Lunar Regolith Particles Interacting with Lander Rocket Plume at lower Altitudes.

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Abstract. Economic opportunities, scientific knowledge, and colonization are some of the few reasons for conducting space exploration missions. Returning humans to the Moon is the first step for other missions, including Mars. Before doing that, it is critical to understand and mitigate the potential damage caused by rocket plume interactions with lunar regolith. As the rocket plume approaches the lunar soil, erosion mechanisms[1] and particle lifting occur, ejecting micron-sized particles at high velocities[2], possibly exceeding 3000 m/s. At this speed level, particles may damage nearby structures, orbital objects, and the lander itself, as particles may reach values higher than lunar escape velocity (~2400 m/s). This study presents the results of a numerical investigation using the DSMC method[3] of the trajectory, velocity, and angle of particles ejected by rocket plumes of a 40-ton lander at low altitudes (1, 3, 5, and 7 meters) above the lunar surface. For solving the particle trajectory, the Lagrangian approach uses the rocket plume flow solution through a one-way coupling while considering drag and weight forces. We simulated a broad range of particle initial radial positions (1 to 10 m) and sizes (1 to 1000 μm) to investigate their terminal velocity and angle beyond the influence of plume flow. In the present study, all particles are placed initially at 0.3 m above the ground surface, a similar strategy done by Lane et al.[4]. This strategy ensures the particles will not be attached to the ground, which has low overlying velocities. Shock waves in the bowl format are present in all altitudes, except for a lander at 1 m. Due to the drag force, regolith particles will be ejected from their initial position, assuming high velocities according to the plume flow region crossed. When particles leave the numerical domain, the drag force is negligible because of the fast plume gas expansion in the nearly perfect vacuum environment. Thus, particles at the boundary of the numerical domain will follow ballistic trajectories. The maximum particle velocity was around 755 m/s, which is not higher than the lunar escape velocity, considering the initial particle conditions adopted in this study. However, no planar ground surfaces may affect the plume flow, leading particles in high-velocity regions. Particles in these regions would reach higher speeds than lunar escape velocity with higher damage potential and mission risk.

References

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