INCENTIVES FOR KEEPING SPACE CLEAN: ORBITAL DEBRIS AND MITIGATION WAIVERS

*By Stephen J. Garber**

While many authors have written about the safety, technical, policy, and even legal aspects of orbital debris, certain key aspects remain largely unexplored. Strong economic incentives to mitigate (prevent) and remediate (clean up) debris do not currently exist. Although the U.S. has stringent technical mitigation guidelines, data on NASA and military (the two government launching organizations) waivers to these guidelines are generally not publicly available. In addition, there is no executive branch authority outside of NASA and the military for granting waivers to them. Some options for an improved waiver review process and for new economic incentives to deal with debris are thus presented. Ultimately, more attention should be paid to mitigation before domestic policymakers can deal with the equally important and more complex remediation issues, and then tackle both prevention and cleanup of debris internationally.

I. BACKGROUND AND CONTEXT

A. Introduction

This essay begins with the framing of the orbital debris issue, explaining that it is a form of pollution that potentially can harm people or property on orbit or even on the ground. It then describes

* NASA History Division, Washington, DC. This article is written in his personal capacity and the views expressed do not represent the views of NASA or the U.S. Government. Quite a number of people assisted me in various ways with this article. Special thanks go to Bill Barry, Jay Finch, Pete Hays, Dana Johnson, Josef Koller, Darren McKnight, Steve Mirmina, Scott Pace, Audrey Schaffer, Brian Weeden, and several others. My sincere thanks to all of these space professionals, as well as a number of family and friends for their patience serving as sounding boards. As is usually the case, any errors are my responsibility.

the extent of the problem and some recent notable events before going on to lay out the relevant domestic and international guidelines to minimize future debris.

In the second section, I argue that the Secretary of Defense and NASA Administrator's authority to permit the launches of military and civilian spacecraft that do not comply with domestic debris prevention guidelines presents a potential or perceived conflict of interest. Fortunately, the military and NASA have taken seriously these responsibilities. I also argue that adequate financial incentives do not exist for government and especially commercial space operators to clean up existing debris.

Section three argues for making waiver data more publicly available and outlines some potential approaches to alleviate the perceived conflict of interest for the NASA Administrator and Secretary of Defense, possible financial incentive structures for reducing debris, and some ways to encourage more international cooperation on debris, an inherently global issue.

I conclude by arguing that while the domestic standards for preventing orbital debris are very sound, the U.S. Government could do more to deal with debris by proactively publicly sharing data on adherence to domestic debris standards and by altering its administrative processes in this regard. Some creative solutions may also be in order to create financial incentives to develop the technologies that will be needed to clean up existing debris. Overall, a more comprehensive domestic and international approach to prevent future debris (i.e. mitigation) and clean up existing debris (i.e. remediation) is needed.

B. Nature of the problem

Orbital debris is a vexing problem that has the potential to disrupt spacecraft operations; destroy expensive and critical national security spacecraft; and cause damage to property and people on the ground. Low Earth Orbit (LEO) is the most congested orbital regime and both small and large pieces of debris are problematic there.

In a lay (non-legal) sense, orbital debris may be considered a "tragedy of the commons."[1] Some specialists contend that debris is more accurately categorized economically as a "common pool resource" (CPR) issue.[2] Since it is basically pollution in space, perhaps debris is best characterized as a negative economic externality, in which all users of space potentially suffer from the actions of polluters.

There are definite financial and other costs to mitigating (preventing) future orbital debris and there is little incentive for space operators to pay those costs when the risk of being harmed by debris is relatively low.[3] Concern over debris has risen in recent years but has not reached a "critical mass" prompting a paradigmatic shift in action yet.

While physically removing debris (remediation) from LEO may seem intuitively attractive, it is currently considerably more challenging than mitigation because relevant proven technologies

---

1 *See* Garrett Hardin, *The Tragedy of the Commons*, Science, Dec. 13, 1968, at 1243-1248. (term was popularized by this article); *See also W. F. Lloyd, Two Lectures on the Checks to Population (*Oxford Univ. Press, 1833)*(Hardin's concept adapted from this article), reprinted (in part) in Garrett Hardin, Population, Evolution, and Birth Control (Freeman, 1964); See also Jared B. Taylor, Tragedy of the Space Commons: A Market Mechanism Solution to the Space Debris Problem,* 50 COLUM. J. TRANSNAT'L L. 253*, 254-279 (2011); Scott J. Shackelford, Governing the Final Frontier: A Polycentric Approach to Managing Space Weaponization and Debris,* 51 AM. BUS. L. J.*, 435 (2014) (explicitly using this terminology when referring to orbital debris).*

2 Henry Hertzfeld, Brian Weeden, and Christopher Johnson, *How Simple Terms Mislead Us: The Pitfalls of Thinking about Outer Space as a Commons*, Int'l Astronautical Congress paper (IAC-15-e7.5.2 x 29369); Brian Weeden and Tiffany Chow, *Taking a Common-Pool Resources Approach to Space Sustainability: A Framework and Potential Policies*, 28 SPACE POLICY 166, 167-172 (2012). Both papers draw on the Nobel Prize-winning economic work of Elinor Ostrom. *Shackelford's Governing the Final Frontier article also adds a layer of international relations theory by categorizing the situation as a "prisoner's dilemma," in which multiple actors would benefit by cooperating but aren't able to communicate and thus everybody loses; See p. 443, where he cites Elinor Ostrom A Polycentric Approach to Coping with Climate Change (World Bank Policy Research Working Paper No. 5095, 2009),* http://www19.iadb.org/intal/intalcdi/pe/2009/04268.pdf.

