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On Who Should Pay When Orbital Debris "Trickles-Down" in a Tragedy of the Low Earth Orbit Commons

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ON WHO SHOULD PAY WHEN ORBITAL DEBRIS "TRICKLES-DOWN" IN A TRAGEDY OF THE LOW EARTH ORBIT COMMONS

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ABSTRACT

In March 2023, NASA released the most rigorous and wide-reaching orbital debris analysis in the space law literature that provides a cost-benefit analysis of removing orbital debris from low Earth orbit (LEO), a region of the Earth's environment with no environmental regulation. NASA contextualized the motivation in releasing this report as rooted in the exponential growth of the commercial satellite industry, noting that "the number of tracked and untracked debris in LEO is projected to grow . . . even if no new satellites are launched into space, yet launch traffic is likely to increase in the coming decade compared to recent history." Similarly, in a May 2023 Congressional Budget Office (CBO) report, the CBO argued that the "number of satellites operating in LEO has increased significantly in recent years, driven in large part by commercial [satellite] constellations," which are networks of identical satellites whose orbits and positions are coordinated to accomplish a given mission, such as providing global broadband internet.

Underscoring the dangers of launching thousands of satellites into a finite orbital space with no environmental regulation, SpaceX, who operates the world's largest constellation, Starlink, reported that from December 2022 to May 2023, Starlink had to perform 25,299 collision avoidance maneuvers in LEO. This number of collision avoidance maneuvers is double the number

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of maneuvers reported by SpaceX during the previous six-month period, which is alarming to industry experts. Concerning the risks that satellite constellations pose to the sustainability of LEO, experts note that the global space market grew by 8% to $424 billion in 2022 and is expected to be valued at more than $737 billion by 2030, which is a market that will certainly be impacted if LEO is enshrouded in an impenetrable maelstrom of orbital debris moving at speeds seven times faster than a bullet.

Cross-referencing the most current orbital debris numbers from the European Space Agency with NASA's estimated costs of $300 per debris removed with ground-based lasers, and $6,000 per debris removed with space-based lasers, the total estimated cost to remove the 1,036,500 trackable pieces of orbital debris from LEO is from $310 million to $6.2 billion. On the other hand, the cost to remove the estimated 130 million pieces of currently untraceable orbital debris from LEO is from $39 to $780 billion, all of which is a sizeable liability for the United States (U.S.) government to allocate to the U.S. taxpayer. Indeed, under both the Outer Space Treaty and the Proposed ORBITS Act of 2023, which is a bipartisan bill recently unanimously passed by the U.S. Senate, the U.S. taxpayer will be left with footing the bill for remediating the debris left behind by U.S.-authorized commercial satellite operators.

Describing the LEO environment as a classical "tragedy of the commons" and drawing from studies conducted by NASA, the Government Accountability Office, the CBO, United Nations, and others, the purpose of this article is to tackle the question of who should pay when orbital debris "trickles down" in a manner that compromises Earth's satellite-reliant infrastructure and otherwise causes damage to Earth's environment, persons, and property. This article then recommends specific language to amend Title III of the Communications Act of 1934, which created and charged the Federal Communications Commission (FCC) with regulating commercial satellite systems, to establish a satellite constellation "orbital use fee" (OUF), which the FCC will levy as a requirement for receiving a license to operate in LEO. This OUF will then fund orbital debris remediation projects, related research, and remediation of the environmental impacts of satellite constellations.

Given that the U.S. leads the world in the total number of satellites in space per country, and SpaceX will own more satellites than each country in the world combined once it fully deploys Starlink, this article concludes by arguing that the U.S. is uniquely positioned to engage its allies in forging the foundation of customary international space law. First, through passing into law the

types of model legislation provided in this article, which will then form the basis of bilateral and multilateral treaty negotiations with both current and potential space-faring nations. This legislative and diplomatic strategy will help to operationalize the 1967 Outer Space Treaty (OST) proclamation establishing space as the "province of all mankind," and promote its peaceful use and exploration for the "benefit and in the interests of all countries."

