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As the Grapefruit Turns Sixty, It's Time to Get Serious About Clean Up in Outer Space

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**AS THE GRAPEFRUIT TURNS SIXTY, IT'S TIME TO GET
SERIOUS ABOUT CLEAN UP IN OUTER SPACE**

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I. INTRODUCTION

IN THE EARLY MORNING HOURS of St. Patrick’s Day 1958, a nervous satellite team waited, “like expectant fathers,”¹ for the continuation of a countdown that had already been thrice canceled.² A short hold for electronic problems was followed by a “stretch-out.” Incredibly, the United States’s second satellite (and only the fourth satellite to ever be launched from Earth) was on a traffic hold. Kurt Stehling, head of the launch vehicle division of Project Vanguard at the Naval Research Laboratory, marveled at the “unprecedented event.”³ He admitted, “that never in [his] earlier life did [he] expect to see the day when

¹ Constance McLaughlin Green & Milton Lomask, *Vanguard, A History*, NASA HISTORICAL SERIES (Aug. 28, 1997), Chapter 12, <https://www.hq.nasa.gov/office/pao/History/sputnik/chap12.html> [perma.cc/H87V-M22Z].

² *Id.*

³ *Id.*

one would have to wait until satellite traffic in the sky was cleared for the launching of another orbiter.”⁴ Lift off was achieved at 07:15:41, and *Vanguard 1*, or the “Grapefruit Satellite” as it was dismissively nicknamed by Nikita Khrushchev,⁵ reached its appointed orbit where it remains today as the “oldest manmade satellite still in orbit about the Earth.”⁶ Though the satellite stopped communicating with Earth in 1964, it continues to be tracked visually and is expected to remain in its orbit for another 180 years.⁷ On the fiftieth anniversary of the *Vanguard 1* launch, space analyst James Oberger suggested that space and robotic technology had advanced enough to contemplate a mission to retrieve the satellite that has outlived “almost all of the human beings who created it.”⁸ The launch, operations span, lifespan, and proposed retrieval of the Grapefruit Satellite palpably frames our relatively brief interaction with outer space. On one hand, it underscores the tremendous advancement made in space technologies during the nearly sixty years *Vanguard 1* has been on-orbit. On the other hand, it reveals a troubling trend where a spacecraft’s lifespan vastly outlasts its operational capability, leaving inert and inoperative satellites—often much larger than grapefruits—to crowd our precious orbit without providing any benefit.

The ability to physically interact with an on-orbit object has been stymied by its formidable cost, yet the potential rewards are incalculable. Autonomous on-orbit servicing (OOS) vehicles could potentially repair or salvage an ailing satellite or remove it from orbit. The former could help recoup the considerable re-

⁴ *Id.*

⁵ *Vanguard 1 Celebrates 50 Years in Space*, PHYS.ORG (Mar. 13, 2008), <https://phys.org/news/2008-03-vanguard-celebrates-years-space.html> [perma.cc/DV2Q-YQG6].

⁶ Clair Wood, *Vanguard 1, the Oldest Manmade Satellite Still in Orbit, May be Displayed in a Museum*, BANGOR DAILY NEWS (Jan. 29, 2014), <https://bangordailynews.com/2014/01/29/outdoors/vanguard-1-the-oldest-manmade-satellite-still-in-orbit-may-be-displayed-in-a-museum/?ref=relatedBox> [perma.cc/UJG7-J6NS].

⁷ Initially, the lifespan of *Vanguard 1* was expected to be 2,000 years, “but it was discovered that solar radiation, pressure and atmospheric drag during high levels of solar activity produced significant perturbations in the perigee height of the satellite, which caused a significant decrease in its expected lifetime to only about 240 years.” *Satellite Tracking, Prediction and Informations about Objects in the Sky*, INFO-SATELLITES (last updated Dec. 12, 2012), <http://www.infosatellites.com/vanguard1-satellite-information-norad-5.html> [perma.cc/5AJJ-E6MG].

⁸ James Oberger, *Satellite Turns 50 Years Old . . . in Orbit!*, NBC NEWS (Mar. 17, 2008), http://www.nbcnews.com/id/23639980/ns/technology_and_science-space/t/satellite-turns-years-old-orbit/#.WPUKtWkrJhF [perma.cc/G55P-BZT4].

sources invested in the development and construction of a satellite, and the latter would reduce space debris. In short, the development of OOS should be promoted rather than budgeted out. This article will explore the legal ramifications and complications of unmanned OOS missions. After reviewing the international framework and the current state of affairs, this article suggests that States have an obligation to repair, salvage, or remove from orbit defunct space objects and proposes an organizational framework that will promote compliance with efforts to clean up the junkyard surrounding our planet.

II. OUR HEAVENLY JUNKYARD

A. BY THE NUMBERS

Since the launch of *Vanguard 1* in 1958, many other objects have been left in orbit, “ranging from small ejectables to defunct satellites and burned-out upper stages of rockets.”⁹ Though the larger objects “generally fall back to Earth quickly,”¹⁰ many non-operational satellites remain in orbit. The United Nations Office for Outer Space Affairs (UNOOSA) Online Index of Objects Launched into Outer Space lists 8,049 entries.¹¹ Of those, the Union of Concerned Scientists database indicates that 1,738 are operational.¹² The U.S. Department of Defense (DoD) Joint Space Operations Center (JSpOC) has cataloged 16,140 satellites of which it estimates 87% are “defunct payloads and debris.”¹³ By other estimates, there are approximately 2,600 non-operational satellites in low Earth orbit (LEO).¹⁴ We should

⁹ Martin J. Losekamm et al., Legal and Political Implications of Future On-Orbit Servicing Missions, Conference Paper delivered at the 66th International Astronautical Congress, IAC-15-E3.IP.10x27754 (Oct. 2015) at 2.