3 Taylor notes that the "current legal regime fails to solve the tragedy of the space commons" issue (p. 264). Citing Jonathan Baert Wiener, *Global Environmental Regulation: Instrument Choice in Legal Context*, 108 YALE L.J. 714 (1999), and Jon Hanson and Kyle Logue, *The Costs of Cigarettes: The Economic Case for Ex Post Incentive-Based Regulation* 107 YALE L.J. 1174 (1998), Taylor also states that the "incentive-based market mechanisms … are preferable to conduct-based regulatory strategies… on cost-efficiency grounds" (p. 275). This subject of incentives and regulatory mechanisms with respect to orbital debris is addressed further later in this paper.

do not exist yet, and because of political, legal, diplomatic, and national security issues. Engineers need to develop, test, and deploy one or more technologies to clean up the debris; and since there are no "off-the-shelf" products, this will take time and be expensive. There are complex legal liability issues associated with remediating another operator's property and it is not always possible even to identify the source and thus ownership of objects in space. Moreover, there are significant dual-use issues associated with "rendezvous and proximity operations" because if an operator has the technical capability to move a piece of debris, this technology also could be utilized for military purposes in space.

Technical experts generally agree that working now to prevent creating future debris is more cost-effective, but there are also significant policy hurdles surrounding mitigation. Currently there are a variety of national and international mitigation standards and guidelines for government and commercial launches, although they are all based on certain key principles. Many U.S. launches need waivers from the relatively strict U.S. standard practices, often because of legacy launch vehicles, which would be expensive to retrofit to be compliant or because the launching organization effectively would need to purchase excess capability to ensure proper post-mission disposal.

In addition to the technical and financial challenges, there are policy inconsistencies, both domestically and internationally, as described below. It is likely that a coordinated, collaborative, and comprehensive interagency ("whole of government") and international approach will be necessary to arrive at appropriate diplomatic, technical, and legal remedies. In general, the United States is considered a world leader in developing and implementing appropriate space policies and has taken the lead in analyzing the debris issue technically. As a leader, the United States could do more to improve the procedures to ensure compliance with domestic mitigation guidelines. Due to the inherent nature of orbital debris, any "solution" likely will include a significant international component.

C. Scope of the problem and a recap of some recent troubling events

Two events in the last decade, one deliberate and one accidental, significantly increased the amount of debris in LEO and concomitantly, the public awareness of this issue. In January 2007, the Chinese Government conducted an antisatellite (ASAT) test that destroyed their own FengYun 1C satellite and created more than 3,400 pieces of debris. Secondly, in February 2009, the Iridium-33 satellite accidentally collided with the inoperative Cosmos 2251 satellite, creating more than 1,600 pieces of debris.[4]

Graphs from the National Aeronautics and Space Administration (NASA) Johnson Space Center's Orbital Debris Program Office (ODPO) show the total number of objects in space (the vast majority of which are not operational spacecraft) sharply spiked after the 2007 and 2009 incidents. In general, the total keeps climbing. In 2014, the total number of objects 10 cm and bigger dipped slightly because of high solar activity (which increases atmospheric drag on objects in LEO, causing more of them to reenter the atmosphere and burn up). Still, the total mass of space debris continued to increase.[5]

One simple way to characterize the issue is to differentiate between large and small debris. There are more than 500,000 small objects (5 mm to 1 cm) and fewer very large (up to about 9 tons) objects. One prominent expert has estimated that 99 percent of the total debris mass in LEO is from pieces 10 cm or larger.[6] Together the United States and Russia account for over 85 percent of the mass in LEO, while 900 of 1,100 tons of rocket bodies in LEO and

---

[4] *See*, Phillip Anz-Meador, *Top Ten Satellite Breakups Reevaluated*, Orbital Debris Quarterly News, January/April 2016, at 5, 6; Nicholas L. Johnson, *Orbital Debris: The Growing Threat to Space Operations*, (AAS 10-011) 137 Guidance and Control: Advances in the Astronautical Sciences 5, (2010).

[5] *See*, J.C. Liou, *USA Space Debris Environment, Operations, and Measurement Updates* presentation to 52nd session of the Scientific and Technical Subcommittee of the Committee on the Peaceful Uses of Outer Space, United Nations, Feb. 2 – 13, 2015, pp. 3-4 (http://www.unoosa.org/pdf/pres/stsc2015/tech-28E.pdf). Regarding the number of operational satellites, one specialist recently estimated that there over 500 operational satellites in LEO, approximately 80 in Medium Earth Orbit (MEO), and approximately 400 in geostationary orbit (GEO). Of these, approximately 180 are classified U.S. satellites; *See* Joshua Tallis, *Remediating Space Debris: Legal and Technical Barrier*, Strategic Studies Quarterly 86, 94 (2015). More recently, p. 8 of the Satellite Industry Association's (June) 2016 State of the Satellite Industry Report (available at http://www.sia.org/wp-content/uploads/2016/06/SSIR16-Pdf-Copy-for-Website-Compressed.pdf.).

[6] J.C. Liou, *An Active Debris Removal Parametric Study for LEO Environment Remediation*, 47 ADVANCES IN SPACE RESEARCH 1866, 1867 (2011).

the vast majority of the number of debris pieces are Russian.[7] Current collision probability is based on the number of objects in orbit while future collision probability is driven by mass in orbit.[8]

For several years, technical experts have believed that cleaning up about five large objects per year, along with vigorously implementing existing mitigation standards, would stabilize the LEO environment, while removing more than five objects per year would improve the environment by decreasing the risk of a cascade effect. This model assumes that future launch rates could be extrapolated from the rates of 2002-2010 and that active debris remediation (ADR) would begin in 2020.[9]

Similarly, the notable 2011 "Catcher's Mitt" study[10] supported NASA's suggestion that annually removing 5-10 large objects in LEO, combined with improved adherence to the U.S. mitigation guidelines (see below), would significantly stabilize that region. Ultimately, the "key issue then is the stabilization or reduction of the population of medium debris" through ADR. Its authors called for the near-term remediation of large objects in LEO and geostationary orbit (GEO) as the only practical way to stabilize those space environments.[11]

D. Domestic Guidelines

Domestically, the primary guidance governing orbital debris for U.S. Government spacecraft and launches is the U.S. Government Orbital Debris Mitigation Standard Practices (USG ODMSP)

---

[7] Al Anzaldua and Dave Dunlap, *Overcoming Non-Technical Challenges to Cleaning up Orbital Debris*, The Space Review, November 9, 2015, http://www.thespacereview.com/article/2863/1. Presumably a high number of small (low mass) pieces of debris in LEO are attributable to China.

