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Laboratory investigation of antenna signals from dust impacts on spacecraft

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Electric field and plasma wave instruments act as dust detectors picking up voltage pulses induced by impacts of particulates on the spacecraft body. These signals enable the characterization of cosmic dust environments even with missions without dedicated dust instruments. For example, the Voyager 1 and 2 spacecraft performed the first detection of dust particles near Uranus, Neptune, and in the outer solar system [Gurnett et al., 1987, 1991, 1997]. The two STEREO spacecraft observed distinct signals at high rate that were interpreted as nano-sized particles originating from near the Sun and accelerated to high velocities by the solar wind [MeyerVernet et al, 2009a, Zaslavsky et al., 2012]. The MAVEN spacecraft is using the antennas onboard to characterize the dust environment of Mars [Andersson et al., 2014] and Solar Probe Plus will do the same in the inner heliosphere. The challenge, however, is the correct interpretation of the impact signals and calculating the mass of the dust particles. The uncertainties result from the incomplete understanding of the signal pickup mechanisms, and the variation of the signal amplitude with impact location, the ambient plasma environment, and impact speed. A comprehensive laboratory study of impact generated antenna signals has been performed recently using the IMPACT dust accelerator facility operated at the University of Colorado. Dust particles of micron and submicron sizes with velocities of tens of km/s are generated using a 3 MV electrostatic analyzer. A scaled down model spacecraft is exposed to the dust impacts and one or more antennas, connected to sensitive electronics, are used to detect the impact signals. The measurements showed that there are three clearly distinct signal pickup mechanisms due to spacecraft charging, antenna charging and antenna pickup sensing space charge from the expanding plasma cloud. All mechanisms vary with the spacecraft and antenna bias voltages and, furthermore, the latter two mechanisms also vary with impact location relative to the antenna. The experimental results obtained are successfully used to improve the interpretation of existing data sets.