Radio-Frequency Emission Detection and Scaling from Hypervelocity Impacts on Charged Targets

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Abstract

Hypervelocity impacts with dust-sized meteoroids and space debris are a routine occurrence for spacecraft. While the potential for mechanical damage from sub-microgram mass impactors is negligible, unwanted electrical effects can occur through the impact plasma cloud. This paper investigates into the potential for the production of strong electromagnetic pulses created by hypervelocity impacts on charged spacecraft surfaces. Experiments were conducted at ground-based facilities to recreate impacts under different spacecraft charging conditions. The effects of impactor mass, velocity, and spacecraft charge state on electromagnetic pulse production were investigated. Novel signal processing techniques were developed to isolate the radio-frequency (RF) emissions associated with impact, and plasma theory derived time dilations were developed to allow for impact data aggregation. Wideband RF pulses were detected within 450 ns after impact on targets with a strong negative bias. Scaling laws were developed to determine the dependence of peak electric field strength with impactor mass and velocity. The derived scaling indicates that impacts on strongly negatively biased spacecraft can produce peak electric fields in excess of 10^4 V/m, placing spacecraft electronics at risk. The derived peak electric field strength scaling, and the impacts used to generate it are shown in Figure 1.

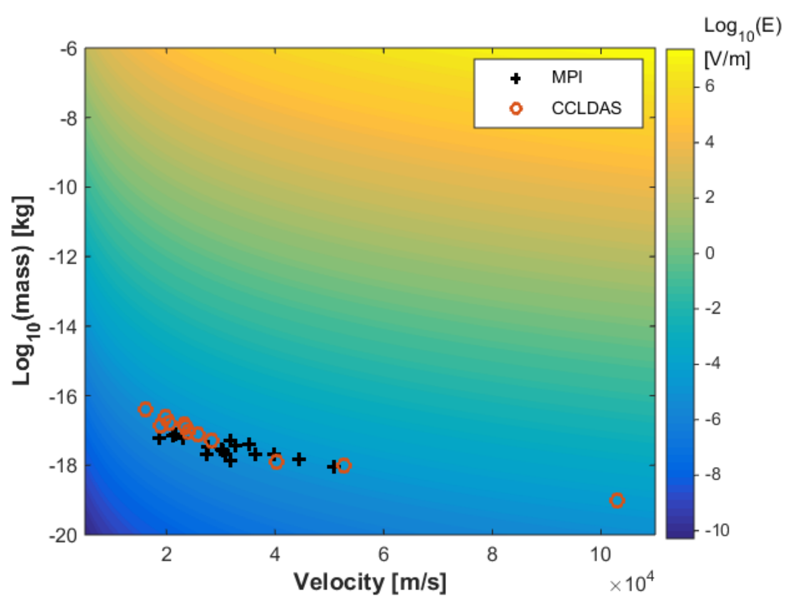

Figure 1. A peak electric field strength scaling law was derived for impacts on -1 kV biased targets using results from both MPI and CCLDAS. 30 impact events were utilized to derive this scaling. These electric field measurements and scaling law are taken at 10-20 cm from impact.