[8] Thanks to Darren McKnight for pointing this out.

[9] J. C. Liou, *The Top Ten Questions for Active Debris Removal* presentation at the European Workshop on Active Debris Removal, Paris, June 22, 2010, (http://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20100025507.pdf), p. 23. A cascade effect, in which an on-orbit collision would create more pieces of debris, which in turn would create more collisions, is commonly known as the Kessler effect (after Donald Kessler, an early pioneer in the orbital debris field). Passive, rather than active, debris remediation is also a possibility, although not often discussed. Thanks to Darren McKnight for making this last point.

[10] Wade Pulliam, *Catcher's Mitt Final Report* Tactical Technology Office, Defense Advanced Research Projects Agency, May 2011, http://www.dtic.mil/dtic/tr/fulltext/u2/1016641.pdf.

[11] *Id*. at 3.

document from February 2001. The USG ODMSP have figuratively and literally set the standards for international debris mitigation guidelines, in that other orbital debris guidelines and standards have followed and been based on this approach. These mitigation guidelines cover four primary areas: controlling release of debris during normal operations (no debris larger than 5 mm should remain in orbit for more than 25 years); minimizing accidental explosions (through passivation of stored energy); avoiding collisions (by using a safe flight profile); and ensuring safe post-mission disposal (through atmospheric reentry, maneuvering to a higher "graveyard orbit" or direct retrieval).[12]

For NASA launch vehicles and spacecraft, NASA Technical Standard 8719.14 currently is the governing document for debris. This Technical Standard was first enacted in 2007, when it superseded an older NASA Safety Standard on orbital debris (upon which the USG ODMSP were based), and was updated most recently in 2011.[13] It is similar to the USG ODMSP, although more stringent in certain areas. For example, NASA-STD 8719.14 calls for limiting the size, number, and lifetime of both small (defined as larger than 1 mm) and large (greater than 10 cm) debris while the USG ODMSP refers only to debris larger than 5 mm.[14]

For military spacecraft and launch vehicles, Department of Defense (DoD) Instruction 3100.12 (Space Support) includes a section on orbital debris that basically mirrors the USG ODMSP.[15] While over 15 years old (dating back to September 2000), this DoD Instruction is still in force and scheduled to be updated at some point in the future. The relevant DoD directive simply refers to the

---

[12] The USG ODMSP are available from http://www.orbitaldebris.jsc.nasa.gov/library/USG_OD_Standard_Practices.pdf online.

[13] NASA Safety Standard (NSS) 1740.14, Guidelines and Assessment Procedures of Limiting Orbital Debris, was released in Aug. 1995. The foreword of the NASA STD notes that it is consistent with the USG ODMSP and other relevant national and international documents such as the IADC and UN guidelines (see below in this paper).

[14] This is available from https://standards.nasa.gov/standard/nasa/nasa-std-871914 online. *See* p. 19, 31, and 37 for these details. In February 2017, a revised NASA Procedural Requirement (NPR) for Limiting Orbital Debris was issued (available from https://nodis3.gsfc.nasa.gov/npg_img/N_PR_8715_006B_/N_PR_8715_006B_.pdf).

[15] DoD Instruction 3100.12 dates from Sept. 14, 2000 and is available from http://www.esd.whs.mil/Portals/54/Documents/DD/issuances/dodi/310012p.pdf online.

USG ODMSP in stating that DoD "will promote the responsible, peaceful, and safe use of space."[16]

E. International Guidelines

Internationally, the Inter-Agency Space Debris Coordination Committee (IADC) was established in 1993. The IADC currently has 13 space agency members: Italy, France, China, Canada, Germany, India, Japan, South Korea, the United States, Russia, Ukraine, the United Kingdom, and the European Space Agency (ESA). Following the adoption of the USG ODMSP in 2001, the IADC adopted the first international set of guidelines in 2002.[17]

In December 2007, the United Nations General Assembly endorsed the mitigation guidelines crafted by the UN Committee on the Peaceful Uses of Outer Space (COPUOS)'s Scientific and Technical Subcommittee. The UN guidelines build upon the IADC guidelines but are organized slightly differently and have some subtle, technical differences. Unlike the USG ODMSP or the IADC guidelines, the UN guidelines do not specify the 25-year time limit for post-mission disposal nor do they specify numerical parameters for appropriate graveyard orbits.[18] Overall, IADC and UN guidelines were designed to help individual nations craft their own mitigation standards and hence these guidelines are not legally binding.

In addition to the United States, four other spacefaring countries have adopted national mitigation guidelines. Japan did so in 1996, France in 1999, and Russia in 2000. In a high irony, the Chinese adopted mitigation guidelines in 2006 before ignoring them with their January 2007 destructive antisatellite test, which in turn led to the cancellation of the spring 2007 IADC meeting in Beijing. Some spacefaring nations and organizations do not yet have

---

[16] DoD Directive 3100.10 for Space Policy, Oct. 18, 2012, available from http://www.defenseinnovationmarketplace.mil/resources/DoD3100-10_dtd12Oct2012.pdf online.

[17] *See* http://www.iadc-online.org/ online. NASA leads the U.S. Government delegation to the IADC. The IADC Space Debris Mitigation Guidelines are available from http://www.spacelaw.olemiss.edu/library/space/IntOrg/IADC/IADC-%2002-01%20-%20IADC%20Space%20Debris%20Mitigation%20Guidelines.pdf and other sources online.

[18] The UN Mitigation Guidelines are available from http://www.iadc-online.org/index.cgi?item=documents online.

orbital debris standards that are consistent with the UN and IADC guidelines.[19]

II. ADMINISTRATIVE ISSUES

A. Mitigation Waiver Issues

The NASA Administrator and Secretary of Defense are responsible, per the 2010 National Space Policy,[20] for granting waivers to upcoming launches from their own organizations that are expected not to comply with their agencies' standards or the USG ODMSP. While this arrangement is not necessarily a conflict of interest, it does raise the perception of a potential conflict of interest, an issue that seldom has been discussed publicly.