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I. INTRODUCTION

"OVER THE NEXT DECADE, commercial operators plan to launch tens of thousands of new satellites into orbit. A veritable Cambrian explosion of commercial space operations is just over the horizon. We had better be ready when it arrives."[1]

[1] Statement of Nathan Simington, Fed. Commc'ns Comm'r; Re: Space Innovation, IB Docket No. 22-271; Mitigation of Orbital Debris in the New Space Age, IB Docket No. 18-313) (explaining his rationale for voting to approve the FCC's adoption of a new rule changing the de-orbiting timeframe for satellites ending their missions in LEO from a twenty-five-year recommendation to a five-year legal requirement).

In March 2023, NASA released the most rigorous and wide-reaching orbital debris analysis[2] in the space law literature.[3] In explaining the rationale for this report—which provides a cost-benefit analysis of removing orbital debris from LEO[4]—NASA contextualizes its concern as rooted in the exponential growth of the commercial satellite industry, noting that "the number of tracked and untracked debris in LEO is projected to grow . . . even if no new satellites are launched into space, yet launch traffic is likely to increase in the coming decade compared to recent history."[5] Indeed, in a May 2023 CBO report[6] on the challenges of operating satellite constellations in LEO, the CBO notes that the "number of satellites operating in LEO has increased significantly in recent years, driven in large part by investments in commercial [satellite] constellations,"[7] which are networks of identical satellites whose orbits and positions are coordinated to accomplish a given mission, such as providing

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[2] *See, e.g.*, Thomas J. Colvin et al., *Cost and Benefit Analysis of Orbital Debris Remediation*, NASA Off. Tech. Pol'y and Strategy (Patrick Besha, Bo Naasz eds., March 10, 2023), https://www.nasa.gov/sites/default/files/atoms/files/otps_-_cost_and_benefit_analysis_of_orbital_debris_remediation_-_final.pdf [https://perma.cc/ST4V-MHKV].

[3] *See* Vijay Iyer, *How Do You Clean Up 170 Million Pieces of Space Junk?*, Fed'n of Am. Scientists (May 24, 2023), https://fas.org/publication/how-do-you-clean-up-170-million-pieces-of-space-junk/ [https://perma.cc/FD6C-75ZM] (noting that NASA's work represents the first report illuminating "the financial costs and benefits of various paths forward to combat one of the fastest-growing dangers in Earth's orbit").

[4] LEO is defined as the region from Earth's edge to 2,000 kilometers of altitude, or roughly 1,200 miles above Earth's edge. *See Photo Gallery*, NASA-ARES, Orbital Debris Program Off., https://www.orbitaldebris.jsc.nasa.gov/photo-gallery; see generally, e.g., Thomas G. Roberts, Aerospace Security: Popular Orbits 101, Ctr. for Strategic and Int'l Stud., https://aerospace.csis.org/aerospace101/popular-orbits-101/ [https://perma.cc/GEY6-M5FV] (updated June 14, 2022); Most orbital debris is located in LEO. See NASA Off. Inspector Gen., IG-21-011, NASA's Efforts to Mitigate the Risks Posed by Orbital Debris (January 27, 2021) https://oig.nasa.gov/docs/IG-21-011.pdf [https://perma.cc/ZL99-RMUD].

[5] *See* Colvin, *supra* note 2, at 9.

[6] *See, e.g.*, Congr. Budget Off., *Large Constellations of Low-Altitude Satellites: A Primer* (May 17, 2023), https://www.cbo.gov/system/files/2023-05/58794-satellite-primer.pdf [https://perma.cc/K49J-UPEY]. This report concludes by noting that it "was prepared at the request of the Chairman and former Ranking Member of the Senate Committee on Armed Services. In keeping with the [CBO's] mandate to provide objective, impartial analysis, the report makes no recommendations." *Id.* at 25.