¹⁰ *Id.*

¹¹ *Online Index of Objects Launched into Outer Space*, U.N. OFFICE FOR OUTER SPACE AFFAIRS, http://www.unoosa.org/oosa/osoindex/search-ng.jsp?lf_id [perma.cc/W3CZ-DWX3] (last visited Feb. 8, 2018).

¹² *UCS Satellite Database*, UNION OF CONCERNED SCIENTISTS, <http://www.ucsusa.org/nuclear-weapons/space-weapons/satellite-database#.WPVXSmkrJhF> [perma.cc/TB9Q-TZEW] (last visited Feb. 8, 2018). There is a slight discrepancy in the numbers because the UN database has entries as late as February 2018 and the Union of Concerned Scientists database only includes launches through August 31, 2017. However, this discrepancy will be relatively small, numbering in the tens rather than the thousands.

¹³ Felix R. Hoots, *Keeping Track: Space Surveillance for Operational Support*, AEROSPACE.ORG (Dec. 10, 2015), <http://www.aerospace.org/crosslinkmag/fall-2015/keeping-track-space-surveillance-for-operational-support> [perma.cc/XNK6-BJSE].

¹⁴ Comm. on the Peaceful Uses of Outer Space, Sci. and Tech. Subcomm., *Active Debris Removal—An Essential Mechanism for Ensuring the Safety and Sus-*

expect congestion to continue to increase in “the orbital bands most useful for today’s space industry: . . . LEO and [the] geostationary orbit (GEO)”¹⁵ because demand for space-based capabilities, including navigation and wireless communication, and “inter-spacecraft communication for both manned and unmanned systems” will only grow.¹⁶

B. A \$450 MILLION EXAMPLE

“If a satellite makes it to orbit, there is no guarantee that it will work as intended.”¹⁷ Moreover, like any terrestrial vehicles or equipment, spacecraft will suffer from normal wear and tear. That said, outer space conditions are “particularly harsh and greatly inhibit[] equipment reliability.”¹⁸ Of course, unlike most of their terrestrial counterparts, satellites are not easily accessible for inspection or repair. Thus, an otherwise minor flaw can “cripple a spacecraft, severely impede research and testing efforts and ultimately frustrate a multi-million dollar investment.”¹⁹ Even worse,

it is more than likely that a ground-based project team will never be able to conclusively determine why a failure or malfunction occurred. In these cases, not only is the spacecraft lost, but invaluable experience vanishes with it. This lack of knowledge in the failure mode of a satellite decreases the ability to implement preventive or other innovative measures in replacement craft which in turn severely impedes the evolution of human ability in space.²⁰

U.S. Naval Academy research provided a revealing case study on Space Systems/Loral, LLC (SSL), the developer of the SSL 1300, one of the most popular communication satellite bus designs in the world.²¹ In 2004, *Telstar 14* (the 53rd spacecraft of that line) was heading for a geosynchronous orbit to deliver

tainability of Outer Space, A/AC.105/C.1/2012/CRP.16 (Jan. 27, 2012) at 24 [hereinafter UNCOPUOS Remediation Report].

¹⁵ Losekamm et al., *supra* note 9, at 2.

¹⁶ Losekamm et al., *supra* note 9, at 2–3.

¹⁷ EDWARD A.S. HANLON ET AL., Am. Inst. of Aeronautics and Astronautics SpaceOps Conference, AUTONOMOUS MOBILE ON-ORBIT DIAGNOSTIC SYSTEM: INITIATING A DOCTRINAL SHIFT IN SPACECRAFT OPERATION 1 (2016) <https://arc.aiaa.org/doi/pdf/10.2514/6.2016-2479> [<https://perma.cc/V48U-B8UL>].

¹⁸ *Id.*

¹⁹ *Id.*

²⁰ *Id.*

²¹ See *id.* at 3; see also Peter B. de Selding, *Spate of Solar-Array Failure on SS/L Satellites Traced to Manufacturing Defect*, SPACE NEWS (Jan. 4, 2013), <http://>

“Ku-band communications” to the southern United States as well as South America.²² Unfortunately, the satellite suffered a crippling solar array failure that could not be addressed, halving the lifespan of the satellite from fifteen to seven years. SSL spent \$13 million attempting to determine the root cause of the failure before abandoning the effort to focus on launching a replacement.²³ However, in 2011, *Telstar 14*'s replacement spacecraft, *Telstar 14R*, suffered the same solar panel failure. SSL spent an additional \$22 million troubleshooting the problem, ultimately tracing the flaw to a malfunctioning nylon hook. Even so, a third solar array failure occurred in 2012. Though still operational, the service lives of all three satellites were considerably reduced, resulting in insurance claims nearing \$422 million.²⁴ Had OOS been available, the full operational lifespan of *Telstar 14* may well have been salvaged. At the very least, SSL could have identified the original failure and avoided replicating the error in two more spacecraft.

C. THE ISSUE OF DEBRIS

Failed conventional satellites, like *Telstar*, are not the only objects populating our heavenly junkyard. The DoD Space Surveillance Network “tracks discrete objects as small as two inches (five centimeters) in diameter in [LEO] and about one yard (one meter) in [GEO].”²⁵ The total number of tracked objects exceeds 21,000 and an estimated 500,000 pieces of debris larger than a marble circle our Earth.²⁶ Imagine what Kurt Stehling would say! However, the issue is much larger than mere traffic management. These pieces of debris “travel at speeds up to 17,500 [miles per hour], fast enough for a relatively small piece of orbital debris to damage a satellite or a spacecraft.”²⁷ Writing in 1978, Donald Kessler developed the theory widely known as

spacenews.com/33046spate-of-solar-array-failures-on-ssl-satellites-traced-to/ [perma.cc/SU7Q-RBHT].

²² *Telstar 14* page, SATBEAMS.COM, <https://www.satbeams.com/satellites?norad=28137> [perma.cc/9JM4-5T9Y].

²³ de Selding, *Spate of Solar-Array Failure*, *supra* note 21.

²⁴ de Selding, *Spate of Solar-Array Failure*, *supra* note 21.

