Paper ID: 85630
oral
student

IAF SPACE EXPLORATION SYMPOSIUM (A3)
Interactive Presentations - IAF SPACE EXPLORATION SYMPOSIUM (IP)

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A SURVEY OF GRAVITATIONAL MODELING TECHNIQUES FOR MINOR BODY PROXIMITY OPERATIONS

Abstract

Exploration of minor celestial bodies is increasingly attracting interest, prompting various space missions to target these objects due to the potential for significant scientific and engineering breakthroughs they offer. Within this context, it becomes imperative to tackle the challenges inherent in operating in low-gravity, deep-space environments. A comprehensive understanding of the dynamics in the close proximity of these celestial objects becomes crucial for optimizing the scientific and technological yield of such missions. This is particularly relevant when employing cost-effective platforms like CubeSats, which operate with limited onboard resources and maneuvering capabilities. Therefore, thorough design and careful mission planning play a key role in maximizing the effectiveness of these missions. The environment in proximity of minor celestial bodies is characterized by a high degree of nonlinearity, resulting from their irregular shape and non-uniform mass distribution.

Accurate modeling and understanding of the gravitational field of minor bodies is crucial for space missions. This paper explores three main modeling methods: spherical harmonics, Mascon model, and polyhedral model. The spherical harmonics method employs mathematical functions to represent the gravity of a body. The Mascon model approximates the body mass distribution using discrete regions, simplifying computations. The Polyhedral model, on the other hand, represent the body as a collection of polygons. Although each method offers unique advantages, researchers aim at simplifying the computational requirements for on-board implementation by conceptualizing different variants of these baseline methods.

This study conducts a comprehensive survey of these modeling techniques in the vicinity of well-known minor bodies with diverse shapes and masses. By evaluating their performance, the research goal is supporting mission designers in selecting the most suitable approach based on the specific target properties and operative scenario. Through extensive analysis, the study assesses the efficacy of each method in accurately modeling gravitational forces near minor bodies with varied shapes. Factors such as computational complexity, accuracy, and suitability for on-board implementation are carefully considered. Whether prioritizing computational efficiency or accuracy, understanding the strengths and limitations of each method is essential to the successful planning of minor body exploration missions.