[7] *Id.* at 12.

global broadband internet.[8] The CBO, which provides non-partisan analyses at the request of and for the U.S. Congress, goes on to argue that "[g]enerally speaking, if more objects are moving in a particular area, it is more likely that some of them will (or will nearly) run into each other,"[9] thereby creating destructive orbital debris.[10]

This relationship between the exponential growth of the commercial satellite industry and the growth of orbital debris-creating risks in LEO, also increases the global risk of a destructive environmental feedback loop first predicted by Donald Kessler, the NASA astrophysicist who assessed the International Space Station's (ISS) vulnerability to orbital debris.[11] This feedback loop, best understood "as a form of high-speed environmental damage,"[12] is "now known as the 'Kessler syndrome.'"[13] Succinctly detailing the nature of this syndrome in the New Yorker Magazine, Raffi Khatchadourian writes that:

> Even a minuscule shard could smash a satellite to pieces, dispersing more high-velocity debris. If the population of objects became dense enough, collisions would trigger one another in an unstoppable cascade. The fragments would grow smaller, more numerous, more uniform in direction, resembling a maelstrom of sand . . . . At some point, the process would render all of [LEO] unusable. Theoretically, Kessler mused, our planet could acquire a ring akin to Saturn's, but made of garbage.[14]

Noting that "some of the most environmentally dangerous activities in space include large [satellite] constellations," Kessler argues that such "[a]ggressive space activities without adequate

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[8] *See id.* Starlink, for example, is a broadband internet service provider specializing in the expansion of coverage to rural and remote communities. It accomplishes this task by launching a constellation of satellites into LEO. *See* Michelle Shen & Elizabeth Pattman, *What is Starlink? Inside the Satellite Business that Could Make Elon Musk a Trillionaire*, USA TODAY (Dec. 6, 2021), https://www.usatoday.com/story/tech/2021/12/05/elon-musk-starlink-satellites-spacex-broadband-internet-globe/8881858002/ [https://perma.cc/3FSJ-X4D4].

[9] *See* CONGR. BUDGET OFF., *supra* note 6, at 16.

[10] *See id.*

[11] *See, e.g.*, Donald J. Kessler & Burton G. Cour-Palais, *Collision Frequency of Artificial Satellites: The Creation of a Debris Belt*, 83 J. GEOPHYSICAL RSCH. 2637, 2637 (1978).

[12] *See, e.g.*, Michael B. Runnels, *Protecting Earth and Space Industries from Orbital Debris: Implementing the Outer Space Treaty to Fill the Regulatory Vacuum in the FCC's Orbital Debris Guidelines*, 60 AM. BUS. LAW. J. 175, 186 (2023).

[13] *See id.* (citing Kessler & Cour-Palais, *supra* note 11).

[14] *See* Raffi Khatchadourian, *The Elusive Peril of Space Junk*, NEW YORKER MAG. (Sept. 28, 2020), *https://www.newyorker.com/magazine/2020/09/28/the-elusive-peril-of-space-junk* [https://perma.cc/VT93-7C7H].

safeguards could significantly shorten the time between collisions and produce an intolerable hazard to future spacecraft."[15] In Earth orbits, this debris hazard moving at speeds of up to seven-times faster than a bullet[16] manifests as a global collapse in the functioning of vital services such as national security,[17] internet access,[18] electronic commerce, GPS, weather forecasting, climate research,[19] and human spaceflight safety.[20] For these reasons, the intentional or negligent creation of orbital debris can both cause "harmful interference" with other countries' sustainable "use of outer space" in a likely violation of Article IX of the 1967 Outer

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[15] Donald J. Kessler, *The Kessler Syndrome: As Discussed by Donald J. Kessler* (Mar. 8, 2009), http://webpages.charter.net/dkessler/files/KesSym.html [https://perma.cc/GQ74-STT9].

[16] *See* The Week Staff, *How Worried We Should be About Space Debris*, THE WEEK (July 25, 2023), https://www.theweek.co.uk/news/science-health/961736/how-worried-about-space-debris [https://perma.cc/38MB-9UX8] (noting that a spent rocket stage from an Indian spacecraft washed up on the Australian coast one week before the publishing of this news article, the authors consider the question of who bears "responsibility for monitoring and cleaning up space junk in orbit, and who is ultimately liable for damage and disposal in the rare instances they fall back down to Earth[?]").

