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ORBIT DESIGN FOR CIRCUMLUNAR FORMATION FLYING

Abstract

Finding relative orbits for satellite formations flying around the Earth, which are long-term bounded under various perturbations, has been a vibrant field of study. However, much less attention has been given to detecting such orbits for circumlunar formation flying missions. As opposed to low-Earth orbits, in circumlunar missions the third-body effect is large, and the magnitude of the C_{22} sectorial harmonic has the same order as the J_2 zonal harmonic. This renders the analysis of bounded relative orbits more challenging. In this paper, we detect a new family of long-term bounded circumlunar relative orbits, which can be used for circumlunar formation flying missions. The main idea is to utilize the benefits of circumlunar frozen orbits, and operate the satellite formation in the vicinity of such orbits. This enables to find an analytical solution for the mean relative distance among the formation satellites, and use it to derive formation geometries that are resilient to the gravitational and third-body perturbations. Two invariant mean-distance conditions and one bounded mean-distance conditions are derived. Numerical simulations indicate that the newly-derived invariance conditions yield long-term bounded relative motion.

Moreover, this research shows that the mean inter-satellite distance squared can be calculated analytically using the exponential matrix function when the chief is on a frozen orbit, approximated as a time series. By using a second-order approximation of the mean distance squared, a boundedness condition can be derived by minimizing the distance drift rate. Simulation results indicate that it is reasonable to use a second-order approximation to estimate the average distance, with an initial error less than 1%. Comparing to the two first-order constraints proposed by previous works, the boundedness condition discussed in this paper behaves better in mitigating the increase of the average distance, no matter whether the circumlunar satellites fly relatively to a frozen or a near-frozen chief orbit. Consequently, the methodology proposed herein can be used for future circumlunar science mission requiring the operation of multiple satellites. The long-term boudedness of relative orbits guarantees the minimization of propellent consumption.