***Paper Two: Overcoming Technical Challenges***

***Challenge 1: Inadequate debris detection, tracking, and conjunction reports***

*Before orbital debris can be removed, stored safely, or rehabilitated through refueling or repair, it must be tracked in real time and down to a size that is still dangerous yet cannot be practically shielded against, i.e. 0.5 cm (Liou 2014 & Beason 2014). Fortunately, The U.S. Naval Research Laboratory (NRL), Geospace Science and Technology Branch, has recently patented its Optical Orbital Debris Spotter (OODS), a compact, low cost, low power space debris concept that can be integrated into larger satellite designs of flown independently on board nano-satellite platforms (Parry 2015). The OODS throws up a laser light sheet capable of detecting debris as small as 0.01 cm near the host spacecraft for near real-time characterization of debris fields. Because this technology is just now emerging, however, it will have to go through a period of testing and development before deployment.*

*The USAF Joint Space Operations Center (JSpOC), through its Space Surveillance Network (29 telescopes & radars), tracks > 20,000 debris objects roughly the size of a softball (10 cm) or larger. Using several sightings for each object being tracked, JSpOC, only determines the object’s position every 90 minutes. Moreover, conjunction predictions are only accurate within plus or minus 1 km. Satellite owners know that 9,999 out of 10,0000 warnings will likely be false alarms.* Therefore, they ignore most warnings*. Better tracking of objects, including those < 10 cm, could lead to much fewer false alarms and better satellite owner compliance (Riot 2012)*

*To deal with the above challenge, and-in-hand with emerging small debris detection technology, six new detection and tracking systems are also emerging, and two are commercial. (See Annex B for a list of tracking entities and other details.) With international commercial space detection and tracking systems in place, all objects at or above 0.5 cm would ideally be tracked, improving the situational awareness and security of both military and commercial spacecraft users.*

*Therefore, potentially interested buyers and potentially capable sellers exist. What is missing is a debris data-trading floor to facilitate buying and selling. The National Space Society recommends setting up a civilian-run, international, regulated Debris Data Exchange, operating like a stock exchange (Levin 2014). All catalogued debris objects could be listed on such an exchange, including, ideally, defunct military stages and satellites. To avoid military concerns, operational satellites of any stripe need not be listed – unless particular satellite operators wish to list theirs. Such an exchange could be set up by the international orbital debris convention suggested earlier.*

***Challenge 2: Lack of Ready Technology to deal with Space Debris***

*Because of the attenuation of the atmosphere increases as distance from the Earth’s surface increases, the length of time that orbital debris persists depends on its altitude. Debris persists few days if under 200 km (125 mi); a few years if between 200 km and 600 km (370 mi); decades if the debris is between 600 km and 800 km (500 mi); and centuries if over 800 km. The difficulty of detection and tracking with Earth-based sensors also increases with increasing altitude, as does the difficulty faced by Earth-launched remediating spacecraft, especially those using chemical propulsion. This situation, therefore, favors space-based sensors and non-propellant or at least non-chemical propellant, remediating spacecraft.*

*Although most of the trackeddebris is in LEO, with the greatest concentration found between 750 – 1100 km altitude,as can be seen in the figure below, total debris numbers and total mass peak at different altitudes. This means that the greatest* current *threat is around 780 km altitude, the greatest* future *threat will be around 840 km, as the rocket bodies that compose most of the debris mass at that altitude will inevitably begin colliding with one another. Although one can be tempted to focus only on the greatest present threat and leave the future threat for the future, as we will explain below, there are important psychological and geopolitical reasons also to deal quickly with the future threat as soon as possible.*

*Figure 4. Image: ESA. From Darren McKnight, Donald Kessler, “We’ve Already Passed the Tipping Point for Orbital Debris.” 26 September 2012.*

*Many technologies have been proposed for orbital debris remediation, including those using lasers, harpoons, nets, electron beaming, electrostatic manipulators, grappler-satellites and others, the most promising of which we will describe below. The idea behind these proposed technologies is either to remove debris, repurpose defunct satellite parts, recycle debris metal, or rehabilitate defunct satellites by refueling or repairing them. Because orbital debris objects have a range of societal, economic, political, and geophysical connections, however, the best remedies will differ with the debris object’s altitude, size, type, ownership, and former use. For this reason, the National Space Society endorses studying and testing a wide range of debris management technologies and strategies, then developing the most promising ones.*

*Several of the more promising debris removal technologies and practices described below include:*

* *propellantless electrodynamic or electrostatic-beaming vehicles to capture and move large debris objects for rehabilitation, deorbit, safe parking or salvage;*
* *ground-based pulsed-laser systems to nudge large debris objects for collision avoidance or to deorbit small debris objects (shrapnel);*
* *space-based electron beaming to deorbit or move medium to large debris by electromagnetic deflection;*
* *low-power, space-based pulsed laser ablation to deorbit small debris objects; and*
* *pop-out drag-to-deorbit technologies.*