[17] *See* Jeff Foust, *U.S. Air Force Releasing More Data on Orbits of Military Satellites*, SPACENEWS (Dec. 17, 2018), https://spacenews.com/u-s-air-force-releasing-more-data-on-orbits-of-military-satellites/ [https://perma.cc/K4GZ-A22M].

[18] *See* Nathan Hurst, *Why Satellite Internet Is the New Space Race*, PCMAG (July 30, 2018), https://www.pcmag.com/article/362695/why-satellite-internet-is-the-new-space-race [https://perma.cc/8E47-4R8X].

[19] *See What Are Satellites Used For?*, UNION CONCERNED SCIENTISTS (Jan. 15, 2015), https://www.ucsusa.org/nuclear-weapons/space-weapons/what-are-satellites-used-for#.XDfGNM9Kiu4 [https://perma.cc/G76U-ME74].

[20] *See* W. Robert Pearson & Benjamin L. Schmitt, *2022 Is the Year for a Space Summit*, FOREIGN POL'Y MAG. (Jan. 1, 2022, 6:00 AM), https://foreignpolicy.com/2022/01/01/space-russia-anti-satellite-test-debris/ [https://perma.cc/GES2-DHUF] (describing the consequences of a satellite that was destroyed by the Russian Federation in 2021, Pearson writes that "[i]mmediately after the satellite was destroyed, NASA told [International Space Station] personnel to conduct shelter-in-place drills to prepare for a potential collision. NASA implemented further procedures to duck and dodge danger based on a calculation that the ISS would pass 'through or near the cloud every 90 minutes.'" Similarly, Russia's debris' proximity to Starlink also forced individual satellites within that constellation, to take evasive action); *see also* Press Release, United States Space Command, Russian Direct-Ascent Anti-Satellite Missile Test Creates Significant, Long-Lasting Space Debris (Nov. 15, 2022), https://www.spacecom.mil/Newsroom/News/Article-Display/Article/2842957/russian-direct-ascent-anti-satellite-missile-test-creates-significant-long-last/ [https://perma.cc/C4XJ-THVN] (noting that the U.S. government's "initial assessment is that the debris will remain in orbit for years and potentially for decades, posing a significant risk to the crew on the International Space Station and other human spaceflight activities, as well as multiple countries' satellites").

Space Treaty (OST),[21] which is the foundation of all international space regulation that proclaims space as the "province of all mankind."[22] In this way, America's current laissez-faire regulatory environment, governing the commercial satellite industry, which neither requires the public disclosure of the real-time positions of satellites in orbit nor an environmental assessment of how satellite operations in LEO may create orbital debris,[23] may not only enable violations of the OST but also "fall[s] well short" of providing the kinds of safeguards that Kessler argues are required for the sustainability of Earth orbits.[24]

In July 2023, finding that "the safety and sustainability of operations in [LEO] and nearby orbits in outer space have become increasingly endangered by a growing amount of orbital debris,"[25] the U.S. Senate Committee on Commerce, Science

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[21] *See* Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies art. IX, Jan. 27, 1967, 18 U.S.T. 2410, 2410 (The OST was the first international space law treaty, which was originally negotiated between the United States and the Soviet Union).

[22] *Id.* at art. I. Regarding the sustainable use of the outer space environment requirement arising from Article IX of the OST, Article IX provides, in relevant part, that:

> In the exploration and use of outer space . . . States Parties to the Treaty . . . shall conduct all their activities in outer space . . . with due regard to the corresponding interests of all other States Parties to the Treaty. States Parties to the Treaty shall pursue studies of outer space, including the Moon and other celestial bodies, and conduct exploration of them so as to avoid their harmful contamination . . . If a State Party to the Treaty has reason to believe that an activity or experiment planned by it or its nationals in outer space . . . would cause potentially harmful interference with activities of other States Parties in the peaceful exploration and use of outer space . . . it shall undertake appropriate international consultations before proceeding with any such activity or experiment.

