Sensor to Avoid Arcing Due to Grappling

GOEMBEL INSTRUMENTS

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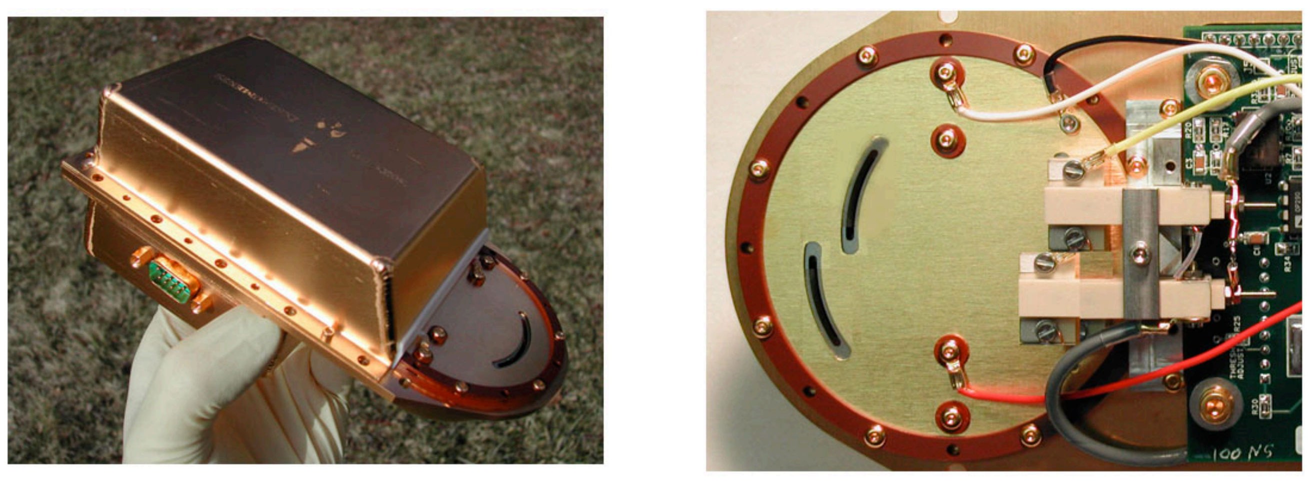
Introduction

This poster updates the ongoing development of an instrument that could prove useful during grappling missions in GEO. The instrument is being designed to determine low level positive and negative absolute floating potential (chassis potential relative to the space plasma). It may be able to measure positive potentials that range from ~3 volts to the highest expected (less than 100 volts) and determine when negative potentials are between ~5 volts and less than100 volts.

A low chassis potential may indicate that environmental conditions are such that arc-inducing charging is unlikely and that arcing is not likely to take place during grappling. Two measurements made by the device would be used to determine if chassis potential is low. If ambient (known to be non-spacecraft generated) electrons are detected, then the spacecraft is charged to a low positive potential and conditions are safe for grappling. If ambient ions of less than 100 eV are detected, then the spacecraft is charged below an arc-inducing potential, and grappling can proceed.

The sensor will include a novel high energy-resolution large geometric factor hemispherical analyzer. It is based on improvements to the Photoelectron Experiment (PES) of the Atmosphere Explorers –C, -D, and –E. Like its predecessor, the device will be able to collect detailed (2% ΔE/E) charged particle energy spectra in the low energy range. It is impossible to predict its performance as a floating potential monitor since spectra of the sort it would collect in GEO have yet been collected. As such, experimentation (use in space) is required to determine its utility.

