative velocities of the particles and Gateway, an initial risk analysis and mitigation plan will be presented. Likewise, the impact on lunar surface infrastructure will also be examined. The results of the simulation will be compared to the limited available existing data on dust patterns taken from Apollo and LCROSS/LRO observations.

EXPECTED RESULTS

The final product of this study is intended to create a baseline for predicting the lunar dust environment in orbit and in the presence of high levels of activity. Furthermore, these results will be designed to aid in the development of a dust mitigation plan for orbiting vehicles for the Artemis program and beyond, especially when operating in low gravity ($a_g < 0.33$ g) environments in which there may be high levels of activity either from manned presence or from natural phenomenon such as the dust and gas ejecta plumes, as was observed on Bennu.

REFERENCES

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