Id. at art. IX.

[23] *See generally, e.g.*, Runnels, *supra* note 12, at 186.

[24] *See, e.g.*, Gordan Long, *The Impacts of Large Constellations of Satellites*, MITRE CORP. 101–02 (Jan. 21 2021), https://www.nsf.gov/news/special_reports/jasonreportconstellations/JSR-20-2H_The_Impacts_of_Large_Constellations_of_Satellites_508.pdf [https://perma.cc/D7K3-HDYL] (noting that the only real FCC regulations that constrain the growth of satellite constellations regard the availability of radio spectrum, arguing that the FCC's 2020 orbital debris guidelines are mere requirements for disclosure rather than mandated thresholds, and concluding that FCC regulations fail to effectively mitigate orbital debris in LEO orbits and "fall well short of what the FCC evidently thinks are required for safe traffic management in space."). JASON was asked by the National Science Foundation and Department of Energy to assess the possible growth and impact of future satellite constellations on orbital debris, satellite constellation impacts on optical astronomy generally, infrared astronomy, radio astronomy, cosmic microwave background studies, and laser guide-star observations. *See id.* at 1.

[25] ORBITS Act of 2023, S. 447, 118th Cong. (2023), https://www.congress.gov/118/bills/s447/BILLS-118s447is.pdf [https://perma.cc/W93T-L45U].

and Transportation passed the bipartisan Orbital Sustainability Act of 2023 (ORBITS Act), which was unanimously passed by the U.S. the Senate in October 2023.[26] The ORBITS Act would task NASA, the Federal Communications Commission (FCC), and other relevant federal agencies with addressing the adverse impacts of orbital debris and appropriating one hundred fifty million dollars to NASA to pursue these efforts.[27] The significance of this funding provision clearly signals that the U.S. taxpayer will "foot the bill for remediating the debris left behind by commercial satellites,"[28] rather than the commercial satellite industry driving up the risk of the Kessler syndrome becoming a reality. This then raises a fundamental question of economic ethics.

A previous article tackled the questions of how the OST confers jurisdictional authority upon the FCC to regulate orbital debris,[29] and why the U.S. Supreme Court's June 2022 ruling in *West Virginia v. EPA*[30] demonstrates the court's willingness to deconstruct the "administrative state,"[31] and now requires the passage of new

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[26] Press Release, Cantwell, Hickenlooper Bill to Clean Up Space Junk Passes Senate Unanimously, U.S. S. Comm. Com., Sci., & Transp. (November 1, 2023), https://www.commerce.senate.gov/2023/11/cantwell-hickenlooper-bill-to-clean-up-space-junk-passes-senate-unanimously.

[27] *See* Cong. Rsch. Servs., Summary: S.447 – Orbits Act of 2023, Congress.Gov (2023), https://www.congress.gov/bill/118th-congress/senate-bill/447 [https://perma.cc/6RGX-Z4PF].

[28] *See* Clay Hill, *The ORBITS Act is a Giant Leap Forward for Environmental Law*, Env't, Nat. Res., & Energy L. Blog (Jan. 20, 2023), https://law.lclark.edu/live/blogs/214-the-orbits-act-is-a-giant-leap-forward-for [https://perma.cc/TV66-8TPG].

[29] *See, e.g.*, Runnels, *supra* note 12, at 198–202; *see also* Carson Turner, Julia Englebert, and Narintohn Luangrath, *The Next Generation of Space Regulation: Scholars Explain how the Commercial Space Age Creates Demands for Regulatory Reform*, The Regulatory Review (Aug. 19, 2023), https://www.theregreview.org/2023/08/19/saturday-seminar-the-next-generation-of-space-regulation/ (explaining that "Runnels recommends amending federal law to require commercial satellite operators to disclose data essential to preventing satellite collisions . . .. Clear congressional authorization to protect Earth's orbital environment will, argues Runnels, help realize the [Outer Space Treaty's] goal of using space for the 'benefit and in the interests of all countries'").

