ABSTRACT

ORBIT DESIGN AND CONTROL OF PLANETARY SATELLITE ORBITERS IN THE HILL 3-BODY PROBLEM

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The exploration of planetary satellites by robotic spacecraft is currently of strong scientific interest. However, sending a spacecraft to a planetary satellite can be challenging due to strong perturbations from the central planet. The primary goal of this dissertation is to identify and utilize the main dynamical features of the system in the orbit design process.

The system is modeled using a modified form of Hill's 3-body problem, where the effect of the planetary satellite's gravity field is included in the low-altitude analysis. A thorough study of the dynamics of the system is performed by applying averaging theory to reduce the complexity and degrees of freedom of the system. The reduced system has one degree of freedom (DOF) and has equilibrium solutions called frozen orbits. These frozen orbits are first used as targets for transfers from capture trajectories in 'safe zones'. The 'safe zones' in phase space are numerically determined; they contain trajectories that enter the Hill region and allow an uncontrolled spacecraft to remain in orbit without impact or escape for specified time periods. Transfers from safe trajectories to frozen orbits are identified and criteria on their costs evaluated.

Unstable low-altitude, near-polar frozen orbits are the basis for the design of long lifetime science orbits. The stable and unstable manifolds of these frozen orbits in the 1-DOF system are investigated and the desired path for long lifetime orbits is identified. An algorithm is developed to systematically compute initial conditions in the full system such that the orbits follow the desired path and have sufficiently long lifetimes to be practical as science orbits about planetary satellites. The analysis of the control of a planetary satellite orbiter begins with the evaluation of the effect of orbit uncertainty on the science orbits and the identification of criteria to ensure that the orbits have the desired behavior. Then, two control schemes are developed: a) given the terminal conditions of a science orbit, redesign a new science orbit and execute a low-cost transfer to it, b) return the spacecraft to its nominal trajectory via a two-sequence set of maneuvers.