²⁵ *Space Debris and Human Spacecraft*, NASA (last updated Aug. 7, 2017), https://www.nasa.gov/mission_pages/station/news/orbital_debris.html [perma.cc/XJA6-SB74].

²⁶ *Id.*

²⁷ *Id.* “Even tiny paint flecks can damage a spacecraft when traveling at these velocities. In fact a number of space shuttle windows have been replaced because of damage caused by material that was analyzed to be paint flecks.” *Id.*

the Kessler syndrome, highlighting the very real danger that orbital debris poses to humanity's spacefaring potential:

Because many of these satellites are in orbits which cross one another, there is a finite probability of collisions between them. Satellite collisions will produce a number of fragments, some of which may be capable of fragmenting another satellite upon collision, creating even more fragments. The result would be an exponential increase in the number of objects with time, creating a belt of debris around the earth.²⁸

The inevitable result of this “self-sustaining cascading collision of space debris”²⁹ will be to make LEO virtually impassable. The 2009 collision between a defunct Russian satellite and an operating communications satellite owned by a U.S. firm was deemed “very rare”³⁰ at the time, but it is only a matter of time before such an event occurs again. By 2015, the U.S. National Aeronautics and Space Administration (NASA) had already reported that the International Space Station has needed to make “collision avoidance maneuvers” twenty-five times.³¹ Similarly, the European Space Association (ESA) reports that one of its ten LEO satellites receive a “high-risk collision alert every week on average”³² and must undertake avoidance measures at least once or twice each year. ESA's own *Envisat* is a prime example of a defunct satellite threatening to cause a collision that will not only damage a third-party satellite but will also contribute greatly to the Kessler syndrome.

Envisat, launched in 2002, stands out for both its enormous size and cost. The now defunct satellite cost “\$2.9 billion in today's dollars” and “was the biggest non-military Earth observation satellite ever built.”³³ *Envisat* “stopped communicating with

²⁸ Donald J. Kessler & Burton G. Cour-Palais, *Collision Frequency of Artificial Satellites: The Creation of a Debris Belt*, 83 A6 J. OF GEOPHYSICAL RES. 2637, 2637 (1978).

²⁹ Michelle La Vone, *The Kessler Syndrome: 10 Interesting and Disturbing Facts*, SPACE SAFETY MAG., <http://www.spacesafetymagazine.com/space-debris/kessler-syndrome/> [perma.cc/PJ5F-WPCN] (last visited Feb. 8, 2018).

³⁰ Yuri Poshkin & Melissa Gray, *Russia, U.S. Satellites Collide in Space*, CNN (Feb. 12, 2009), <http://www.cnn.com/2009/TECH/02/12/us.russia.satellite.crash/index.html?s=PM:TECH> [perma.cc/YP5A-7SXL].

³¹ *Two More Collision Avoidance Maneuvers for the International Space Station*, ORBITAL DEBRIS QUARTERLY NEWS at 1 (Oct. 2015).

³² *Space Debris Problem Getting Worse, Say Scientists*, PHYS.ORG (Apr. 18, 2017), <https://phys.org/news/2017-04-space-debris-problem-worse-scientists.html> [perma.cc/TYY7-ZUZF].

³³ Peter B. de Selding, *Huge Satellite Poses 150-Year Threat of Space Debris*, SPACE.COM (July 26, 2010), <http://www.space.com/8829-huge-satellite-poses-150-year-threat-space-debris.html> [perma.cc/5ZKR-UCX2].

ground stations”³⁴ in 2012 and now drifts blindly 800 kilometers above the Earth. As Kessler himself observed: “it seems ironic that a satellite intended to monitor the Earth’s environment is . . . likely to become a major contributor to the debris environment.”³⁵ Kessler predicts that a collision involving the (thirty-foot wide) *Envisat* could “instantly produce[] a debris environment that, under the most optimistic conditions, we would not [otherwise] expect to have for at least 100 years.”³⁶

D. OOS TO THE RESCUE?

Considering the costly implications of satellite failure, the crowding of orbits, and the Kessler syndrome, the concept of autonomous OOS has become too important to ignore.³⁷ Numerous OOS development projects—both private and government-sponsored—are currently underway, and some anticipate deploying as early as this year.³⁸ While they all take different approaches, autonomous OOS vehicles can perform three basic functions from a practical standpoint: move, manipulate, and observe.³⁹ Given these capabilities, an OOS spacecraft can provide a variety of services with varying degrees of invasiveness.⁴⁰

If a satellite has partially or totally failed, and its owner does not know the cause, the OOS vehicle can observe and image the

³⁴ Tariq Malik, *Huge Satellite Envisat is Dead in Space*, SPACE.COM (May 9, 2012), <http://www.space.com/15608-huge-satellite-envisat-dead-space.html> [perma.cc/U9VV-G7TA].

³⁵ Andrea Gini, *Don Kessler on Envisat and the Kessler Syndrome*, SPACE SAFETY MAG. (Apr. 25, 2012), <http://www.spacesafetymagazine.com/space-debris/kessler-syndrome/don-kessler-envisat-kessler-syndrome/> [perma.cc/2A8E-WNA6].

³⁶ *Id.*

³⁷ Of course, OOS is not a novel idea. The Hubble Space Telescope was “specifically designed to allow service and repair by astronauts.” ON-ORBIT SERVICING WORKING GRP., *On-Orbit Servicing Commercial Opportunities with Security Implications*, Space Generation Congress (Toronto 2014) at 55. Indeed, Hubble benefited from five service missions on the U.S. Space Transportation System, commonly known as the Space Shuttle. However, each mission cost at least \$200 million. See Clinton Parks & Brian Berger, *NASA’s Mission to Service Hubble in 2008 Will Cost \$900 Million*, SPACE.COM (Oct. 31, 2006), <http://www.space.com/3057-nasa-mission-service-hubble-2008-cost-900-million.html> [perma.cc/9JJS-2JHB].

