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ANALYTICAL SOLUTION OF THE THIRD-BODY PROBLEM FOR HIGHLY ELLIPTICAL ORBITS BASED ON THE TIME-DEPENDENT LIE-DEPRIT TRANSFORM

Abstract

When dealing with highly elliptical orbits, we have to face several difficulties. Due to the fact that such orbits cover a wide range of altitudes, the hierarchy of the perturbations acting on the satellite changes with the position on the orbit. At low altitude, the oblateness of the Earth (the so called J2 effect) is the dominant perturbation while on high-altitude the lunisolar perturbation acceleration can reach or exceed the order the J2 acceleration.

The traditional analytical theories of celestial mechanics are not well adapted to this particular dynamic. On the one hand, analytical solutions are quite generally expanded into power series of the eccentricity and so limited to quasi-circular orbits. On the other hand, the time-dependency due to the motion of the third body is almost always neglected.

We propose several tools to overcome these limitations.

Firstly, we have expanded the third-body disturbing function into a finite polynomial using Fourier series in multiple of the satellite's eccentric anomaly (instead of the mean anomaly) and involving Hansen-like coefficients.

We have performed a normalization of the expanded Hamiltonian, which aims to eliminate all periodic terms. To this end, we have applied a perturbative method based on time-dependent Lie-Deprit transform (1969). Of course, as in the Brouwer's case, the theory in closed form is more difficult to elaborate than a theory using truncated expressions in mean anomaly. The main difficulty lies in the fact that the generator of the transformation must be computed by solving a PDE involving derivatives with respect to the mean anomaly, which appears implicitly in the perturbation. We present a method to solve this equation by means of an iterative algorithm.

As the result, we have obtained an approximated analytical solution of the third-body problem.

Finally, comparisons between the analytical model and the numerical simulations of high-altitude Earth satellites disturbed by the Sun and the Moon will be presented, and their effects investigated.