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UNOBSERVED MANEUVER RECONSTRUCTION AND PROPAGATION USING THE ESSENTIAL THRUST FOURIER COEFFICIENTS

Abstract

If an arbitrary perturbing acceleration is represented as a Fourier series in eccentric anomaly, then the secular effect of that perturbation is found to be a function of only 14 Thrust Fourier Coefficients (TFCs). We study the relationship between the secular rates of change of the orbital elements (OEs) and these TFCs and find that some combinations of TFCs induce undesired secular drifts in other OEs and require more thrust expenditure to control their secular motion. We identify a minimum set of 6 TFCs that effectively represent the secular effect of any perturbing acceleration. The controllability of these OEs and their sensitivity to the TFCs are checked and a cost analysis of various TFC sets is performed. The selected "essential set" consists of 6 TFCs that are zero or first-order terms: a constant radial thrust component, two sinusoidal normal thrust components and three circumferential thrust components, a constant and two sinusoidal. Any perturbing acceleration can be represented as this essential TFC set with respect to the secular behavior of the OEs.

We apply the essential TFC set for orbit determination problems to determine the perturbing elements of an arbitrary maneuver or model perturbation with sparse observations. With the computed essential TFC values, the basis of an unknown acceleration is constructed by inverse processing of the Fourier expansion and we are able to interpolate dynamically between states across an unobserved maneuver. This preliminary analysis provides us with a basic understanding of perturbing forces on our nominal trajectory, which allows us to also propagate orbit uncertainty through the reconstructed dynamics using the essential TFC set. In this paper, simple data sets are perturbed by drag, SRP or an artificial step input as an unknown acceleration. Then, orbit determination simulations are performed to recover the fundamental elements of the perturbing accelerations and to propagate the orbit uncertainties by using the essential TFC set. Using both the mean OE solution and the osculating OE solution, we propagate reconstructed accelerations and orbit uncertainties and compare these results. The goal of this work is to make use of the previous orbit knowledge, represented as a covariance matrix of uncertainty information, and use it to map it to a specific epoch after the maneuver. Development of this approach could allow for periods of mis-modeling or maneuver firing to be fit through without having a precise model of the event.