³⁸ For an excellent review of existing projects, see Joseph Pelton, *New Solutions for the Space Debris Problem*, SPRINGERBRIEFS IN SPACE DEV. 11 (2015).

³⁹ See Joerg Kreisel, *On-Orbit Servicing of Satellites (OOS): Its Potential Market & Impact*, Paper delivered at 7th ESA Workshop on Advanced Space Technologies for Robotics and Automation ‘ASTRA 2002’ (Nov. 2002), at 2.

⁴⁰ See generally Tare C. Brisibe, *Satellite Servicing On-Orbit by Automation and Robotics: Legal and Regulatory Considerations*, 29 J. SPACE LAW 22 (2003); Losekamm et al., *supra* note 9, at 3.

satellite, returning data to ground stations for analysis and review. While the OOS vehicle will have to perform delicate proximity operations, it will not have to attach itself to the satellite unless the satellite owner has a specific concern that requires close examination. If the satellite owner knows definitively that the operational life of the spacecraft is waning due simply to a lack of fuel or propellant, the OOS vehicle can be fitted to refuel the satellite. In order to do so, the OOS provider will need to coordinate with the satellite owner to confirm fueling structure and strategies. The OOS vehicle will again have to perform delicate proximity procedures. It will most likely have to attach to the satellite during the refueling process and then detach and propel itself out of the way once refueling is complete.

The OOS vehicle can also serve to restore a spacecraft's orbit, requiring even more delicate proximity operations. The OOS vehicle will need to be fitted with a safe means of either pushing or tugging the satellites as needed. The OOS vehicle can also mechanically intervene to repair or ameliorate a failure or to perform an upgrade or other modification. This would require a high level of interaction between the OOS provider and the satellite owner, as the OOS vehicle would need to be fitted with proper replacement equipment.

Finally, if the satellite is not repairable, the OOS vehicle can salvage parts and ultimately deorbit the satellite. While this is an extremely invasive act, at that point there would be no concern about damaging the spacecraft, so grappling strategies need not be as precise. In all of these cases, an autonomous OOS system can help extend—or save—the operable life of an expensive satellite and, perhaps more importantly, help clear LEO and GEO of larger debris, alleviate overcrowding and help prevent a fatal cascade of collisions.⁴¹ Nevertheless, given the invasive aspects of proposed OOS vehicle activities, it is necessary to review the obligations imposed by international law on the States that authorize their launch and deployment.

III. OOS AND THE LAW

While outer space is not a lawless frontier, activities in space are not strictly supervised or policed. The treaty regime guiding outer space activities is, for the most part, aspirational and founded on three principal themes: (1) a recognition that space

⁴¹ See *On-Orbit Servicing Commercial Opportunities with Security Implications*, *supra* note 37, at 54.

must belong to all humankind; (2) a belief that exploration must occur on the basis of equality; and a (3) prescient understanding that effort should be made to prevent earthly squabbles from tainting the heavens.⁴²

A. THE OUTER SPACE TREATY IMPOSES LIABILITY

1. Article VI—Application: What is Private is National

American attorney Laura Montgomery insists that the Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies⁴³ (Outer Space Treaty) does not govern private, non-governmental space activities.⁴⁴ This stance seems to openly contradict the plain language of the Outer Space Treaty. Article VI makes it clear that all State Parties “bear international responsibility for national activities in outer space . . . whether such activities are carried on by government agencies *or by non-governmental* agencies.”⁴⁵ Moreover, Article VI requires unequivocally that “[t]he activities of non-governmental entities in outer space . . . shall require authorization and continuing supervision by the appropriate State Party to the Treaty.”⁴⁶ Montgomery, in a valiant (albeit misguided) effort to reduce the regulatory burden on commercial space actors, argues that a State may decide what commercial activities to regulate:

If Article VI truly meant that all activities had to be overseen, where would oversight stop? Life is full of activities, from brushing one’s teeth to playing a musical instrument, which take place now without either federal authorization or continuing federal supervision. Just because those activities take place in outer space does not mean they should suddenly require oversight.⁴⁷

⁴² See *Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies*, UNOOSA, <http://www.unoosa.org/oosa/en/ourwork/spacelaw/treaties/introouterspacetreaty.html> [perma.cc/D5T3-ZYBW] (last visited Feb. 8, 2018).

⁴³ *Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies*, Jan. 27, 1967, 610 U.N.T.S. 205 [hereinafter *Outer Space Treaty*].

⁴⁴ See Laura Montgomery, *Testimony of Laura Montgomery Before the Committee on Science, Space, and Technology Subcommittee on Space*, GROUND BASED SPACE MATTERS (Mar. 8, 2017), <http://groundbasedspacematters.com/index.php/2017/03/10/testimony-to-house-space-subcommittee> [perma.cc/MBG4-5TVN].

⁴⁵ *Outer Space Treaty*, *supra* note 43, art. VI (emphasis added).

⁴⁶ *Outer Space Treaty*, *supra* note 43, art. VI.

⁴⁷ Montgomery, *supra* note 44.

Here, Montgomery misses the point. It is in the best interest of each State Party to continue to closely supervise their non-governmental national activities because the international responsibility that the State Party bears in respect to its nationals can be onerous. In short, a State is ultimately liable for the activities of all of its nationals in outer space.

2. *Article VII—Liability*

With OOS vehicles' groundbreaking ability to directly interact with satellites comes a heightened risk of outer space collisions.⁴⁸ This increased risk of accident raises the question: who will be liable for damage? Pursuant to Article VII of the Outer Space Treaty, each State Party "that launches or procures the launching of an object into outer space . . . and from whose territory or facility an object is launched, is internationally liable for damage to another State Party."⁴⁹ Read together with Article VI, this provision makes a State Party liable for damages caused by any and every object it or its nationals launch into space. Moreover, the State Party is liable for objects launched from its facilities or territory, even if the State Party has no other connection with the space object. This broad burden illustrates the weight of the responsibility that State Parties expect each other to shoulder with respect to space activities. If a State Party merely permits its territory to be used for launch, it is culpable for the object launched. Period. So, to counter Montgomery, inquiry into whether Article VI imposes a requirement for State Parties to regulate private activities conducted in space by their nationals is futile. The State Party will be liable, and it is therefore in the best interest of the State Party to properly and responsibly authorize and supervise any private national activity in space.

