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SYMPOSIUM ON SPACE DEBRIS (A6)
Space Debris Removal Concepts (6)

Author: Mr. Juan Luis Gonzalo
Technical University of Madrid (UPM), Spain, juan.luis.gonzalo@upm.es

Dr. Claudio Bombardelli
Technical University of Madrid (UPM), Spain, claudio.bombardelli@upm.es

TARGET SEQUENCE DESIGN FOR LOW-THRUST MULTIPLE ADR MISSIONS

Abstract

A rich variety of Active Debris Removal technologies have been proposed in recent years, both with mechanical coupling (robotic arms, nets, harpoons, etc) and contactless (ion beams, etc). Some of these technologies allow to target several debris during a single mission, which can lead to important cost reductions. However, the design of such a mission profile is a challenging mathematical problem involving not only the selection of the target debris but also their sequence, phasing, waiting time between maneuvers, etc. Additional advantages can be obtained by leveraging the high propellant efficiency of low-thrust propulsion systems, but this further complicates design by turning each trajectory leg into an optimal control problem. With an abundant catalog of possible targets, designing the deorbit sequence maximizing the benefit (measured as an increase in operational safety) for a given cost is a highly complex tasks. All this topics are crucial in the mission design of LEOSWEEP (improving LEO Security With Enhanced Electric Propulsion) [Ruiz, Space Propulsion Conference 2014, Koeln, Germany], an EU-funded project employing contactless ion beam actuation for ADR.

This paper deals with the challenging task of optimizing a low-thrust multiple debris removal sequence. Each possible sequence is formed by up to four targets selected from a family of 22 Zenit upper stages, chosen for their high impact in operational safety. The ADR technology of choice is the Ion Beam Shepherd, which uses electric propulsion both for maneuvering and for acting on the debris. One of the key issues is the elevated computational cost of calculating all the low-thrust legs of each candidate trajectory. Given the large number of possible sequences, performing a full optimization for each candidate is not feasible. The availability of fast yet reasonably accurate estimates is then essential for the first phases of design. In recent years, these authors have proposed a solution for the optimal orbit correction using relative motion formulation, including analytical estimates for the time of flight [Gonzalo and Bombardelli, 26th AAS/AIAA Space Flight Mechanics Meeting, Napa, CA, USA]. These estimates are now used to construct and prune a search tree leading to a set of candidate missions. Results show the advantages of this approach in reducing the computational cost to acceptable levels despite the high complexity of the problem and the large number of possible sequences.