This is not to say that either NASA or DoD is self-serving in granting itself waivers. Both organizations have established processes to consider various extenuating factors that reflect common sense. NASA's Tropical Rainfall Measurement Mission (TRMM), for example, was extended because it could help provide tracking data about hurricanes that likely would save more lives than would be endangered by debris from the spacecraft's uncontrolled reentry.[21] Nevertheless, having an organization grant itself waivers to rules is an inherent structural administrative issue.

Both NASA and DoD incorporate the concept of independent technical authority. NASA's governance model separates program-

---

[19] Preface, *Space Debris Mitigation Guidelines of the Committee on the Peaceful Uses of Outer Space*, quoted in Nicholas Johnson, *Current Issues in Orbital Debris*, First Canadian Workshop on Orbital Debris, St.-Hubert, Quebec, Canada, June 21-22, 2011, (http://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20110012005.pdf), p. 3; Nicholas Johnson, "Space Debris Mitigation Guidelines" presentation at the Symposium on Small Satellite Programmes for Sustainable Development, Graz, Austria, Sept. 13-16, 2011 (http://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20110014989.pdf); China's national industry standard was developed in 2005 and put into effect in 2006 – its content apparently is similar to the UN and IADC orbital debris guidelines; (See Zizheng Gong, *CASC [China Aerospace Science and Technology Corporation] Efforts on Dealing with Space Debris toward Space Long Term Sustainability*, presentation to COPUOS Scientific and Technical Committee, Vienna, Feb. 11-22, 2013, (http://www.unoosa.org/pdf/pres/stsc2013/2013lts-03E.pdf), pp. 24 – 26).

[20] National Space Policy, June 28, 2010, (http://history.nasa.gov/national_space_policy_6-28-10.pdf) p. 8.

[21] *See* http://www.nasa.gov/content/goddard/the-trmm-rainfall-mission-comes-to-an-end-after-17-years.

matic and technical authority. This means that the Associate Administrator for Safety and Mission Assurance is given an independent voice on programmatic safety issues, rather than, for example, giving the Associate Administrator for the Science Mission Directorate the sole ability to make final decisions about the safety of robotic spacecraft. After the *Columbia* Space Shuttle accident in 2003, NASA officials implemented formal Independent Technical Authority. Previously, NASA personnel had been looking at the Navy's SUBSAFE program in 2002 and other NASA-DoD "benchmarking" efforts based on this concept in the Navy had been done even earlier.[22]

By the time a spacecraft is almost ready for launch, however, it is by definition much too late to change its construction or reconfigure it for an alternate launch vehicle that might produce less debris. Such factors need to be considered when spacecraft are being designed, not prepared for launch. It would be rather expensive to redesign a spacecraft or even potentially to provide it with additional fuel to maneuver for post-mission disposal. Thus in many cases, the Secretary of Defense and NASA Administrator effectively have had little choice but to approve exceptions to the rules, especially when critical national security spacecraft are involved (which includes virtually all DoD missions).

Calendar year 2017 appears to be the first year in which the Air Force did not request any waivers from the Secretary of Defense. This notable achievement may be due to the fact that for several years, the Secretary of Defense has directed the Air Force to reach compliance by including the USG ODMSP requirements into future space launch acquisitions strategies and contracts.[23]

NASA and DoD compliance rate data (i.e.: how many waivers are granted to the USG ODMSP per year) typically are not widely

---

[22] *See*, NASA, Office of the Chief Engineer, "Technical Authorities," http://www.nasa.gov/offices/oce/functions/tech_auth.html; Columbia *Accident Investigation Board Report*, volume 1 (August 2003), p. 227; Rear Admiral Paul E. Sullivan, testimony before the House Science Committee on the SUBSAFE Program, in *NASA's Organizational and Management Challenges in the Wake of the Columbia Disaster*, Hearing before U.S. House of Representatives Science Committee (Oct. 29, 2003).

[23] *See* Robert Work, Memorandum for Secretary of the Air Force regarding Compliance with U.S. Orbital Debris Mitigation Standard Practices (ODMSP) (Feb. 6, 2017) (on file with author.

available (they are unclassified, however). In terms of reporting requirements, the 2010 National Space Policy calls for the Secretary of Defense and NASA Administrator to notify the Secretary of State of their waivers. Typically, however, the State Department does not forward this information to any international bodies such as the UN COPOUS or the IADC, or even compile the data in a systematic way. Sharing this domestic compliance data internationally would bolster the U.S. Government's deserved reputation as an international leader in debris mitigation and encourage other nations such as China and Russia to collect such data and report them internationally.[24]

Additionally, there are some, albeit more minor, gaps and inconsistencies in regulatory coverage of commercial satellites that are launched domestically. The Federal Aviation Administration (FAA) regulates launch vehicles, while the Federal Communications Commission (FCC) and the National Oceanic and Atmospheric Administration (NOAA) regulate communications and remote sensing spacecraft, respectively. The FAA currently holds commercial launch operators only to the first three sections of the USG ODMSP and not the fourth section on post-mission disposal of launch vehicles. As part of their licensing processes, NOAA and the FCC include stipulations about post-mission disposal of spacecraft in conjunction with the USG ODMSP.[25] Unfortunately, there is no significant enforcement mechanism short of the government not granting a license (it is not clear whether this has ever occurred) so there is little to no overt incentive to comply with the regulations.

The FCC has regulatory authority over commercial spacecraft because even if a spacecraft is not designed for a telecommunications mission *per se*, ground operators usually still need to communicate with the spacecraft. Thus, the FCC typically regulates the

---

[24] *See*, the National Space Policy, June 28, 2010, http://history.nasa.gov/national_space_policy_6-28-10.pdf p. 8 (p. 12 of the pdf) for the notification language. In the context of orbital debris, page 2 (p. 6 of the pdf version) of this National Space Policy notes that "As the leading space-faring nation, the United States is committed to addressing these challenges."