This conclusion is buttressed by the Convention on International Liability for Damage Caused by Space Objects (Liability Convention), which imposes liability on the "launching State"

⁴⁸ Dave Belcher et al., *United States Legal and Policy Impediments to On-Orbit Satellite Servicing Activities, with Recommended Policies and Legal Implementations*, GEORGE WASH. UNIV., <https://iistp.elliott.gwu.edu/sites/iistp.elliott.gwu.edu/files/Belcher%202014.pdf> [perma.cc/BX3X-P25J] (citing Brian Weeden et al., *International Perspectives on On-Orbit Satellite Servicing and Active Debris Removal and Recommendations for a Sustainable Path Forward*, SECURE WORLD FOUND. (2013) at 4, <https://swfound.org/media/119601/iac-13-e3.4.7-paper.pdf> [perma.cc/5E6L-2GL9]).

⁴⁹ Outer Space Treaty, *supra* note 44, art. VII.

for damage caused by its space objects.⁵⁰ Liability is absolute if damage is done on Earth or to aircraft in flight, but is based on fault if damage occurs elsewhere.⁵¹ The broad definition of “launching State” parallels the Outer Space Treaty in its inclusion of the “State which launches or procures the launching of a space object . . . [and the] State from whose territory or facility a space object is launched.”⁵² While the term “space object” is not defined, extrapolating from the plain language of Article VI of the Outer Space Treaty, it must mean any object that is launched into outer space.

3. Article VIII—Registering

The Outer Space Treaty makes an effort to enforce its liability provisions through the use of registration requirements. Article VIII references a “registry” to be maintained by each State Party and indicates, as a logical antecedent to the burden of liability, that the State “shall retain jurisdiction and control over such object . . . while in outer space.”⁵³ The registration process is further detailed in the Convention on the Registration of Objects Launched into Outer Space (Registration Convention).⁵⁴ The Registration Convention opens with a preamble that reminds States that they “bear international responsibility for their national activities in outer space.”⁵⁵ It is noteworthy that this reiteration uses the term “national activities” rather than simply “its activities,” which emphasizes States’ responsibility for their nationals.⁵⁶

The Registration Convention goes on to implement a mandatory registration system for space objects. A launching State, defined in the same language as the Outer Space Treaty and the Liability Convention, is charged with maintaining its own registry⁵⁷ and furnishing information to the Secretary-General of the United Nations to be used in the United Nations Registry (UN Registry).⁵⁸ One of the goals of the UN Registry is

⁵⁰ Convention on the International Liability for Damage Caused by Space Objects art. II, Mar. 29, 1972, 961 U.N.T.S. 187 [hereinafter Liability Convention].

⁵¹ *Id.* arts. II, III.

⁵² *Id.* art. I(c).

⁵³ Outer Space Treaty, *supra* note 44, art. VIII.

⁵⁴ Convention on the Registration of Objects Launched into Outer Space, Jan. 14, 1975, 1023 U.N.T.S. 15 [hereinafter Registration Convention].

⁵⁵ *Id.* at Preamble.

⁵⁶ *Id.*

⁵⁷ *Id.* art. II.

⁵⁸ *Id.* art. IV.

to facilitate determinations of which State is responsible when a space object causes damage.⁵⁹ The UN Registry also solidifies the sovereignty of a State Party over its own space object. State Party sovereignty is further supported by the UN Agreement on the Rescue of Astronauts, the Return of Astronauts and the Return of Objects Launched into Outer Space,⁶⁰ requiring any space objects “found beyond the territorial limits of the launching authority [to] be returned to or held at the disposal of representatives of the launching authority.”⁶¹ The launching State retains sovereignty over their space objects even if they are reduced to debris.

B. APPLYING THE OUTER SPACE TREATY REGIME TO OOS:
LIABILITY

1. *Situation One: All the Same State*

An OOS vehicle developed either by a State or by a private national that only services spacecraft of that State will not, in providing that service, trigger debate under the Outer Space Treaty or the Liability Convention. In these situations, the OOS vehicle operator and the satellite owner will simply enter into a contractual agreement that covers liability, responsibility, and potential damage either to the spacecraft itself or to third-party spacecraft or property. If both entities are private, the State in question will likely seek authority and supervisory responsibility since that State that will be liable to a second State if the OOS vehicle or spacecraft damages a third-party space object or produces damage on Earth. These situations can be handled through data gathering during the licensing process and a requirement to procure proper levels of insurance.

2. *Situation Two: Different State “From Whose Territory”*

Unfortunately, the above scenarios are easily muddied in practice. The Liability Convention plainly states that a “State from whose territory or facility a space object is launched shall be regarded as a participant in a joint launching” and consequently will be jointly and severally liable for any damage caused.⁶² Consider a scenario where the State from whose terri-

⁵⁹ *See id.* art. VI.

⁶⁰ Agreement on the Rescue of Astronauts, the Return of Astronauts and the Return of Objects Launched into Outer Space, Apr. 22, 1968, 672 U.N.T.S. 119.

⁶¹ *Id.* art. 5(3).

⁶² Liability Convention, *supra* note 50, art. V.

tory a space object is launched is different from the State that procured the launch—not an unusual situation. If the object is properly registered, only one State will be able to claim ownership and authorize interaction with an OOS vehicle. That State would obviously be liable if the object causes third-party damage. However, under the Liability Convention, the State from whose territory the object was launched could also be held accountable, despite not having any ownership or authority over the object.

