Investigating Reentry Plasmas using Sounding Rockets

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Abstract

When spacecraft travel at high velocities in a planetary atmosphere, the ambient air compresses and heats to high temperatures. If the temperature is high enough, the air ionizes and proceeds to flow around the vehicle. The resulting plasma is highly dense causing many particle collisions, such that for radio wave communications, the radio wave attenuates or is lost completely. This phenomenon has plagued high speed vehicles since the first hypersonic flight in 1949 and still does today. The need to understand the plasma environment around such vehicles is necessary to help mitigate the effect of communications loss. Sounding rockets provide a low-cost test bed for developing and verifying proper plasma diagnostic instruments necessary for future reentry communication blackout mitigation.

Reentry Plasmas and RF Communications

The composition and characteristics of the plasma depends upon the ambient atmosphere. For Earth at high altitudes, typically atomic oxygen, molecular nitrogen, and molecular oxygen are the dominant neutral species. The heating at the vehicle produces free electrons from these constituents and various cation derivatives.

Reentry plasmas have blocked out communications for S-band through X-band frequencies driving the need for higher frequency usage of K-band and even optical. Communication systems at these higher frequencies typically require antenna pointing, which is difficult or impossible based on the reentry alignment of the spacecraft. This has somewhat been mitigated during the shuttle missions using TDRSS communications relying on atmospheric recombination in order to communicate through the vehicle wake; however, there still have been some communication issues with this communication scheme.

Reentry Plasma Diagnostics using Sounding Rockets

To formulate a proper mitigation strategy, the plasma environment needs characterization. A novel plasma diagnostic instrument will be developed investigating the vehicle surface plasma parameters including: electron plasma density, electron-neutral collision frequency, electron temperature, and plasma sheath profile. The instrument utilizes an impedance probe technique using new derived theories. With the understanding of these plasma parameters, a method for communicating with the surrounding plasma may be found.

The first reentry communication experiments were performed on sub-orbital platforms in the early 1960s. There have also been sounding rocket flights conducted by the German research institution, DLR, and through the NASA sounding rocket program. This presentation reviews these past flights and the adaptation of current sounding rocket vehicles to provide similar reentry velocities and trajectories.

Conclusions

The understanding of the plasma environment around reentry vehicles is an important piece of the puzzle in solving the communications blackout issue. This presentation expresses the necessary first steps for investigating a solution using sounding rockets.

Figure1. Photograph of DLR's SHEFEX during the ESA Symposium on Rockets and Balloons 2007.