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Author: Mr. Joseph Carroll
Tether Applications, Inc., United States, tether@cox.net

CAN PULSED LASER ABLATION PREVENT MOST DEBRIS CREATION?

Abstract

Nearly all of the direct debris threat to operating spacecraft in Low Earth Orbit (LEO) is from >200,000 gram-class pieces of untracked shrapnel that can disable even large satellites. The main indirect threat is massive debris collisions that generate more such shrapnel. Such collisions now have 0.06 chance/year. They will often involve two ton-class objects and can generate more new shrapnel than the Fengyun/A-sat and Iridium/Cosmos collisions together.

This paper argues that instead of developing a ground-based pulsed-ablation laser for wholesale debris deorbit, a better early step may be a cheaper low-duty-cycle laser that prevents predicted shrapnel-generating collisions, by occasional 1mm/sec nudges that adjust debris orbit periods. Focusing on intact objects and large kilogram-class fragments allows better tracking and orbit predictions. Better predictions can drastically reduce both the number and the size of required nudging impulses.

The main driver of laser-ablation system cost is maximum target range. Longer range requires both larger lasers and larger telescope apertures, for tighter focus and also to limit non-linear losses. About a fourth of future shrapnel should come from objects with average altitudes of 940-1000 km, but only 0.05 should come from objects >1000 km. Hence being able to nudge objects up to 1000 km altitude seems like a useful system design requirement.

Maximum range is driven by ground-track offset as well as by altitude. Half the debris mass <1000 km is 7-9 degrees from polar orbit, and <0.06 is >26 degrees from polar orbit. One laser site near 70 degrees N or S latitude may be enough, if it has clear enough weather and seeing for even daytime adaptive optics and nudging of large intact targets. The weapons potential of such lasers suggests that if any country builds one, several may. But if they collaborate or coordinate nudging operations, diversity of site locations and weather should let several sites outperform a single site.

The paper also briefly discusses treaty issues. Russia owns >0.70 of the LEO debris mass below 1000 km, and the US owns half of the rest. The 1972 Space Liability Convention lets states agree among themselves on indemnification for liabilities under the convention. A bilateral agreement between the US and Russia may allow prevention of most serious debris collisions, and may be the only new international agreement needed.