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COULOMB TESTBED FORCE MODEL VERIFICATION FOR CHARGED RELATIVE MOTION EXPERIMENTS

Abstract

A unique 1-D testbed has been developed to study the utilization of electrostatic (Coulomb) forces to control spacecraft formations. This paper investigates the effects of the terrestrial (laboratory) environment on the generation of Coulomb forces in the testbed. Charge controlled relative motion experiments are used to examine and verify force capabilities and results presented. Estimation techniques and findings of the laboratory hardware implementation can be used to assist future space applications. Close operating spacecraft formations are a growing area of research that can be used for scientific or exploratory missions including Earth monitoring, deep space communications, solar power extraction or planet searching to name a few. Utilizing a formation of spacecraft offers advantages that include the use of smaller, lighter, redundant, and ultimately cheaper spacecraft. In 2001 the idea of using Coulomb forces to control a formation of spacecraft was proposed. The concept uses electrostatic (Coulomb) forces to maintain a desired separation distance between spacecraft. Each spacecraft is equipped with a charge control device that can drive the spacecraft to an electrostatic potential for either attractive or repulsive relative forces. The Coulomb control concept offers unique advantages, including its low-power usage (Watt level), its virtually propellant-less thrust, and requires technology that is already space proven. Very precise inter-spacecraft forces can be achieved making it suitable for high-accuracy missions and spacecraft rendezvous and docking. A multi-faceted development program at the University of Colorado at Boulder is investigating the Coulomb control concept. This includes the development of a unique testbed dedicated to low force Coulomb controlled vehicle relative motion experiments in a terrestrial environment. It offers a near-frictionless 1-D track with disturbances below 1 mN. Relative motion experiments that mimic the motion of two spacecraft in 1-D constrained orbital orientations are performed. Analysis of experiments conducted in the lab indicates interaction or shielding of the Coulomb force from the atmosphere and surrounding apparatus. This research details the investigation and modeling of the Coulomb force in the atmosphere. Results identify and quantify influences affecting the Coulomb force produced. This includes atmospheric shielding, charge development and induced effects at close separations. This is achieved through electrostatic measurements along with relative position estimation for model verification of the atmospheric Coulomb force. Parallels are drawn to the shielding that occurs between charged spacecraft in space plasma. This research also considers the effective use of charged spacecraft relative motion sensing to predict plasma shielding in orbit.