

Propellantless Control of Spacecraft Swarms using Coulomb Forces

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NASA has demonstrated a need to begin research on the next generation of very small, capable satellites employed in collaborative formations for various space missions. Of the many technologies that must be developed to enable deployment of microsatellite swarms, perhaps spacecraft propulsion and collaborative control issues are the most challenging. Fine positioning and formation-flying of swarms of microsatellites will require very controllable thrust on the order of micro-Newtons. Apart from the difficulty in engineering such thrusters, issues of concern are controllability of thrust, finite fuel supply, and inter-spacecraft contamination during close proximity operations due to exhausted propellant from neighboring craft.

The goal of this proposal is to develop the technologies required to enable propellantless control of swarm satellite formations using Coulomb forces generated between spacecraft. By either harvesting ambient space-plasma electrons or actively emitting electrons, the net spacecraft charge can be controlled. In this innovative concept, it is feasible to generate tens of micro-Newtons of attraction and repulsion between spacecraft separated by tens of meters, with the possibility for hundreds of μN hinted at through flight data. Sufficient Coulomb forces can be generated with only a few Watts of power. The mutually interacting Coulomb spacecraft will orient themselves in stable minimum-energy structures that can be reconfigured using active control. Although ambitious, the proposed concept is supported by flight heritage from the SCATHA spacecraft. In this 1979 experiment, electron emission was successfully used to control the potential of the spacecraft over many kilo-volts. The demonstrated SCATHA control was sufficient to generate the inter-satellite forces proposed here.

Results of the proposed investigation are expected to (1) circumvent the need for micro thrusters in close proximity operations of satellite swarms, (2) increase formation mission lifetimes by harvesting in-space resources, (3) greatly improve fine position-keeping within a swarm through active feedback, (4) facilitate a wider range of satellite formation of flying orbits, (5) provide the ability to reject external disturbances to the formation, and (6) increase swarm robustness through fault-detection and reconfiguration.

