Abstract: Debris Selection and Optimal Path Planning for Debris Removal on the SSO: Impulsive-Thrust Strategy.

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The large number of space debris makes the active removal of space debris a difficult problem for mission designers. It has been concluded that 5 to 10 big debris have to be removed per year. The selection of debris to remove is dictated by their respective size, mass, and the collision probability at a given date. The most densely populated orbits are in the 800 - 1000 km altitude region, and are nearly polar. Indeed, studies[1] indicate that the debris in regions of inclination 70°-75°, 80°-85°, and 95°-100° and altitudes in 800-850 km, 950-1000 km, and 1450-1500 km have the highest probability of collision. It is a first reasonable step to concentrate on a set of the biggest debris in the SSO region.
While the solutions for removing debris are still being discussed, the current paper deals with the actual trajectory design and the propulsion options. There is no definitive answer to the propulsion system to use. On the one hand, continuous-thrust has many advantages in term of consumption and acceleration induced by the debris, but the duration of the mission is a important. Some very inventive concepts actually use low-thrust propulsion as a mean of de-orbitation [2]. On the other hand, impulsive thrust allows fast and flexible transfers, but the required propellant may penalise ADR concepts severely.

The current paper focuses on the global optimisation for debris selection and accurate optimal control for trajectory design with impulsive thrust. A random set of 900 debris, with mass, on the SSO, will be generated. A global optimisation stage selects the candidates debris to remove over a year, according to a heuristic objective function (dependant on transfer deltaV and total debris mass removed), and dynamical constraints (using Hohmann + inclination change maneuver, and a specific Lambert's problem solver with J2 correction to quickly evaluate candidate sequences). A parallel implementation is devised to reduce computational time. Optimal control theory (primer vector theory [3]) is then used to refine solutions, and compute multiple-impulse trajectories between debris. Eventually, the minimum fuel requirement for such missions is obtained. Solutions between 200m/s and 700 m/s were found, and are presented. The trajectory solutions give an overview of what would be required for an ADR platform.

[1] J.-C. Liou, and N.L. Johnson, "A Sensitivity Study of the Effectiveness of Active Debris Removal in LEO," Acta Astronautica. Vol. 64, 2009, pp. 236-243

[2] C. Bombardelli, J. Pelaez , Ion beam shepherd for contactless space debris removal, Journal of Guidance, Control, and Dynamics, Vol. 34, No. 3, May–June 2011, pp 916–920.

[3] J. Olympio, *Designing Optimal Multi-Gravity Assist Trajectories with Optimal Number of Impulses*, 21st International Symposium on Space Flight Dynamics, 2009.