[25] See NOAA, "About the Licensing of Private Remote Sensing Space Systems," http://www.nesdis.noaa.gov/CRSRA/licenseHome.html and *Disclosure of Orbital Debris Mitigation Plans, Including Amendment of Pending Applications*, Oct. 13, 2005, http://hraunfoss.fcc.gov/edocs_public/attachmatch/DA-05-2698A1.pdf.

use of that portion of the electromagnetic spectrum if it is communicating with a ground station within the United States, whether or not the spacecraft is a domestic or foreign one. However, a potential policy gap exists in cases involving spacecraft that are not directly controlled from the ground such as the experimental Polar Orbiting Passive Atmospheric Calibration Sphere (POPACS) spacecraft, which lacks maneuverability to avoid collisions.[26]

B. Remediation Issues – Who is Leading?

While the 2010 National Space Policy calls for NASA and DoD to research and develop ADR technologies and techniques, thus far this has been, figuratively speaking, an "unfunded mandate" and so very little work has been done.[27] In recent years, the Naval Research Laboratory (NRL) funded three ADR technology demonstration projects as Small Business Innovative Research (SBIR) efforts and has also cosponsored a small ADR effort with NASA. The Air Force Research Laboratory has sponsored another ADR project with SBIR funding. Researchers at NASA's Ames Research Center have also developed a ground-based technology concept for orbital ADR that is being staffed minimally. All of these efforts involve relatively small amounts of funding (approximately $3 million or less total for each project) and are for cutting-edge concepts that are low

---

[26] Regarding the FCC's rules on mitigation of orbital debris; *See* https://apps.fcc.gov/edocs_public/attachmatch/FCC-04-130A1.pdf and K. Kensinger, S. Duall & S. Persaud, *The United States Federal Communications Commission's Regulations Concerning Mitigation of Orbital Debris*, Proceedings of the 4th European Conference on Space Debris, April 18-20, 2005 (ESA Publication SP-587, Aug. 2005). For more information about POPACS, see, for example, Jeff Foust, *CubeSats Get Big*, Sept. 10, 2012 at http://www.thespacereview.com/article/2155/1 online.

[27] See *National Space Policy of the United States of America*, June 10, 2010, http://history.nasa.gov/national_space_policy_6-28-10.pdf, p. 7.

in terms of their Technology Readiness Levels.[28] As the NASA Administrator conceded in 2015, "Not a lot of countries are putting money into debris removal development and more of us need to."[29]

Should we look to the private sector or international actors to conduct ADR research? The European Space Agency (ESA) is moving forward with a mission called e.deorbit, which would use either a robotic arm or a net to capture an old ESA spacecraft in LEO and safely destroy it through a controlled atmospheric reentry.[30] The Swiss Clean Space One ADR effort has gained some attention, although its technical ambitions are somewhat modest and its budget is relatively small.[31]

The United States is rightly viewed as a leader in dealing with orbital debris because domestic technical experts developed the mitigation standards that are used internationally but little has been done domestically on remediation. For various political and economic reasons, it is unlikely that China or Russia, the other two main contributors to the debris problem, will provide much leadership in developing remediation technologies.[32] Because of the nature of this economic externality problem, it is unrealistic to expect private companies to invest significantly in ADR research without government support. On the other hand, one commercial space company manager recently said that the IADC guidelines are actually too lenient and that his company is voluntarily planning to add ex-

---

[28] The NRL ADR efforts are Elimination of Space Debris Through Induced Drag Enhancement, Tether Electrodynamics Propulsion CubeSat Experiment (TEPCE), and Enabling Technologies for an Electrodynamic Service Vehicle. The joint NRL/NASA ADR project is Navigation for Electrodynamic Delivery Express (EDDE) and the AFRLL ADR effort is the Orbital Debris Remover (ORDER) + Satellite on Umbilical Line (SOUL) concept. NASA Ames' ADR effort is called Project Lightforce.

[29] Michael Casey, *NASA Chief: Time to clean up all that space junk*, Fox News, Nov. 14, 2015, http://www.foxnews.com/science/2015/11/14/nasa-chief-time-to-cleanup-all-that-space-junk.html.

[30] See *DeoOrbit*, United Space in Europe, April 12, 2016, http://www.esa.int/Our_Activities/Space_Engineering_Technology/Clean_Space/e.Deorbit/%28print%29 and *The Clean Space Blog*, October 18, 2017, http://blogs.esa.int/cleanspace/category/e-deorbit/.

[31] *Clean Space One*, September 28, 2017, https://espace.epfl.ch/CleanSpaceOne_1 and *Cleaning up Earth's Orbit: A Swiss Satellite to Tackle Space Debris*, Sept. 3, 2012, http://actu.epfl.ch/news/cleaning-up-earth-s-orbit-a-swiss-satellite-to-tac/.

[32] Darren McKnight points out at least one Russian ADR proposal; *See* Ju. Makarov, Ja. Shatrov, Trushlyakov, L. Anselmo, and C. Pardini, *Proposals for a Flight Experiment on Active Removal of a Spent Rocket Stage*, 4th European Workshop on Active Debris Removal, Paris, CNES HQ, June 6-8, 2016.

tra fuel to deorbit his company's satellite fleet and also adding fixtures to grapple them easily in case they fail.[33] Industry personnel are also proactively discussing the fairness of the 25-year rule. If, for example, the predicted lifetime of a satellite is much shorter (even days, not years), would it be fair to other operators to allow such a satellite to remain on orbit that long?[34]

III. POLICY OPTIONS

A. Potential New Ways to Deal with Mitigation Waivers

To start, it could be helpful for NASA and DoD to publicly report waivers either to Congress or to the White House. Making such data public would go a long way towards validating the United States' role as a leader in debris mitigation, without changing the administrative process of how waivers are reviewed. Even without a formal reporting requirement, the data could be posted on public NASA and DoD Web sites.

It might also be helpful to reexamine the administrative process. One of various potential options would be to have an executive branch organization outside of NASA and DoD make such waiver decisions. Setting up a standing interagency body or perhaps just granting authority to the White House Office of Science and Technology Policy (OSTP) to review debris waiver requests would enable NASA and DoD to weigh in on such requests, while not giving the NASA Administrator and Secretary of Defense authority to grant waivers to their own organizations.

