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PROPELLANT-LESS FORMATION FLIGHT APPLICATIONS USING ELECTROMAGNETIC SATELLITE FORMATIONS

Abstract

The alternative to using propellant for actuation of formation flying satellites is for each spacecraft to produce their own electromagnetic field that others in the formation can react against. This technique can be achieved by creating a steerable magnetic dipole and is called Electromagnetic Formation Flight (EMFF). EMFF can be implemented on a spacecraft by driving current through three orthogonal electromagnetic coils to create a steerable magnetic dipole in three dimensions. In order to create a large magnetic field necessary for actuating formation flying spacecraft, EMFF uses high temperature superconducting (HTS) wire since it is able to hold a large current. The HTS coils are powered by solar energy, a limitless resource, making the mission lifetime that is dependent on formation control theoretically unbounded. Momentum conservation prohibits control of the motion of the center of mass of the formation using EMFF since only internal forces are present. However, EMFF, in concert with reaction wheels, can be used to control the relative separation, relative attitude and inertial rotation, which are the critical maneuvers for sparse aperture arrays.

This paper investigates the applicability of EMFF as a means for attitude and translation control of multiple spacecraft maneuvering in close proximity. One example scenario is using two EMFF satellites as an inspector system to examine a non-EMFF satellite that is nearby. In the proximity operation the EMFF inspector satellite uses circular and linear trajectories to view the target at distances of 25 meters in approximately 5 minutes and does not disturb the target position or attitude. The results of the analysis show the design of the proximity guidance, navigation and control laws that allow for rapid inspection scenarios. One conclusion was that the linear trajectories created by EMFF have higher agility than circular trajectories, however their control was very sensitive to changes in the magnetic moment profile. To understand these boundaries of sensitivity, escape velocity and the idea of operating with margins was introduced.

The primary role of EMFF is to impart forces and torques to maintain a satellite array. This paper also investigated using EMFF in a multi-role sense, in other words, determining potential secondary roles of EMFF. These included power transmission, passive, offensive capabilities, and use of the HTS coils as torque coils for geostationary satellites. The results of this paper show that EMFF is a promising propellant-less formation flight technology for future missions.