Drag- and SRP-induced effects in uncertainty evolution for close approaches

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Abstract

A key characteristic of drag and solar sails is their high area-to-mass ratio, which provides great cost-efficiency for tasks such as end-of-life deorbiting. However, it also negatively affects collision risk by increasing the spacecraft's collisional Cross-Sectional Area (CSA), and the stronger perturbing accelerations from drag and Solar Radiation Pressure (SRP) can contribute to a faster growth in position and velocity uncertainties. This second effect is especially relevant when there are additional uncertainties regarding the magnitude of the drag- and SRP-related accelerations, for instance due to uncertainties in attitude which in turn affect the CSA. These considerations are not restricted to sails but apply to any object with a significant area-to-mass ratio. Other relevant cases can be rocket upper stages, as their elongated shape and uncontrolled attitude can difficult the reliable estimation of their CSA over time.

In this work we deepen into the effects of drag and SRP in uncertainty evolution, focusing on applications related to close approaches. Numerical and semi-analytical methods based on planODyn for the propagation of the covariance ellipsoid representing the uncertainties in position and velocity are presented and compared, both in terms of accuracy and computational cost. Although sails are a clear application case the results are not restricted to this kind of objects, and a sensitivity analysis over a significant range of area-to-mass ratios is performed. Furthermore, different propagation times and uncertainty levels for area-to-mass and the drag and SRP coefficients are considered, to assess their influence. The b-plane of the nominal close approach is used to project and characterise the evolution of the uncertainties from a physical point of view, relating it to collision risk and the design of collision avoidance manoeuvres. The results show that drag and SRP effects in uncertainty propagation can be neglected for small area-to-mass and short timespans but become significant as the area-to-mass ratio increases, especially when combined with uncertainties over the effective CSA and the drag and SRP coefficients.

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