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A Framework for Precise Orbit Determination of Small Body Orbiting Spacecraft

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Spacecraft flying in close proximity of small bodies face a very complex dynamical environment with numerous types of perturbing forces acting on them. Development of new techniques are needed for precise navigation of spacecraft in such environments. This study focuses on furthering our understanding of precise orbit determination of spacecraft in close proximity of small bodies via implementation of new methods for precise representation of strong and weak perturbing forces acting on spacecraft, such as the irregular gravitational field, strong solar radiation pressure effects, and thermal radiation pressure effects from the surface of small bodies.

Solar radiation pressure is a strong perturbing force acting on spacecraft in the orbital environment of small bodies that constantly pushes the spacecraft in a general direction away from the Sun. The existence of strong solar radiation pressure effects creates a complex dynamical environment around asteroids and comets that results in a particular set of orbital regimes, such as the family of the terminator or close to terminator orbits, whose dynamical evolution may not be intuitive. Small perturbations caused by maneuver errors and other sources may lead to large deviations in a spacecraft trajectory from its nominal orbit. Understanding the evolution of errors and uncertainties in the orbital elements of spacecraft is a crucial piece of mission planning and spacecraft navigation. In this thesis, we derive analytical expressions that govern the secular motion of the perturbed orbital elements in an environment that is strongly perturbed by the solar radiation pressure effects. Furthermore, we study a framework based on a Fourier series expansion for precise representation of the solar radiation pressure and small body surface thermal radiation pressure effects on spacecraft. This method is utilized in generating precise orbit determination solutions for simulated spacecraft in orbit about small bodies in the presence of dynamical and modeling errors.

Gravitational perturbations are other major disturbing forces in the proximity of a small body. This is especially true for spacecraft that come close to the surface of asteroids or comets in a landing or touch-and-go (TAG) scenario. Due to the irregular shape of these objects, a significant portion of the landing or TAG trajectory may lie inside a circumscribing sphere, where the conventional spherical harmonics expansion of the gravitational field is not convergent. Recent studies developed a so-called *interior* gravity field spherical harmonics expansion that extends down to the surface of the object without divergence issues. The interior gravity field, however, is not studied in the context of orbit determination and spacecraft navigation. This study investigates the feasibility of the utilization of such model to navigate spacecraft in a trajectory that is close to the surface of an irregularly shaped body of mass. The study will further examine the capability of estimating the spherical harmonics coefficients for an interior gravity field via orbit determination solutions.