3. *Situation Three: OOS Vehicle and Satellite Operator from Different States*

Similarly, if the OOS provider and the satellite owner are from different States, the two States remain inexorably involved, even if the provider and owner are both private entities. A private contract between private parties will not protect a State against third-party claims. Thus, one can foresee a scenario where an OOS provider organized in State A services a satellite owned by an entity organized in State B which is registered in State B. Should damage occur on the ground of State C, both State A and State B are jointly and severally liable. However, if the damage occurs to State C's space object in orbit, liability is assigned by fault.

The Liability Convention urges parties to reach settlements through diplomatic negotiations.⁶³ Otherwise, fault will be determined by a Claims Commission.⁶⁴ That being said, the very formation of the Claims Commission is fraught with issues. Namely, the Liability Convention anticipates three members: “one appointed by the claimant State, one appointed by the launching State and the third member, the Chairman, to be chosen by both parties jointly.”⁶⁵ The Convention states that jointly- and severally-liable launching States “shall collectively appoint one member of the Commission” and expressly forbids increasing the size of the Commission to accommodate different interests.⁶⁶ Yet, under these circumstances, it is unlikely that State A's and State B's interests will align. They may feel they have actionable claims against each other pursuant to the Convention. On top of that, imagine the confusion that would ensue if the space

⁶³ Liability Convention, *supra* note 50, art. IX.

⁶⁴ Liability Convention, *supra* note 50, art. XIV.

⁶⁵ Liability Convention, *supra* note 50, art. XV.

⁶⁶ Liability Convention, *supra* note 50, art. XVII.

objects, the OOS vehicle, the satellite being serviced, and the third-party spacecraft damaged during the servicing process were all launched from different State territories, thus bringing in claims against States D, E, and F.

Despite their appearances, these scenarios can be resolved relatively easily. The Liability Convention expressly permits States to enter into bilateral and multilateral agreements addressing issues of liability.⁶⁷ As such, where the satellite operator has either hired or consented to the OOS service, the parties and their governments may address all of these liability issues contractually in advance. Liability provisions in these bilateral and multilateral agreements provide an important framework for dispute resolution that can facilitate the assignment of responsibility.

C. APPLYING THE OUTER STATE TREATY REGIME TO OOS: RESPONSIBILITY

But what happens when there is no such agreement? Pursuant to the Outer Space Treaty and as implemented by the Registration Convention, the State Party “on whose registry an object launched into outer space is carried shall retain jurisdiction and control over such object.”⁶⁸ In other words, only the State of Registry may consent to have a satellite serviced, repaired, re-orbited, or de-orbited. Should OSS vehicles be permitted to approach, salvage, or de-orbit derelict satellites without permission from the State of registry?

As articulated by the UNCOPUOS Remediation Report, space treaties “must, as a matter of necessity, be interpreted and applied in the most useful way in order to achieve optimal results.”⁶⁹ The Outer Space Treaty places a direct responsibility on State Parties to “conduct all their activities in outer space . . . with due regard to the corresponding interests of all other State Parties.”⁷⁰ The Outer Space Treaty goes on to say that the State

⁶⁷ Liability Convention, *supra* note 50, art. XXIII. For an insightful example of States changing the nature of their liability to one another under specific circumstances, see The Agreement Among the Government of Canada, Governments of Member States of the European Space Agency, the Government of Japan, the Government of the Russian Federation, and the Government of the United States of America Concerning Cooperation on the Civil International Space Station, January 29, 1998, T.I.A.S. 12927.

⁶⁸ Outer Space Treaty, *supra* note 43, art. VIII.

⁶⁹ UNCOPUOS Remediation Report, *supra* note 14, at 31.

⁷⁰ Outer Space Treaty, *supra* note 43, art. IX.

Parties “shall pursue studies of outer space . . . and conduct exploration of them so as to avoid their harmful contamination.”⁷¹ While the Outer Space Treaty does not indicate what might be considered “harmful contamination” or what might constitute a lack of “due regard,” it does allow a State Party to “request [a] consultation concerning [any] activity or experiment.”⁷² Inoperable spacecraft are considered a form of contamination, and leaving a derelict spacecraft in LEO or GEO can indicate a lack of “due regard” for the corresponding interests of other States.⁷³ As discussed previously, inoperable satellites like *Envisat* occupy precious orbit space, pose a direct threat to other spacecraft, and contribute to the frightening imminence of Kessler’s prediction of impassable orbital obstruction.

To its credit, ESA is actively pursuing a removal mission recently funded with \$445 million.⁷⁴ While Article IX was not formally invoked before ESA took remedial action, the Article can, and should, be used to provoke remedial action from all spacefaring State Parties. Derelict satellites pose a real issue to all space activity. Moreover, State Parties’ mere abandonment of defunct space objects within the Earth’s orbit “may be deemed faulty, negligent or abusive.”⁷⁵ The State Parties must call upon each other for an Article IX “consultation” to deal with this “harmful contamination” of Earth’s orbit. Each State with an inoperable spacecraft or derelict space object must attend in order to ensure that they are giving “due regard” to the interest of all other State Parties.

IV. ARTICLE IX CONSULTATION ON SPACE DEBRIS

The proposed multiparty Article IX consultation on space debris (the Consultation) would have a multifaceted agenda. There are numerous questions that need to be addressed in relation to all types of space debris. This article focuses on larger

⁷¹ Outer Space Treaty, *supra* note 43, art. IX.

⁷² Outer Space Treaty, *supra* note 43, art. IX.

⁷³ Outer Space Treaty, *supra* note 43, art. IX.

⁷⁴ *E.Deorbit: It is Time to Make Active Debris Removal a Reality for the European Space Sector*, CLEAN SPACE BLOG (Jan. 30, 2017), <http://blogs.esa.int/cleanspace/2017/01/30/e-deorbit-it-is-time-to-make-active-debris-removal-a-reality-for-the-european-space-sector> [perma.cc/3ZH9-DE5M].

