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AUTOMATIC PLANNING AND SCHEDULING OF ACTIVE REMOVAL OF NON-OPERATIONAL SATELLITES IN LOW EARTH ORBIT

Abstract

Since the beginning of the space era, humankind have put into orbit over 10,000 objects. Only 6% of these are active satellite (Rossi 2006) while the rest are space debris. The growth of space debris population represents a collision threat for satellite and manned spacecraft in Earth orbit. Recent studies have concluded that regions within Low Earth Orbit (LEO) have already reached a critical density of objects which will eventually lead to a cascading process known as the Kessler syndrome (Kessler 2010). It is expected for the LEO debris population to increase by approximately 30% in the next 200 years. The Inter-Agency Space Debris Coordination Committee has issued guidelines to mitigate the growth of space debris (IADC 2007). However it has been proved that compliance with these recommendations will not stop the exponential growth and that an active removal of between five to ten large objects per year is required to stabilize the population (Liou 2011).

In this paper two novel strategies to automatically design an optimized mission to retrieve and de-orbit 10 non-cooperative objects per year are proposed, targeting the region within 800 and 1400 km altitude in LEO. The underlying idea is to use a single servicing spacecraft to de-orbit several objects applying two different approaches. The first strategy is analogous to the Traveling Salesman Problem: the servicing spacecraft rendezvous with multiple objects in order to physically attach a de-orbiting kit that performs the re-entry. The second strategy is analogous to the Vehicle Routing Problem: the servicing spacecraft rendezvous with an object, spiral it down to a lower altitude orbit, and spiral up to the next target.

In order to maximize the number of de-orbited non-operative objects with minimum propellant consumption, an optimal sequence of targets is identified using an innovative incremental automatic planning and scheduling discrete optimisation algorithm derived from a novel algorithm for automatic planning and scheduling of multi-gravity assist trajectories developed for CNES and Thales Alenia Space (Romero IAC-2014).

The obtained optimal sequence of targets is then used to compute a low-thrust trajectory to reach each non-functional object, de-orbit it, and then move to the next target. The optimization of the trajectory is realized using a direct method and an analytical propagator based on a first-order solution of perturbed Keplerian motion. The analytical model takes into account the perturbations deriving from the J2 gravitational effect, the atmospheric drag and the solar radiation pressure.