*Unfortunately, NASA adopted a policy in June 2014 to support development of orbital debris removal only through Technology Readiness Level (TRL) 4 (Werner 2015). Although in Annex B we give an overview of orbital debris objects and describe debris removal technologies already at TRL-5 and TRL-9, most proposed technologies are at TRL 4 or lower.* ***NSS therefore urges NASA again to fund orbital debris technology beyond TRL-4.*** *Our proposed NASA policy change is particularly important because we cannot predict which technological approaches will become cost-effective ways to remediate the variety of orbital debris objects at various altitudes.*

*The ISS: Ideal Test-Bed for Debris Remediation Technologies*

*We urge that the ISS be used as a testbed to develop potential orbital debris remediation technologies such as EDDE, electrostatic-electromagnetic deflection, electrostatic tether capture, solar electric power (SEP), pulsed-laser ablation, satellite refueling and repair, and cellularization of salvaged spacecraft parts. This ISS-based testing and developed should be carried out with international partners, including Russia and China.*

*In this regard, we note that the ISS has features that can facilitate debris-removal technology demonstrations: its own electrical power supply, a redundant international supply chain, human extravehicular capabilities, robotic grappling and docking, a Ka Band microwave transmission antenna, an airlock, a platform for servicing and refueling other spacecraft, and capacity for add-ons such as an electron-beaming module.*

*The Naval Research Laboratory has a 3U EDDE-cubesat precursor test scheduled to deploy from the ISS in 2015. The next step would be to test EDDE hardware with a 12U format cubesat (Carroll, “Delivery….” 2014). Eventually electrodynamic vehicles should be able to scale up, extend their reach, and capture ever larger objects as well as remove old cubesats from higher orbits.*

*We also note that the ISS generates ten tons of test-amenable waste annually, and the international space community already spends money and effort to remove it. Electrodynamic vehicles could potentially bring another 100 tons of orbital debris to the ISS for either de-orbiting, repurposing, or salvage for recycling metal (Carroll, “Delivery….” 2014).*

*Once we have learned to deal with small amounts of debris in connection with the ISS, we will be better prepared to deal with the estimated 2200 tons of dangerous large debris objects in LEO and elsewhere. In sum, we highly recommend that the ISS be used as a test bed for various debris remediation technologies, including those for moving for collision avoidance, deorbiting, repurposing, recycling (salvaged metal), and rehabilitating (by refueling or repairing). The costs of the ISS as an international space lab could not be better justified than by this purpose.*

*The United States Government should offer public-private COTS-type programs to test and develop cost-effective debris remediation technologies from the ISS as soon as possible. We face a pay-now or pay-more-later situation that will result from inevitable ton-class collisions affecting USG military and civilian satellites. Taking proactive public-private action to develop propellantless and low-propellant cleanup technologies might jump-start international commercial investments in such as well.*

*The Bottom Line*

*We don’t yet know the cost or the feasibility of the various debris cleanup options mentioned in this paper, although there are indications that, at least in LEO, electrodynamic vehiclesand energy-beaming technologies to deflect and remove debris should be the most cost-effective, simply because they would use no propellant and involve relatively low mass in orbit. In GEO, various capture and “touchless” technologies offer hope.*

*Whatever orbital debris remediation technologies win out in the end, the longer we put off testing and developing the various possible technologies for orbital debris remediation, the more costly the debris remediation will be in the long run (McNight 2010). This will be especially true if there is another catastrophic collision in orbit,* something that will certainly occur without orbital debris remediation*.*

***Summary of NSS Recommendations***

***Non-Technical Recommendations***

*To overcome adverse economic incentives, the NSS recommends creating an international, transparent, and refundable deposit-on-launch system to raise funds for bounties to pay private companies for the successful removal or rehabilitation of orbital debris objects, when satellite entities do not remove such objects themselves. To administer such a system nationally and coordinate with similar systems internationally, the NSS recommends the creation, through White House executive action, of an Orbital Debris Cleanup Executive Committee.*

*To overcome policy and legal barriers, NSS recommends removing the 25-year free orbital parking guideline and expanding on the Outer Space Treaty Article IX provision to avoid “contamination” of the Earth with “extraterrestrial matter” through an International Orbital Debris Convention.*

*To overcome geopolitical sensitivities, NSS recommends that the United States undertake an agreement with Russia to remove non-sensitive upper stages from Low Earth Orbit (LEO) and collaborate with a variety of countries, including Russia and China, to use the International Space Station (ISS) as a testbed for developing debris cleanup technologies.*

***Technical Recommendations***

*To overcome the lack of detection and tracking of debris objects smaller than 10 cm, the NSS recommends further development of the Optical Orbital Debris Spotter recently developed by the Naval Research Laboratory.*

*To overcome the lack of real-time, precise, and frequent detection, tracking, and conjunction reports, the NSS recommends international legal and policy facilitation for the seven new debris tracking entities described in this paper.*

*To address the lack of ready technology for engaging constructively with multi-shaped and sized, tumbling, high—velocity and multi-altitude debris objects, the NSS urges full utilization of the ISS and other space installations worldwide to test and develop the below-described orbital debris mitigation and remediation technologies, especially those using low and non-propellant spacecraft. As part of this effort,* we urge NASA again to be willing to fund the testing of orbital debris technology above TRL-4.

*In general, the National Space Society recommends crash, internationally coordinated, public-private campaigns to test and develop the technologies described in this paper, and any other promising ones that may emerge.*

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