⁷⁵ Philip De Man, *The Removal of Inactive Satellites and the Role of the International Telecommunications Union in Space Debris Remediation* 24 (Leuven Centre for Global Governance Studies, Working Paper No. 104, 2013).

debris: the derelict satellites that remain on-orbit and would require an OOS vehicle mission to re-orbit, salvage, or de-orbit.

A. MAKE THE UN REGISTRY RELEVANT

The first issue in need of consideration is the UN Registry. The current terms of the Registration Convention lack both clarity and enforcement. The Consultation should prepare a guide that helps States understand their obligations under the Convention as they have evolved since becoming effective in 1974. For example, the Convention requires that registry information be furnished to the Secretary-General “as soon as practicable.”⁷⁶ Forty years ago, furnishing information may have required laborious copying, collating, and sorting for multiparty distribution. Today, the information and data to be furnished is most likely stored electronically and can be easily manipulated to ensure the transmission of required information only. States should be urged to submit such information within days, if not hours, of a launch. In the meantime, States should be given a period of three months or less to bring their registry entries up-to-date, including confirming the operational status of each of their space objects.⁷⁷

B. IS IT DEBRIS?

The Article IX Consultation should also convene a panel of scientists to designate which disused satellites should be categorized as space debris. Rather than attempt to arrive at a definition, the panel should simply review the status of spacecraft on an *ad hoc* basis. This group can work with the United Nations to “trace uncontrolled and non-functional space objects and/or component parts thereof back to their respective States of registry.”⁷⁸ The International Telecommunication Union (ITU) can also contribute to this process because it maintains a register of radio frequency and orbit assignments.⁷⁹ Furthermore, flexibility must reign. For example, the owner of a “disused satellite

⁷⁶ Registration Convention, *supra* note 54, art. IV.

⁷⁷ See McGill Declaration on Active Space Debris Removal and On-Orbit Satellite Servicing, UNCOPUOUS Remediation Report, *supra* note 14, at Appendix A(8) [hereinafter McGill Declaration].

⁷⁸ UNCOPUOUS Remediation Report, *supra* note 14, at 31.

⁷⁹ See De Man, *supra* note 75, at 11. De Man makes a compelling case that “the binding, detailed and regularly updated regulations of the International Telecommunication Union . . . may be applied to assist in the international space debris mitigation and remediation effort.” *Id.* at 4.

whose sole purpose is to occupy a commercially advantageous orbital position lest it be freed up to other users”⁸⁰ may be granted assurance by the ITU that the position, or a comparable position, will nevertheless be reserved.

Once this list is complete, it should be disseminated to all States who have furnished information to the UN Registry for review and further action. At this point, States will have the opportunity to share with the Consultation their views on objects that have been classified as space debris. Final status determination should then be reached by consensus. Additionally, objects that are classified as space debris should be assigned a scaled value to indicate the level of urgency with respect to their removal.

If any space object deemed derelict by the panel is *not* included in the UN Registry, a State should have a reasonable window of time to claim the object, including any objects that might be component parts of larger objects. Once the reasonable time has expired, unclaimed space objects should be considered property of the launching State(s). If the launching State is indeterminate and no State accepts responsibility, the object should be immediately listed as a target for salvage or de-orbit by the panel, and any State that might have had responsibility or authority over the object will be deemed to have consented to its removal.

C. REMOVAL PLAN

The State of registry for an object classified as space debris by the Consultation should have the opportunity to propose a reasonable removal plan. Since OOS vehicle technology remains in test phases, State Parties should be encouraged to work together and share relevant research in order to expedite progress. Ideally, States will jointly fund a venture to develop an OOS vehicle that can perform multiple or repeated services, rather than single-mission removals. Reusable OOS vehicles would also be integral tools for debris mitigation. They would be able to refuel and re-orbit spacecraft as well as diagnose, and even repair, failures, thus extending the lives of what would otherwise become more space debris.

Nevertheless, States may be unwilling or unable to contribute financially to removal efforts. Even in such cases, the State of registry must remain primarily liable. However, it has been sug-

⁸⁰ De Man, *supra* note 75, at 21.

gested that a Global Economic Fund for Space Debris Removal be created to cover the cost of such situations.⁸¹ That fund should be created by the Consultation in order to assure that space debris posing the greatest risk will be removed regardless of the responsible party's financial or technological resources. The liable party should be given a loan by this fund to finance the removal, which should be repaid upon reasonable terms. The fund and loan structure would only need to cover objects currently on-orbit and would have the potential to be phased out if national debris mitigation laws are promulgated (as recommended in Section F below).

D. LIABILITIES

Spacecraft owners must be incentivized to remove their derelict space objects from orbit. As such, the Consultation must include an agreement stipulating that States that fail to remove or consent to the removal of an object classified as space debris will be held absolutely liable for any damage the object, or component part thereof, causes to any functioning spacecraft in orbit. Similarly, in order to promote OOS activities, OOS vehicles engaged in the process of repair or removal should be liable only for damages resulting from gross negligence or intentional behavior.

E. NATIONAL SECURITY ISSUES

One of the biggest stumbling blocks for the proliferation of OOS services is the undeniable dual-use potential. Due to OOS technology's "significant strategic and military applications," it may raise some national security concerns. The Consultation can do three things to alleviate national security concerns. First, the *ad hoc* nature of the proceedings permits a State to assert ownership and responsibility for a space object. Participation in the Consultation essentially assures that no other State may approach a registered space object without consent. Second, even if a spacecraft is classified as space debris, the State of registry is still responsible for its removal. Again, no other State may interfere with the object without the State of registry's consent. Finally, the Consultation should set out guidelines that ensure the debris removal process is organized and well planned. Any OOS vehicle that enters orbit must faithfully maintain complete openness and transparency regarding its mission. The OOS vehicle

⁸¹ McGill Declaration, *supra* note 77, at Appendix A(10).

should register its orbital plans with the Consultation both to assure that the Consultation removal goals are being met and to ensure that other States are aware of its proposed undertaking well in advance. The risk that an OOS vehicle may have the capability and opportunity to destroy or disable what may be considered a dangerous weapon is simply an unavoidable reality. With this in mind, it is in the best interest of all States that OOS vehicles are developed on a multilateral basis so that deployment decisions involve the interests of as many diverse States as possible.