Two engineers, Thomas Percy and Brian Landrum, have proposed creating a domestic interagency "Central Space Licensure Board." Percy and Landrum suggested that agencies such as NASA, DoD, NOAA, FAA, and the FCC be granted membership on such a Board. Such an interagency panel would have the advantage of having key Governmental stakeholders represented at the figurative table, again without giving the NASA Administrator and Secretary of Defense authority or responsibility to grant waivers to their own

---

[33] *See*, Peter B. de Selding, *OneWeb Pledges Vigilance on Orbital Debris Mitigation Issue*, Space News 5, Oct. 19, 2015; *See also* Peter B. de Selding, *OneWeb is Looking Proactive on Debris Question*, Space News 18, Oct. 26, 2015.

[34] Thanks to Josef Koller for making this salient point.

organizations.[35] If this worked well, it even could be a model for an international regulatory board that could grant waivers.

Another option conceivably could be to have some sort of standing outside body deal with waivers, but usually outside bodies such as National Research Council (NRC) committees can only advise, not regulate. NASA does have a NASA Advisory Committee with a number of subcommittees but again, this structure is designed to provide outside advice to NASA, not regulate it.[36] The Defense Science Board is charged with advising the Department of Defense of promising new technical areas of weapons research so this advisory board would not seem like an ideal fit.[37] Thus it is difficult to think of an historical precedent for such an arrangement.

The Aerospace Safety Advisory Panel (ASAP) has overseen NASA's safety procedures and been recommending ways to improve its safety since 1968. Its charter includes broad language calling for the ASAP to "advise the NASA Administrator and the Congress with respect to the hazards of proposed or existing facilities and proposed operations," conceivably giving it latitude to include debris waivers.[38] Potentially expanding the ASAP's purview to include dealing with debris waivers would certainly be a major organizational shift of responsibilities.

Another option is to encourage international industry standards such as the International Standards Organization (ISO) for debris mitigation. In theory, if the Government required its launch providers and spacecraft manufacturers to observe ISO 9000 standards, then these would become *de facto* industry standards because of the Federal Government's significant role in space launches.[39]

The above examples comprise a non-exhaustive list of policy options, identifying just some of the pros and cons of each. If analysts and policymakers more fully considered the default process for

---

[35] Thomas K. Percy and D. Brian Landrum, *Investigation of National Policy Shifts to Impact Orbital Debris Environments*, 30 SPACE POLICY 23, 33 (2014).

[36] *See* "NASA Advisory Council," http://www.nasa.gov/offices/nac/home/index.html.

[37] *See Charter and Membership Balance Plan*, Defense Science Board, http://www.acq.osd.mil/dsb/charter.html.

[38] *See Aerospace Safety Advisory* Panel, National Aeronautics and Space Administration, Aug. 26, 2015, http://oiir.hq.nasa.gov/asap/documents/ASAP_Charter_2015_Signed.pdf.

[39] Percy and Landrum, *supra* note 35 at 30.

granting debris mitigation waivers, other solutions might well surface. Hopefully, outlining some of the most obvious solutions above stimulates debate on this point.

B. Potential New Financial Incentives

In addition to adopting a new process for granting debris mitigation waivers, potential economic incentives comprise another set of possible levers for encouraging operators not to create more orbital debris. The Federal Government could, for example, use at least three different kinds of levers: levy fines for debris-generating satellites, initiate a deposit system in which a company could get a refund once a space mission was safely concluded, or issue permits for debris generation (perhaps similar to the cap-and-trade system for atmospheric pollution).[40]

As in the second option (a deposit system), the federal government could levy an "orbital use" tax on domestic space launches. The tax proceeds then could be pooled for remediation technology research and development. An analogy would be to maintaining terrestrial infrastructure such as highways. Such a model thus would have dual purposes: creating a financial disincentive to create new debris and creating a funding stream to clean it up eventually.[41] Any kind of financial system that provided money to federal agencies outside the usual appropriations process certainly would require congressional approval.

One space industry analyst fleshed out this idea based on the obscure Universal Service Administrative Company, a nonprofit corporation that administers taxes on consumers' telecommunications bills and distributes the proceeds to providers in rural or low-income areas.[42] If such an analogous company were established for

---

[40] Molly Macauley, *Regulation on the Final Frontier*, Regulation, Summer 2003, at 40-41, (https://www.law.upenn.edu/institutes/regulation/papers/MacauleySpaceRegulation.pdf).

[41] Elizabeth Evans and Scott Arakawa, *Time for a Solution to the Orbital Debris Problem*, 24.3 THE AIR AND SPACE LAWYER 9-13, 23 (2012); Natalie Pusey, *The Case for Preserving Nothing: The Need for a Global Response to the Space Debris Problem*, 21 COL. J. OF INT'L ENVIR. L. POL'Y 448-449 (2010); and Mark Williamson, *Space: The Fragile Frontier* (Reston, VA: American Institute of Aeronautics and Astronautics, 2006), p. 270 citing B.C.M. Reijnen, *The Pollution of Outer Space*, 4/5 ENVIR. L. REV. 117, 121 (1993).

[42] Jeff Foust, *Putting a Bounty on Orbital Debris*, THE SPACE REVIEW, July 27, 2009, http://www.thespacereview.com/article/1427/1 discusses space attorney Jim Dunstan's ideas regarding the Universal Service Administrative Company analogy.

space debris, it conceivably could tax all domestic space launches or at least those that do not comply with the USG ODMSP and then use the proceeds to fund ADR research. However, such a tax arrangement would likely be seen as an unfair burden on U.S. launch providers that would encourage the use of foreign launch vehicles.[43] Such a company could even place "bounties" on specific pieces of debris based on their size and/or risk. Such a nonprofit company or perhaps, a future government space traffic management agency, could then ensure that the bounty hunters operated safely in space and indemnify them for losses not covered by their insurance (akin to launch insurance requirements and indemnification).[44] Somewhat similarly, on the remediation side, one option could be a tax credit as a reward for an operator that safely removed a large piece of debris from orbit, as a way to stimulate private-sector investment in ADR technology.[45] A parallel might be to the established maritime law concept of salvage and reward.[46]

While such financial incentive and disincentive systems have an inherent appeal, they also raise a number of significant questions. With any potential tax system for debris mitigation, how would the federal government, the major launcher of spacecraft domestically, tax itself? Even if a suitable tax could be devised, this would presumably only apply to the commercial sector. Perhaps there is a precedent with military bases that pollute the land or water nearby, such as with an Environmental Protection Agency-mandated cleanup after a Base Realignment and Closure commission base closure. Regardless, the idea of the government taxing itself certainly raises some thorny issues.