Instrument Design



Electron only SCM (2006) — Proposed Modification for Ions and e-

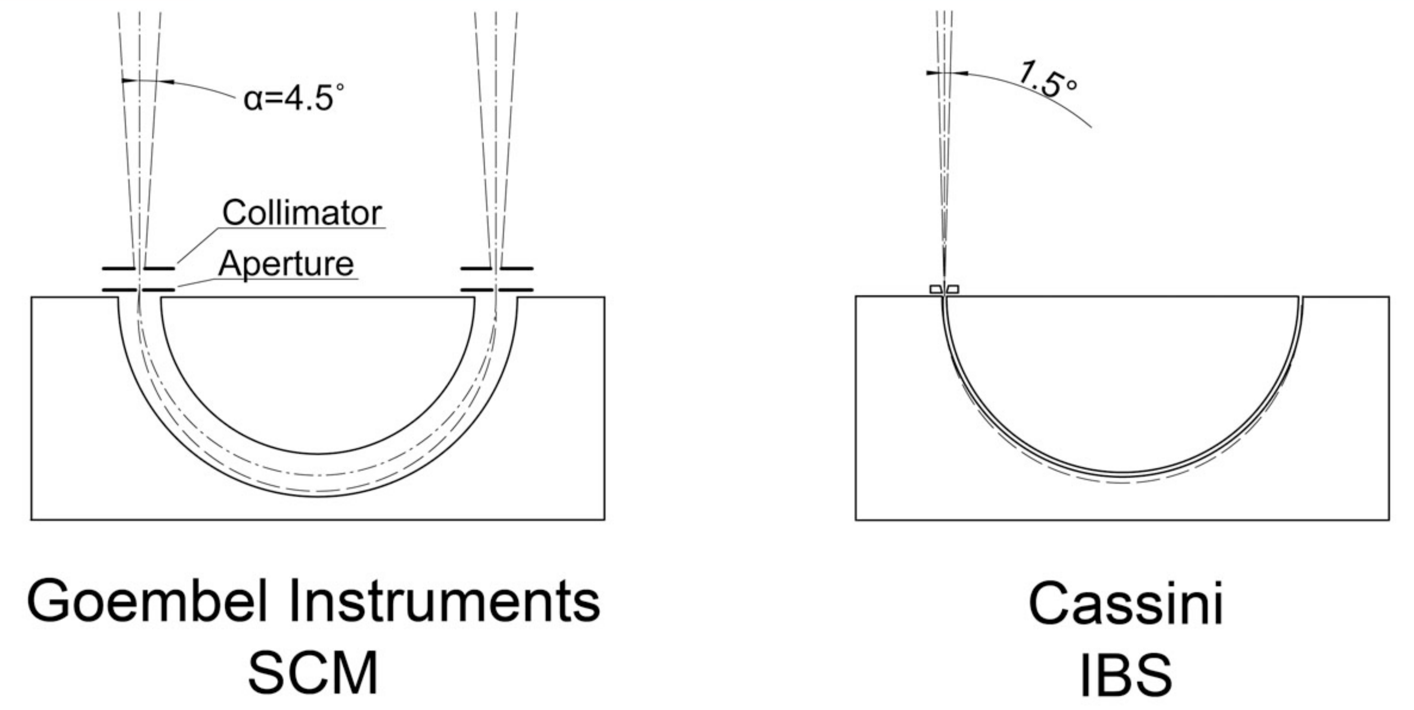
The design is based on the Spacecraft Charge Monitor (SCM) that was delivered to NASA in 2006. The SCM was designed to determine floating potential in LEO through identification of the energy shift in spectral features of the atmospheric photoelectron spectrum [1]. The sensor for use in GEO for grappling missions will be the SCM modified to analyze for a shift in the energy location of spectra of: 1) ambient cold plasma electrons for positive potentials, and, 2) the lowest energy ambient ions for negative potentials.

The high energy resolution of the device in will facilitate the on-board computer analysis of spectra for floating potential.

The image on the right (above) has 20-fold better resolution than the image on the left. The SCM has 20-fold the energy-resolution of an instrument that now collects spectra for the determination of floating potential in GEO, the Magnetospheric Plasma Analyzer (MPA). The very high energy-resolution of the SCM may prove invaluable in distinguishing between spacecraft generated and ambient charged particles. Spacecraft placement, such as the aiming the spectrometer's field of view toward spacecraft north or south, may also limit contamination of the ambient spectra.

The hemispherical analyzer will offer 80-fold the geometric factor (particle gathering power, the speed at which spectra can be gathered) per unit volume of the only comparable instrument that has flown, the Cassini Ion Beam Spectrometer (IBS). The nearly two orders of magnitude increase in geometric factor per unit volume is due in large part to the instrument's patented high energy-resolution charged-particle optics.

Design (continued)

