SPACE DEBRIS SYMPOSIUM (A6)
Mitigation, Standards, Removal and Legal Issues (4)

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ULTRASHORT OPTICAL PULSES APPLIED TO DEORBITING SMALL DEBRIS ELEMENTS

Abstract

We examine ultrashort pulse laser systems designed to reduce the fraction of small debris, dimensions of 1-10 cm, in near Earth orbit. We estimate rate of removal as a function of parameters characterizing the debris and the ultrashort pulse laser system. Laser resonator design, thermal management, system mass, power management, pointing and tracking, and debris ephemerides are addressed. The need to monitor the new ephemeris of a given debris object after exertion of a laser mediated impulse, strategies for optimally illuminating the debris elements, and the temporal window available for exerting a given deorbiting impulse are also considered. We make the case that the achievable force F using ultrashort pulses as a function of average laser power P and velocity vej of the ejected material can approach F = 2P/vej. This is the same upper limit as for an ideal chemical rocket using power P and ejecting material at velocity vej. A practical problem encountered in approaching this upper limit is the need to avoid absorption of the incident laser light by the cloud of material ejected from the debris element illuminated by the laser pulse. We propose this loss can be minimized by using a patterned sequence of ultrashort optical pulses. Optimum efficiency favors individual pulses shorter than the time required for the cloud of ejected material to emerge, 1 picosecond. Also an interval between pulses long compared to the time required for the ejected cloud to become approximately transparent to the incident laser light, 1 microsecond is required. We seek optimally safe use by delivering the deorbiting impulse specifically to a given debris element and only that debris element. We discuss conclusions regarding developing laser systems of practical interest. We find the needed laser systems do not exist now, but we also conclude such systems are feasible of development within order of years as opposed to order of decades. We suggest one such laser system equipped spacecraft could remove a significant fraction of the small debris in low Earth orbit within range of the laser system in a time period short compared to a year. Here the region accessed by one laser system within a matter of months is the space between two concentric spherical surfaces separated by order of the laser range, e.g. 20 km, and centered at a radial distance equal to that of the laser system from the center of the Earth.