MEDUSSA Spacecraft

**Goals**

- Investigate the physical processes responsible for the formation of meteoroid-induced EMPs
- Investigate the effects associated with electron and proton impacts compared to meteoroid impacts and characterize RF power according to electrostatic or electromagnetic effects
- Correlate the properties of ESD and EMP as a function of pointing and orbit

**Configuration**

The MEDUSSA spacecraft conforms to the CubeSat 3U form factor (10 x 10 x 34 cm). It has four deployable solar panels providing approximately 20 W of power. On the other end of the spacecraft, a 1 x 1 m screen is attached, providing a surface that should yield nearly one impact event per hour. The screen is held in place by metallic booms that double as antennas. An Attitude Determination and Control System (ADACS) uses reaction wheels and magnetic torque coils to orient the spacecraft. An experimental electrospray micro-thruster on the end of the chassis will be used for minor orbital changes.

**Sensors**

Impacts on the meteor screen will be detected and localized using an optical camera. The RF signal from the plasma will be picked up by antennae tuned to a range of frequencies from VLF (3-30 kHz) to S-band (>2 GHz). Tape-spring material is used for the VLF antennae so that they will self-deploy and remain straight. Silicon diodes mounted on the chassis sides will be used to count electrons and protons from the plasma as well as from other sources such as the solar wind.

**Screen deployment**

The meteor screen is housed in the bottom end of the spacecraft, and is held in place by the folded solar panels and a detachable panel underneath. The plasma detection antennae are also coiled and stored with the screen spool. Upon deployment of the solar panels, the screen will deploy using stored strain energy in four steel tape-springs. A spring-plunger will push the rear panel downward, releasing the antennae from their housing.

**Hypervelocity Impact Model**

Meteoroids are small, solid, extraterrestrial objects that range from sand- to boulder-sized. MEDUSSA will detect impacts from sub-microgram particles moving at hypervelocity velocities (typically greater than 11 km/s). In general, meteoroids will impact the spacecraft from Earth’s direction of travel.

**Impact and charge generation**

When a meteoroid impacts a spacecraft (Figure 2a), the meteoroid is vaporized along with part of the spacecraft surface. Some of the initial kinetic energy also ionizes the vaporized particles, creating a plasma (Figure 3). This plasma cloud is modeled as being initially spherical with a diameter equal to that of the impact crater (Figure 2b).

**Plasma expansion and radiation**

Initially, due to high plasma density, there will be many random collisions causing bremsstrahlung radiation. However, the radiated power in this mode is low. Because the plasma is highly collisional, we assume that electrons and ions are at the same temperature.

Once the plasma cloud expands and collisions become rare, we assume that the plasma remains isothermal and that there is no energy exchange with the environment. Electrons, being much less massive than positive ions, will expand faster (Figure 2c), until the ions pull them back. The plasma now has an expanding shell of ions, with electrons that oscillate about the ions (Figure 2d). Underneath this shell, the bulk plasma remains electrically uniform. As the plasma expands, its density drops and the electron oscillations slow down. The radiated power spectrum from the expanding plasma has a peak at low frequencies and can have another peak at the plasma frequency if oscillations are fast relative to the plasma expansion (Figure 3).

**Power spectrum of expanding plasmas**

![Power spectrum of expanding plasmas](image)

**References**


**Acknowledgment**

Thanks to Andrew Kalman, Ivan Linscott, and Dave Lauban for their contributions, to Patrick Colesstock, and Sergio Pellegrino for their advice regarding the design of the spacecraft. Thanks also to Stan Green and Pete Worden for their interest and support of this project.

**Further Information**

Please feel free to contact us if you have any questions.

Email: sigridc@stanford.edu
Website: http://sess.stanford.edu