Spacecraft Charging as an Asset to Interplanetary Small Spacecraft

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Abstract

Small spacecraft operate on a far more limited power budget than their larger counterparts, a problem compounded for interplanetary spacecraft in the outer solar system. The reduced solar flux beyond Earth's orbit makes solar panels less effective for spacecraft exploring the gas giants and they are susceptible to damage by intense radiation belts. Radioisotope thermoelectric generators are expensive and bulky compared to their power output. Interplanetary small satellite missions benefit from both alternative energy sources and low-power electronics to power their buses and scientific payloads. Traditionally, spacecraft engineers treat the space environment as a hazard, but it nevertheless offers a potential solution. Currents from space plasmas charge spacecraft to high potentials and can cause electrical arcing to occur between differentially charged surfaces. The spacecraft can harvest a small amount of power — $< 10\,\mathrm{mW/m^2}$ at Jupiter — from the electric field between these surfaces to do useful work, either by charging a battery or directly powering an instrument or actuator. While using the energy directly has limited use due to the low electron density and temperature of most space plasmas, it can nevertheless be used in situations where solar panels are not desirable, such as high radiation environments. Two applications — a Langmuir probe and an attitude control actuator — exploit the disparate current-voltage characteristics between surfaces with different material properties and require minimal input power to operate.