TARGET IDENTIFICATION AND DELTA-V SIZING FOR ACTIVE DEBRIS REMOVAL CAMPAIGNS

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ABSTRACT

The Aerospace Corporation, under the auspices of the United States Air Force (USAF) developmental planning and architectures group (SMC/XRD), recently performed modeling of the future growth of the space debris environment in Low Earth Orbit (LEO). The results indicated that some of the consequences of the projected growth include an expected 3 to 18% increase in the cost of space missions due to reliability degradation of orbiting assets by 2050, increased number of collision avoidance alerts, and increased likelihood of launch windows being closed[3]. Other studies have shown that actively removing debris-producing objects can reduce the rate of debris growth and that tracking objects with a higher degree of fidelity can reduce the number of collision avoidance alerts.

One of the difficulties in performing debris risk reduction missions is that spacecraft and launch vehicles are expensive. In order to make a mission worthwhile, the benefit (i.e., the effectiveness of the mission) must outweigh the cost. One way to reduce the cost is to launch missions that have multiple targets. For example, a small mini-satellite (like a 3U CubeSat) could either be placed on or very near a selected target. The mini-satellite could then deploy a drag-enhancement device or simply act as a beacon allowing for high precision tracking. A larger vehicle capable of moving between targets would be required to deploy the mini-satellites. In this study, an on-orbit vehicle will be assumed that has either an impulsive or low-thrust delta-V capability to move between targets.

The tracked objects in low Earth orbit (LEO) are generally categorized in terms of three groups: satellites (payloads), rocket bodies, and debris. It was found through the debris modeling process that collisions involving intact satellites and rocket bodies produce much more debris than collisions between the smaller debris objects, even though debris outnumbers the intact objects. Table 1 lists the intact objects that were found to have the potential to generate the largest amount of debris based on a combination of the likelihood of collision and the severity of the consequences of the collision averaged over 100 Monte Carlo runs. The objects in Table 1 have been grouped by similarity of orbit and therefore could possibly be reached by a single vehicle.

While the groups in Table 1 are the result of an average of 100 Monte Carlo runs, individual objects can move on and off the top 100 list depending upon the specific Monte Carlo run selected for examination. This makes the choice of which individual objects to target for a real-world mission problematic. For example, the 19 SL-16/Tselina-2 objects are a subset of the 39 SL-16/Tselina-2 objects (18 SL-16 & 21 Tselina-2) that are in the public Resident Space Object catalog in a similar orbit. There is no way to know a priori which of the 39 will contribute to the future real-world debris growth and which won't. Therefore, they must be treated as a group when planning missions.

Name	Inclination (deg)	Altitude (km)	# out of 100	# in catalog
SL-16 R/B & Tselina-2	71	835	19	39
Sun-synchronous	~98-99	770-1000	24	189
Mostly SL-8 R/B	83	980	30	311
SL-3 R/B & various satellites	81	865	6	58
SL-8 R/B	74	770	6	100
Iridium	86	780	13	85

Table 1: Most likely debris-generating objects from model simulation

Given that plane changes require the largest delta-V, the first step to maximize the number of reachable targets is to pick objects that are in similar inclinations. For example, when examining just the 18 SL-16 rocket bodies in Table 1, the inclinations range from 70.89 to 71.02 degrees. With similar altitude, eccentricity and inclination, the main orbit element that needs to be adjusted is the right ascension of ascending node (RAAN). Figure 1 shows the 18 SL-16 rocket bodies as a function of right ascension of ascending node at a given snapshot in time. There were two groups of 4 objects each that could be reached for less than a total 1.8 km/sec of impulsive delta-V. This limitation could be mitigated by using a long duration mission of several years in length, which would allow for a beneficial natural right ascension of ascending node drift between target orbits. However, for short-duration missions, the RAANs have to be closely lined up naturally to be able to rendezvous with all the desired targets.

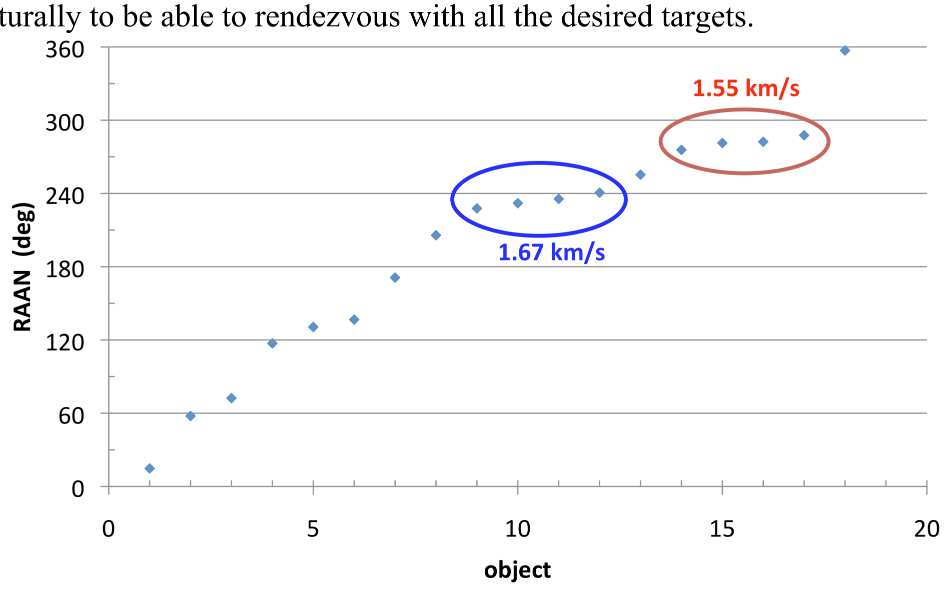

Figure 1: RAAN distribution for SL-16 objects

The final paper will present details of the process, give a greater description of the top 100 objects and where they reside in orbit element space, and show a comparison between impulsive and low thrust delta-V mission profiles for the short-term mission duration (days) and long-term mission (years).