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The Design of Micronewton FEEP Thrusters for Disturbance Reduction Systems

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ABSTRACT

During the last 10 years, an increasing number of scientific missions has been proposed that makes use of active Disturbance Reduction Systems (DRS) to achieve very low residual acceleration levels on a spacecraft. The majority of these spacecraft belong to the class of drag-free satellites, where it is required that the external non-gravitational forces be reduced below a certain threshold in order for the spacecraft to follow a quasi-gravitational trajectory in space. This involves detection of the acceleration produced on the spacecraft by such tiny actions as those due to solar radiation pressure, and computation of a set of counter-balancing forces to be supplied by the onboard thrusters.

The requirements of DRS dictate the use of highly controllable, very low thrust actuators like FEEP. In fact, the recently approved CNES mission MicroScope, aimed at testing the Equivalence Principle with unprecedented accuracy, will employ a drag-free control system based on the use of 100 μN-class FEEP thruster clusters. This choice derives from the need to guarantee very high controllability all over the thrust range, with no moving parts which could spoil the delicate gravitational environment of the satellite.

This paper presents an overview of the main design issues involved in sizing a FEEP system for DRS applications, including both performance-oriented considerations and spacecraft system-level aspects. Issues like selection of the thruster size, choice of the electrode voltages, scaling laws, plume divergency effects, thruster clustering, thrust noise, and response to fast variations of the input will be examined. The effect of the external environment will be summarized and the main thruster/spacecraft interaction issues will be discussed. The propulsion requirements of state-of-the-art drag-free missions will be assumed as a reference.