Hypervelocity Impacts of Microscopic Dust Grains for Orbital Debris Remediation

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Low Earth Orbit (LEO) is becoming increasingly populated by orbital debris of all sizes and shapes that is hazardous to operational spacecraft . NASA has recently determined that a collision with debris between 0.5 mm and a few centimeters would be "mission ending". Recently, a novel technique to remediate small debris (less than 10 cm) from Low Earth Orbit (600 – 1100 km) has been proposed that uses injected high mass density dust particles of 25-50 micron radius to collide with orbital debris, transfer momentum and thus lower the apogee of the debris to an altitude that will naturally decay quickly. The dust is injected at orbital velocities in a polar orbit at the top of an altitude range targeted to be cleared. The dust then forms a ring around the Earth that can continue to exchange momentum with orbital debris in its path. One of the keys to the efficiency of this method is the physics of a hypervelocity impact, in which a very high-pressure shock wave is generated that can fracture, melt, vaporize and ionize the material. This high-pressure material that is not in a condensed state is ejected from the debris at large velocity, in effect acting like retro-rockets and greatly enhancing the exchange of momentum. The efficiency of the momentum transfer is measured by a parameter κ which is 1 for inelastic collisions and 2 for elastic collisions. Assuming a relative impact velocity of 10-15 km/s (twice the orbital speed) and assuming that the melting of aluminum (a standard orbital debris material) is sufficient to eject material from the target orbital debris we can estimate a value of κ to be about 18. The amount of mass necessary to perform the remediation is inversely proportional to κ and hence a solid understanding of the physics of this parameter is critical. We use CTH simulations and analytical theory to calculate the parameter κ, the velocity of the ejecta, and estimate the amount of ionization to occur. We will comment on the creation of electromagnetic radiation created by the impact generated plasma and the potential applications of the radiation.