F. NATIONAL MITIGATION LEGISLATION

As part of the Consultation, States must agree to implement their own national laws—based on model laws promulgated by the Consultation—that will mitigate the production of space debris in the future. Chief among these would be a requirement that any space object, regardless of size, may only be permitted to launch if it has implemented a government-approved end-of-life plan or assured removal clause.⁸² Under such a clause,

the operator shall be required to demonstrate either that the systems have the capability (and plans) to perform a safe controlled re-entry (or transfer to graveyard orbits) at the end of the mission or that the operator has contracted a commercial removal service to carry out the said removal operation at the end of the mission.⁸³

The Space Debris Mitigation Guidelines of the Committee on the Peaceful Uses of Outer Space provide an adequate starting point.⁸⁴ However, given recent technological advancements, the Consultation should also consider whether all spacecraft should include a self-repair or self-diagnosing mechanism. For example, researchers at the U.S. Naval Academy have developed a diagnostic and repair robot that could be embedded in and launch with a conventional host satellite. The RSat, as it is called, is a cube satellite “fitted with arms and manipulators allowing it to locomote around its client spacecraft and perform simple diagnostic acts.”⁸⁵ Once on-orbit, the RSat can move around the host spacecraft. The RSat “remain[s] dormant with

⁸² See McGill Declaration, *supra* note 77, at 45.

⁸³ McGill Declaration, *supra* note 77, at 44–45.

⁸⁴ Comm. on the Peaceful Uses of Outer Space, Space Debris Mitigation Guidelines, U.N. Doc A/AC.105/C.1/C.260 (2010).

⁸⁵ Hanlon et al., *supra* note 17, at 4.

negligible impact to standard satellite operations” if no malfunction is detected.⁸⁶ The device can then “provide diagnostic information in a matter of days” in the event that a malfunction does occur.⁸⁷ Ultimately, the RSat (or a similar robot) should be able to repair the most predictable malfunctions on the host satellite. Not only will this maximize the operational lifespan of the spacecraft, it will preserve the satellite owner’s financial and experiential investment. Moreover, as it is self-repairing, no liability issues arise. Current estimates suggest that an RSat can be constructed for approximately \$25,000.⁸⁸ This sum is a relatively small price to pay to prevent inoperability and to help ensure satellite longevity, thereby lengthening the amount of time before deploying replacement spacecraft into a crowded orbit is necessary.

G. FAILURE TO COMPLY

A perennial issue with the international law of outer space is its lack of enforcement mechanisms. This deficiency is compounded by the fact that outer space is physically far-removed from our daily conscience. Though we all rely on space to communicate with our friends and family, steer agricultural decisions that will help alleviate hunger, guide the tools of our maritime trade, and assist in the prediction and remediation of natural disasters, among other integral functions, it is difficult for us to truly conceptualize the scope of the dangers posed by space debris. Certainly politicians with limited governmental funds will find themselves hard-pressed to convince constituencies dealing with poverty and crime that cleaning up outer space is an urgent priority.

Since we cannot rely upon governments to implement unpopular decisions, different incentives must be implemented. One possible solution would be to categorize the failure of a State to partake in the Consultation or its subsequent failure to either remove its own debris or consent to the removal thereof as a factor taken into consideration during the ITU radiofrequency allocation process.⁸⁹ After all, a State that refuses to release an

⁸⁶ Hanlon et al., *supra* note 17, at 4.

⁸⁷ Hanlon et al., *supra* note 17, at 3.

⁸⁸ Hanlon et al., *supra* note 17, at 2.

⁸⁹ For a review of the allotment process, see Ram S. Jakhu, *Regulatory Process for Communications Satellite Frequency Allocations*, in HANDBOOK OF SATELLITE APPLICATIONS 271 (J.N. Pelton et al. eds., 2013).

orbit occupied by an inoperable spacecraft should not be freely obtaining more orbits and frequencies.

V. CONCLUSION

Humanity has advanced greatly in space since the United States launched its "Grapefruit" into orbit nearly sixty years ago. One can only wonder what the architects of our space exploration revolution would think of a world that coordinates launches around space traffic concerns and an orbit in which no spacecraft is safe. They would probably admonish us today for not heeding our early promises, made in the Outer Space Treaty, to avoid "harmful contamination."⁹⁰ Clogging the orbit puts astronauts, our "envoys of mankind in outer space,"⁹¹ and hundreds of millions of dollars of equipment, which cost another hundreds of millions of dollars to launch, at risk on a regular basis. Given this reality, it hardly feels like we are succeeding in ensuring "free access to all."⁹²

States have an obligation, solidified in the Outer Space Treaty, to each other to rid our orbit of these harmful contaminants and repair, salvage, or de-orbit defunct space objects. Commencing a consultation under the auspices of Article IX is an activity that should be embraced by all space actors, both commercial and governmental. It will encourage the development of vital OOS services. These services will not only alleviate the current congestion in orbit, but will also be platforms that can provide investment-saving mission-extension and repair functions. Working through the consulting group structure, transparency and confidence-building measures can be optimized by requiring full records and proposed plans for distinct, and hopefully multilaterally funded, OOS vehicles. State parties must be incentivized to participate by tweaking the liability regime and also by utilizing the ITU processes.

Even as we act to alleviate current conditions, we must also act to assure they do not recur. Government authorities must require, at a national level, that no launches are authorized unless proper end-of-life measures have been approved. As a species, we are just beginning to figure out how to exploit and explore space. We owe it to ourselves and to our future to make sure that we do not impede our own access.

⁹⁰ Outer Space Treaty, *supra* note 43, art. IX.

⁹¹ Outer Space Treaty, *supra* note 43, art. V.

⁹² Outer Space Treaty, *supra* note 43, art. I.