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A NEW APPROACH FOR CONJUNCTION ANALYSIS AND COLLISION RISK RANKING

Abstract

The evaluation and ranking of collision risks associated to predicted conjunctions between two orbiting objects is usually performed through the calculation of the predicted miss-distance and the associated collision probability. The collision probability is theoretically the most rigorous collision risk indicator. However, due to the fact that the predicted position uncertainties have an order of magnitude which is higher that the objects' dimensions, collision probabilities are usually extremely small. This makes difficult both the precise numerical calculation and the decision process regarding alarms. Also, the collision probability calculation lies on the propagation of state vectors uncertainty data, which are not always available or known precisely. This paper is focused on a new approach for conjunction analysis and collision risk ranking. The idea behind this approach is to exploit as much as possible the knowledge of the conjunction geometry to get a more precise collision risk indicator than the miss-distance itself, without having to use uncertainty data. Its principle is to quantify the smallest dispersion on the initial state vectors that leads to the collision event. This approach has been made possible by a new formulation of the collision conditions which will be detailed in the paper. In addition, first-order sensitivity equations - in association with some simplifying hypotheses - make possible to translate the collision conditions from the predicted miss-distance domain to the initial state vector domain. Then, according to the set of initial state variables considered, it is possible to compute the "closest" varied state vector corresponding to the collision event, and derive a global risk indicator. In this study, several variants of this approach have been tested, considering different set of initial state vectors (orbital parameters and/or position and velocity vectors). These indicators have been tested on real known collision cases using archives of TLE orbital data from before the collision events. These two cases are the 1996 Cerise/Ariane 1 debris collision and the 2009 Iridium 33 / Cosmos 2251 collision (although in the latter case, a small station-keeping manoeuvre was allegedly performed just before the event, which is detrimental to the analysis). The most efficient indicator proved to be the minimum quadratic mean of the initial velocity deviations that fulfil the collision conditions. We show that this indicator is more precise indicator than the miss-distance alone and in many cases allows of better ranking of the different collision risks in the absence of uncertainty information.