Moreover, what about foreign space operators, such as the Russian and Chinese governments, who have created large amounts of orbital debris? International cap and trade systems for air pollution might well be analogous and at least one author has

---

[43] Thanks to Scott Pace for making this salient point.

[44] Foust, *Putting a Bounty on Orbital Debris*. Establishing a Governmental entity to oversee space traffic management is obviously a much larger subject than can be fully addressed here. At a minimum, it would have significant national security implications – thanks to Dana Johnson for making this point.

[45] Taylor, *supra* note 1 at 276.

[46] See, Geoffrey Brice, *Maritime Law of Salvage*, third edition (London: Sweet and Maxwell, 1999).

argued for the cost efficiency of "tradable allowances."[47] Of course, such multilateral negotiations tend to be very complex and difficult.

Even if a domestic tax system were implemented, which government agency would administer it? Neither NASA nor DoD is a regulatory agency. One option could be the FAA. Another could be a new federal space traffic management organization, a subject beyond the scope of this article.[48]

C. *International Diplomacy*

The 1967 Outer Space Treaty only addresses orbital debris indirectly by calling for "free access" to space and Treaty signatories are to explore space "so as to avoid … harmful contamination."[49] One option in theory could be to create an international treaty to impose fees on spacefaring nations or organizations based on market share liability. Similarly, the United Nations or some other international body could conceivably establish an international tribunal for space law to adjudicate disputes.[50] Often the United Nations has lacked the political authority to enforce such treaties, however, the political appetite for such actions in the foreseeable future seems quite minimal, to say the least.

Internationally, there is no space analog to the 1972 maritime London Dumping Convention nor does the 1972 space "Liability Convention" directly address debris.[51] Thus, diplomatic tools other than legally binding treaties, such as non-legally binding guidelines and voluntary Transparency and Confidence-Building Measures (TCBMs), increase in importance.

The Department of State already takes the lead in international fora and other forms of diplomacy short of a legally binding treaty. Separate bilateral diplomatic discussions, particularly re-

---

[47] Taylor, *supra* note 1 at 279.

[48] *See*, Mike Gruss, *Washington Weighs an FAA Role in Managing Space Traffic*, Space News, December 3, 2015, http://spacenews.com/might-the-faa-inherit-the-space-traffic-management-role/; Jeff Foust, *Filling in the Details*, The Space Review, February 8, 2016, http://www.thespacereview.com/article/2920/1.

[49] *See,* http://history.nasa.gov/1967treaty.html.

[50] Joseph Imburgia, *Space Debris and Its Threat to National Security: A Proposal for a Binding International Agreement to Clean Up the Junk*, 44 VAND. J. TRANSNAT'L L. 616, 618 (2011).

[51] *Id*. at 629-630, 633.

garding mitigation compliance rates, with Russia and China are potential options. However, due to Russia's annexation of Crimea in 2014, Obama Administration policy prohibited most bilateral negotiations with Russia, except within the context of larger, multilateral fora such as COPUOS and the IADC.[52] While both nations are IADC members, larger geopolitical concerns dim the prospects of gaining consensus on debris. A 2011 congressional amendment bars NASA and OSTP from holding bilateral discussions with China, but other U.S. Departments and agencies are not affected by this restriction. Certainly, overall political U.S.-Russia relations have been strained over such geographic hotspots as Ukraine, Crimea, and Syria, among other issues.[53]

One voluntary approach is a "code of conduct." The Europeans (the European Space Agency and the French, German, Italian, and British national space agencies) established a Code of Conduct for Space Debris Mitigation in 2004; this voluntary Code is designed to help mission designers and is closely related to the IADC guidelines. Language on orbital debris was also included in a broader draft European Union-proposed International Code of Conduct for Outer Space Activities. [54] The Hague Code of Conduct against Ballistic Missile Proliferation (HCoC), the only multilateral TCBM regarding ballistic missiles, is another potential model for limiting orbital debris. Negotiated outside of the UN, the HCoC was signed and entered into force in 2002 and since then the number of nations

---

[52] Thanks to Dana Johnson for clarifying this point.

[53] Despite these tensions with Russia, NASA continues to cooperate fully with the Russian space agency on the International Space Station program. This points out that specific political-military tensions can be divorced from other issues when doing so is in both sides' common interest.

[54] The European Code of Conduct for Space Debris Mitigation is available from http://www.unoosa.org/documents/pdf/spacelaw/sd/2004-B5-10.pdf, *See also* the draft EU ICoC is available from http://www.eeas.europa.eu/non-proliferation-and-disarmament/pdf/space_code_conduct_draft_vers_31-march-2014_en.pdf online. For two opposing views on the EU ICoC, see Michael J. Listner, *The International Code of Conduct: Comments on Changes in the Latest Draft and Post-Mortem Thoughts*, Oct. 26, 2015, http://www.thespacereview.com/article/2851/1; *See also* Akshan de Alwis, *New Tensions on How to Regulate Outer Space*, The Diplomatic Courier, August 10, 2015, http://www.diplomaticourier.com/new-tensions-on-how-to-regulate-outer-space/; For more on codes of conduct, also see Gregory Schulte and Audrey Schaffer, *Encouraging Security by Promoting Responsible Behavior in Space*, Strategic Studies Quarterly 9, 17, (Spring 2012).

joining as signatories has increased from 93 to 138.[55] Such codes of conduct are designed to encourage responsible behavior by space-faring nations and organizations, rather than be enforceable or impose penalties against violators, whether or not they are parties to a code of conduct.

