A Sensor to Mitigate Arc Damage from Grappling

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Why fly blindly into harm's way?

"The largest cause of mission failures related to the space environment is surface ESD." [Koons, et al., 1999.]

200 annoying to serious and 10 critical operational anomalies due to electrostatic surface discharge are expected over the lifetime of a S/C in GEO. [Wrenn, et al., 1993.]

Research into spacecraft charging has focused on the effect on individual spacecraft. The challenge presented by having two independent spacecraft make contact in the extreme charging environment of GEO is relatively new and complex. Techniques such as bleeding charge through a resistor or deploying a plasma contactor are now being considered for arc mitigation during grappling. Methods that work for spacecraft in LEO, where 100 V charging is considered extreme, may not work as well in GEO where 10,000 V charging is expected.

A frame potential monitor can provide the grappling spacecraft's operators the 'eyes' needed to determine when charging conditions are such that it is safe to grapple. Any other method used to reduce the risk of arcing would greatly benefit from knowledge of spacecraft frame potential. A mere 10% difference in spacecraft frame potentials can be 1,000V under high charging conditions. Why grapple at times that invite arcing?

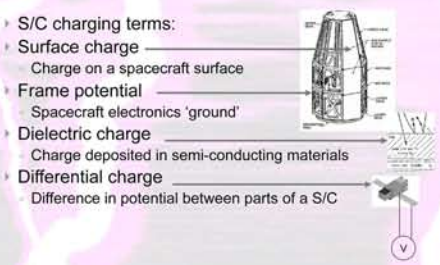
How can a frame potential monitor help?

Spacecraft frame potential is a measure of the spacecraft frame (chassis, electronics ground) floating potential relative to the space plasma.

Two spacecraft in close proximity experience the same charging environment. A frame potential monitor on one spacecraft will indicate charging conditions for both. Verification of the phenomenon appears in studies of multiple spacecraft in GEO [Ozkul et al., 2001].

The spacecraft frame is likely to be the most highly charged part of the spacecraft due to the low capacitance between the frame and space and high capacitance between parts not in electrical contact with the frame (such as thermal blankets, etc.) and the frame. When a frame potential monitor on the grappling spacecraft indicates that its frame potential is at a minimum, risk of arcing during grappling is at a minimum.

The inclusion of a spacecraft frame potential monitor on the grappling spacecraft, as a 'go' or 'no go' indicator for making contact with the target could prevent damage due to arcing with or without the assistance of some other arc mitigating scheme.



Can't we just use a bleed resistor?

Bleed resistors have been used on grappling devices in LEO. The concept is that excess charge will 'bleed' through a resistor when the grappler makes contact with a target until the frame potentials equalize.The use of such a scheme in GEO is untried and presents a number of difficulties.

1) In low inclination in LEO, spacecraft normally charge to tens of volts relative to the space plasma and may charge to 100 V or so under extreme charging conditions. In GEO spacecraft can charge to 10,000 volts.

2) What will be the effect of such a large charge transfer between two spacecraft? Will differential charge (charge between electrically isolated parts of the spacecraft) increase and cause arcing?

Can't we just use a plasma contactor?

Plasma contactors are cold cathode ion sources that have been used to reduce charge on spacecraft. Although they are effective at reducing the charge on the spacecraft to which they are attached, their use in grappling is untried and may present difficulties:

1) NASA/TP-2003-212287 states -
"[Due to the danger of arcing] solar arrays and other active sites should be kept out of induced plasma plumes [which are invisible and are meters in diameter]."

2) Krause et al. 2004 -
A study of a Xe plasma contactor on the GEO DSCS-III satellite reports surfaces retained charges of 1200 V relative to the spacecraft frame even when the contactor was active.

3) Other considerations (from Dr. Dale Ferguson, AFRL)-
"...they require a fuel supply (xenon or other gas), turn-on and operation must be tightly controlled to make sure they do not overrun their maximum current (and fry the cathode), and the plasma they put out will be confined to magnetic field lines."

The PASS sensor

The PASS frame potential monitor is in an advanced stage of development. PASS is based on the flight-ready SCM that was delivered to NASA in 2006. The ~1 kg PASS could be used to determine when it is safe to grapple. More about PASS is published in "Plasma Analyzer for Measuring Spacecraft Floating Potential in LEO and GEO" [IEEE Trans. Plasma Sci., V. 40, Iss. 2, P. 155-166, 2012]. To download the paper, go to www.goembel.biz
Goembel Instruments is a world leader in frame potential monitor research, development, and production.

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