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A METHOD FOR FAST, ACCURATE AND ROBUST COMPUTATION OF LOW-THRUST TRANSFERS BETWEEN LEO ORBITS

Abstract

This paper presents a study carried out by Thales Alenia Space in cooperation with CNES. Its aim was to develop a tool to design optimal trajectories for debris removal missions using low thrust propulsion. Current population of debris in LEO is getting more and more dangerous and recent results prove the need to deorbit a few debris per year in order to avoid the Kessler syndrome. Several deorbiting concepts are currently under study but, irrespective of the concept, removal missions shall treat multiple debris to avoid prohibitive costs.

All multi-debris missions will have to determine the optimal sequence of debris to be removed. Several elements will contribute to the answer, but, amongst them, the DV cost is fundamental. Indeed, the good choice of debris is driven by the objective of minimizing the required total DV (maximizing dry mass).

In order to answer this question, it is necessary to have a tool that can evaluate in a fast, accurate, and robust way the cost of a low-thrust transfer between two LEO orbits, including angular rendezvous. This paper presents the tool that has been developed by TAS, based on an existing software: T3D, that uses an indirect approach of Pontyagrin's Maximum Principle. T3D has been largely validated through results obtained on challenging test cases. Nevertheless, several modifications have been necessary to meet the current needs.

The main issue to be tackled is related to the convergence of the method, since indirect methods require a good initial guess. Here we propose an approach to ensure convergence in almost all cases. The idea consists in defining a sequence of steps that increases convergence probability. The three steps of the process are described as follows:

- First, analytical calculations are performed to obtain a rough estimate of the DV. This first filter aims at proving the feasibility of this transfer. Well-known formulas (Edelbaum-like) have been adapted in order to take into account the J2 effect.
- Secondly, the minimum-time problem is solved by means of indirect methods combined with averaging techniques.
- Third, the minimum-fuel problem is solved using the previous solution as a first guess and increasing gradually the transfer time.

The resulting algorithm has been tested on large populations of debris leading to very promising results. Considering a population of several hundreds of debris, all-against-all runs have been performed and an extremely high rate of convergence has been achieved.