Understanding the Growing Threats to the GNSS Satellite: Characterizing Hypervelocity Impact Using Impact Flash Detection

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Introduction
• Background
• Motivation

Problem
• Science Question

Method
• Experiment

Result
• Geometric Expansion
• Risk Estimation
Protecting our space assets against microparticles

Microparticle Flux Model
[Tribble, 2003]

Electrical Damage

[ESA, 1993]
Hypervelocity impact generates plasma and flash

Charged Particle Acceleration and Oscillation

\[ n \sim 10^{28} \text{ m}^{-3} \]
\[ T \sim 2.5 \text{ eV} \]

[Fletcher, 2015; Lee, 2013]

RF

Optical

0.02 g @ 4.7 km/s
Hypervelocity impact research problem

1. Understand hypervelocity impact plasma formation mechanism
2. Expansion speed, thermal mobility $\rightarrow$ RF/EMP $\rightarrow$ electrical damage
Experiment at ground-based Impact Facility

Van de Graaff Electrostatic Dust Accelerator

Colorado Center for Lunar Dust and Atmospheric Studies

M = 0.1 – 1000 fg
V ~ 15 -100 km/s

10^-5 Torr

Pelletron Accelerator
Dust Source
Beam Path
Chamber
Impact Flash Spatial Measurement

All Wavelength Photodiode

Spatial PMTs

17 µs
34 µs
51 µs
AVGR
AVGR Optical Expansion Polarization

**Plasma Sensor**

- **Grounded Target**
- **Floating Target**
- **RF Sensors**

**Negatively Biased**

- [-50V]

**Positively Biased**

- [+50V]
CCLDAS Optical Expansion Polarization Effect

Positive

Float
Using impact flash to predict electrical anomalies

Maximum Magnetic Field Generation

\[ D_\perp = \frac{kT_e}{16B} \]

\[ \frac{\partial n}{\partial t} = D_\perp \nabla^2 n \]
Using impact flash to predict electrical anomalies

courtesy of A. Nuttall
Summary

- Potential Polarization effect observed in impact events at both dust accelerator and light gas gun facilities.
- Impact Plasma Flash can be used as a diagnostic tool for hypervelocity impacts (plasma evolution and electrical damage) in space.
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