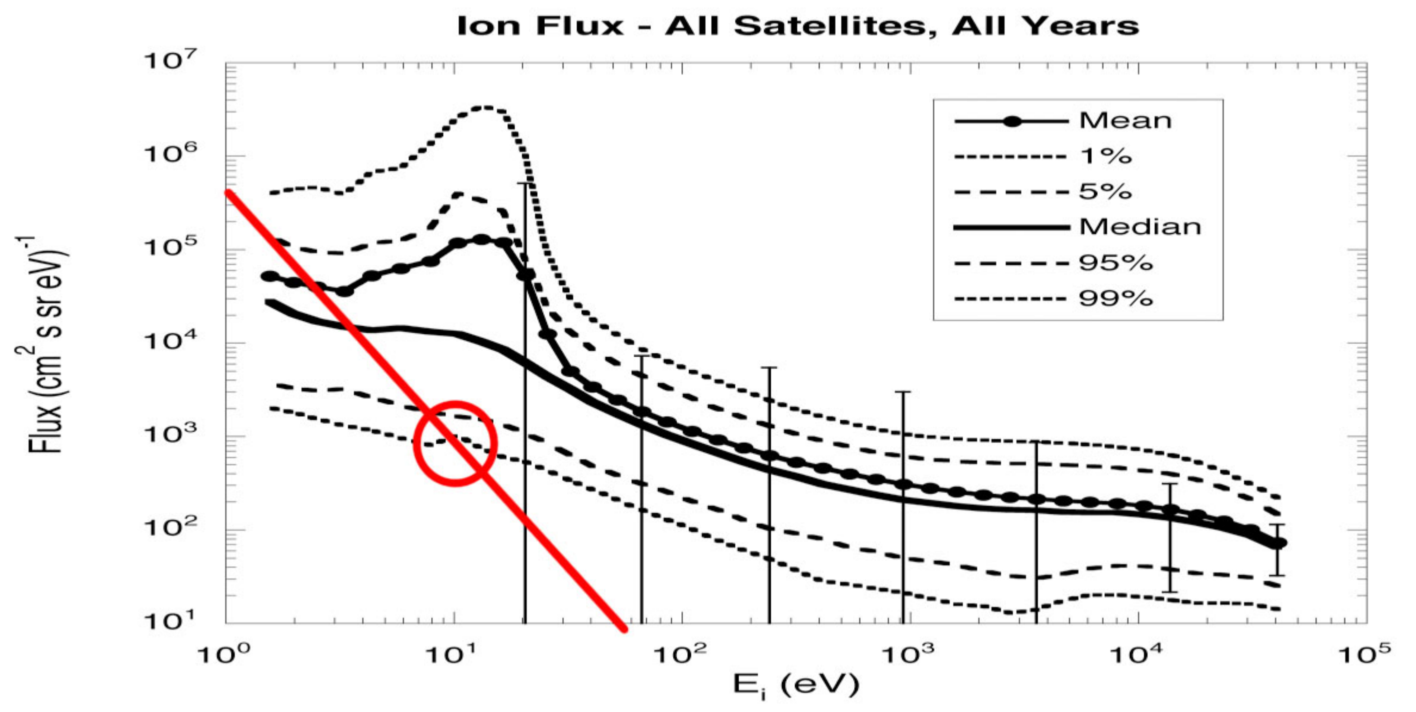


Efficient Particle Transmission — Suffers from Vignetting

The patented optics are based on the optics of PES with an arcuate elongation of the collimator and aperture [2]. Although IBS contains arcuate entrances, it does not contain the patented constrictive aperture/collimator feature nor the widely spaced hemispherical surfaces of the SCM. The IBS has a much narrower field of view (3˚ vs. 9˚) and suffers from mechanical vignetting ("overfilling"). Both reduce IBS's geometric factor. The narrow separation between the IBS plates prevents a significant portion of the particles of the desired energy within its field of view from passing through the spectrometer. The dashed line in the cut-away view of IBS (right image, above) shows that a particle of the selected pass energy entering through the field of view of IBS would have to pass through metal to reach the detector. More information on charged particle optics of hemispherical analyzers, vignetting, and overfilling can be found in "Chris Kuyatte's Charged Particle Optics Lecture Notes" [3]. Further details of the proposed instrument design are given in "Plasma Analyzer for Measuring Spacecraft Floating Potential in LEO and GEO" [4].

Estimated Performance

Data from the GEOS-1 satellite indicate that floating potentials of ~3 volts can be determined from 12% energy-resolution electron spectra [5]. Detection of ambient cold plasma electrons by the proposed instrument would indicate a positive floating potential of ~3 V to <100 V: the sort of potential expected most frequently for spacecraft in GEO.



A full solar cycle of MPA data has been analyzed to produce the plot shown above [6]. It is estimated that it would take 200 seconds or less to gather a spectrum that would show a low energy ion peak at 10 eV at 99% of the fluxes expected in GEO (red circle). The detection of 10 eV ambient ions would indicate a floating potential of 10 volts magnitude or less. The red line shows the minimum flux that would provide a visible ion peak in a 200 second, 200 point scan from 1 eV to 200 eV with a one-second dwell at each point. At the median flux at 10 eV, 20 seconds would yield a useful spectrum. Real-time, on-board processing of the spectra might provide feedback to optimize each proceeding scan so that the floating potential might be determined in the shortest time.

References:

[1] Goembel, L., and J. P. Doering (1998), J. Spacecraft Rockets, 35(1), 66-72.

[2] Goembel, L. (2004) U.S. Patent 6703612, Mar. 9, 2004.

[3] http://www.goembel.biz/PDFs/Kuyatt_Electron_Optics_Lectures_1967.pdf

[4] Goembel, L. (2012) IEEE Trans. Plasma Sci., 40(2), 155 – 166.

[5] Coates et al. (1985), Planetary Space Sci. , 33(11), 1267-1275.

[6] Thomsen et al. (2007), Space Weather, 5(3) S03004.