It seems likely that the Chinese would have conducted the 2007 ASAT test even if they had previously agreed to a code of conduct (after all, they had just voluntarily adopted their own national mitigation guidelines before ignoring them less than a year later). So might there be other diplomatic options less stringent than a treaty but more formal than a code of conduct? One possibility would be TCBMs, a voluntary, practical, faster approach to dealing with near-term problems rather than taking years to negotiate and ratify formal treaties.[56] The previously-discussed International Code of Conduct is an example of a set of TCBMs. Another option simply would be encouraging the broader use of "norms of customary international law" or standards of "best practices," which typically evolve over time.[57] Over ten years ago, one attorney grouped options into three categories: a voluntary regime modeled after the Missile Technology Control Regime (MTCR), an approach centered around the United Nations, and a voluntary code of conduct.[58]

IV. SUMMARY/CONCLUSIONS

First, it is important to recognize that orbital debris is a negative economic externality. It is a truism that we must all share space, especially the increasingly congested LEO area. Debris from any operator can disable any other operator's or his or her own spacecraft. As major nation-states (e.g.: current/former superpowers such as the United States, Russia, and China) generally wield

---

[55] *See*, *The Hogue Code of Conduct against Ballistic Missile Proliferation*, The Hague Code of Conduct, Oct. 26, 2016, http://www.hcoc.at. Thanks to Dana Johnson for suggesting this example.

[56] For more on TCBMs, see, for examples, Jana Robinson, *Transparency and Confidence-Building Measures for Space Security*, 27 SPACE POLICY 27, 37 (2011); United Nations Office for Disarmament Affairs, https://www.un.org/disarmament/topics/outerspace/; And remarks by Frank Rose, Deputy Assistant Secretary for Arms Control, Verification, and Compliance, ASEAN Regional Forum Space Security Workshop, Dec. 6, 2012, https://2009-2017.state.gov/t/avc/rls/201625.html.

[57] Thanks to Dana Johnson for making the distinction between TCBMs and norms.

[58] Steven J. Mirmina, *Reducing the Proliferation of Orbital Debris: Alternatives to a Legally Binding Instrument*, 99 AM. J. INT'L L. 649, 662 (2005) for an interesting analysis.

more political power than international bodies (e.g.: UN COPUOS and the IADC), perhaps we should start by looking at potential domestic solutions that if successful, might then be adopted internationally.

In terms of mitigation then, are current U.S. policies adequate? There is no reason to question the technical sufficiency of the USG ODMSP (and the IADC guidelines that were based on them). There is inconsistent adherence to these guidelines, which is based on the fact that these are guidelines rather than regulations with significant consequences for noncompliance. Currently, solid data on domestic waiver rates are not widely available and the Chinese and Russians likely do not even compile such data for their own launches, let alone share it internationally.

Thus, the United States should start by proactively making its mitigation waiver data more publicly accessible by publishing it online, reporting it routinely to the UN or IADC, or the like to encourage Russia and China to take similar action. It's not even clear whether the Chinese or Russians have formal domestic waiver review processes. Since the IADC already has its own guidelines (somewhat more lenient versions of NASA's and the US ODMSP), perhaps someday the IADC could even encourage reporting of national data on launches that don't comply with its guidelines for more accurate, "apples to apples" comparisons.

A second place to start is with the waiver arrangement for NASA and DoD launches, a subject that has received very little public attention. Policymakers should consider revisiting the NASA Administrator and Secretary of Defense having the responsibility to grant waivers to the USG ODMSP for upcoming launches of their own organizations' spacecraft. Section three above outlined some potential options for tackling this problem and perhaps other solutions would be possible. Without advocating for a particular solution, probably some sort of interagency option or Central Licensure Board within the Executive branch would be preferable for NASA and DoD (rather than having, for examples, a Congressional panel or an outside quasi-Governmental body weigh in). Examining the administrative waiver process might also stimulate helpful discussion about whether the patchwork quilt of FCC, FAA, and NOAA oversight of debris mitigation for private sector launches is adequate.

Another important issue to address is financial incentives for not increasing orbital debris. For the private sector, perhaps an orbital use tax could be employed, initially at the national level. Pooling the proceeds to begin to fund ADR research, as with the Universal Service Administrative Company and highway infrastructure analogies, is an interesting potential option. On the government side, would additional congressional appropriations be needed to redesign legacy spacecraft templates or launch vehicles to comply with mitigation guidelines? Both of these ideas are attractive, but may not be politically viable in an era when politicians are wary of introducing new taxes and Federal budgets are lean.

In addition, a multilateral code of conduct, such as that proposed by the Europeans, could be useful in spreading voluntary "best practices" for mitigation. The IADC guidelines are sufficiently strict so the rub will be to get more nations to agree in principle to these existing mitigation guidelines. Then, more importantly, there need to be enforcement mechanisms behind an international set of mitigation guidelines, which will be difficult politically to implement. A devil's advocate might suggest that orbital debris is a relatively minor issue compared to the other military, economic, cyber, and diplomatic challenges facing U.S. relations with Russia and China. Optimistically, perhaps if a suitable agreement could be reached on orbital debris, then that could even improve the atmosphere for agreements in other areas.

Ideally it would also be good for the U.S. Government to get started now with basic research on remediation technologies (the 2010 National Space Policy called for this but very little funding has been spent thus far on remediation research). A number of ADR technologies are just in the early conceptual stages so it will take some time to develop good options. It is unlikely that the Russians or Chinese will fund such work on their own initiative (except perhaps for military rendezvous and proximity operations) and currently there is little economic incentive for the commercial sector to do so either. Even removing five large rocket bodies per year from LEO, as indicated earlier, would go a long way towards creating a safer operating environment there by reducing the risk of a cascade effect.

Overall, a more comprehensive approach to regulating the mitigation of orbital debris is needed domestically before dealing with international mitigation and remediation. Orbital debris is truly a global problem that will require global solutions. The United States has an opportunity to exercise leadership by devising and implementing more effective orbital debris policies domestically first.