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SPACE DEBRIS SYMPOSIUM (A6)
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AN INNOVATIVE HYBRID ELECTRODYNAMIC AND ELECTROSTATIC (ED-ES) TETHER MODULE

Abstract

Orbital debris poses significant risks to ongoing and future space endeavors. Electrodynamic (ED) tethers had been considered dominantly for debris mitigation. However, simulations and experiments provided discouraging responses due to the heavily dependence of such tethers on environmental magnetic field latitudes and the slow deorbitting rates. We solve the problems by introducing an innovative electric tether (ET) module. It is a hybrid ED and electrostatic (ES) tether system, but relies only on the ED-tether equipment. We describe the basic principle of the ET physics, introduce an equivalent circuit model for the normal ED mode, and illustrate the plasma-tether interactions and effects for the high-voltage (HV) ES mode. In the ED mode, the circuit contains four blocks which include 13 electric elements in total of resistors, inductors, and capacitors. The circuit current depends not only on the tether EMF which is related to the local magnetic field, tether velocity, orbital inclination, etc., but also on the circuit elements. In the ES mode, the plasma-tether interactions in the presence of the HV power drive charged particles to non-Maxwellian distributions in velocity space. The energy of surrounding plasmas is thus enhanced significantly. We make use of the Lagrangian formulation to expose the nonlinear characteristics of the ED-ES tether dynamics through semi-numerical simulations for the different mitigation modes with reference to orbital parameters. we assess the suitability of this new ET module in applications at LEO altitudes. We examine the effectiveness of module to de-orbit objects. Results show that, while the ED mode works at favorable magnetic latitudes, the ES mode plays a leading role to satisfy all mitigation needs. A rapidly applied HV power supply allows efficient orbit modifications due to the presence of the electrostatic Coulomb forces. The de-orbiting process shows a damped oscillations with final altitude between the initial one and the first trough. Surprisingly, repeated application of the HV supply following the first does not produce further altitude reduction. At 800 km altitude, a HV supply of 1 kV on a 16 kg, 1 km long tether for about 30 minutes produces a 3-km deorbiting. We expose the three advantages of the ET module: it can be used as either a deorbitor (ED or ES) or a reorbitor (ES); it is suitable for either low-latitude orbits (ED or ES) or polar ones (ES); it is economical by merely investing the ED-tether system but with the extra functional ES mitigation mode.