[30] West Virginia v. Env't Prot. Agency, 142 S. Ct. 2587, 2610–16 (2022) (reversing EPA carbon dioxide regulations and articulating that the Clean Air Act does not explicitly authorize the EPA to regulate carbon dioxide emissions in a manner that triggers a nationwide transition away from the use of coal and that Congress must speak clearly on the subject for the EPA to exercise this power).

[31] *See* Matt Ford, *The Supreme Court Conservatives' Favorite New Weapon for Kneecapping the Administrative State: Why a Relatively Young Legal Doctrine has Become all the Rage Among the Court's Right-Wing Majority*, New Republic (Mar. 13, 2023), https://newrepublic.com/article/171093/supreme-court-major-questions-doctrine-administrative-state [https://perma.cc/M7WL-ZA47] (defining "administrative state" as "a term often used by conservative legal thinkers to describe (and perhaps

legislation granting clear congressional authorization to the FCC to regulate orbital debris. Previous articles also provided model legislation of what those first orbital debris laws should be, such as including Earth's orbital environment in the definition of "human environment" so that it can be regulated under the National Environmental Protection Act (NEPA),[32] and requiring commercial satellite operators to publicly disclose the data needed to establish space situational awareness (SSA) before gaining an approval to launch,[33] while also framing the international implications of enacting such model legislation.[34] However, few articles provide model legislation rooted in answering the question of who should pay when orbital debris causes damage to persons, property, and the environment.[35] The purpose of this article is to

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make sound more menacing) federal regulatory agencies like the Environmental Protection Agency and the FDA." Carrying out their mission through federal rulemaking, Ford goes on to detail how the Court's use of what is known as the "major questions doctrine," which allows the justices to overturn a federal regulation if they think Congress didn't "speak clearly" enough to authorize it, has seen a meteoric rise amid the court's increasingly conservative tilt); *see, e.g.*, Runnels, *supra* note 12, at 225–26 (describing the legal impact of the Court's *West Virginia* ruling, Runnels argues that while "it may appear to be reasonable to argue" that the FCC has the authority to regulate orbital debris, the Court may view FCC rulemaking in this area as unconstitutional, as Congress has yet to clearly authorize the FCC to regulate orbital debris).

[32] *See, e.g.*, Michael B. Runnels, *On Launching Environmental Law into Orbit in the Age of Satellite Constellations*, 88 J. Air L. Com. 195, 197–202 (2023) (arguing that LEO should qualify as a "human environment" under the National Environmental Protection Act, Runnels provides model legislation that codifies this argument, which will ensure that commercial satellite applicants perform an EA on LEO orbits as a requirement for receiving a license to launch from the FCC).

[33] *See, e.g.*, Runnels, *supra* note 12, at 218–23.

[34] *See, e.g.*, Michael B. Runnels, *On an American Strategy to Forge Global Space Law to Curtail Orbital Debris in the New Space Age*, 19 S.C. .J. Int'l L. & Bus. **151, 158–59** (2023).

[35] *See generally* Michael B. Runnels, *On Clearing Earth's Orbital Debris & Enforcing the Outer Space Treaty in the U.S.*, A.B.A. Bus. L. Today 1, 3, 414 (Jan. 13, 2022), https://businesslawtoday.org/2022/01/on-clearing-earths-orbital-debris-enforcing-outer-space-treaty-in-us/ [https://perma.cc/TM3D-EJ2H] (arguing how, from the perspective of U.S. treaty obligations under the OST, FCC rulemaking in the area of orbital debris is insufficient in addressing the dangers of orbital debris, Runnels then provides two pieces of model legislation, one of which regards the creation of an "orbital use fee." As this January 2022 article was published before the Supreme Court's July 2022 West Virginia ruling and before a series of U.S. government agency reports regarding orbital debris from 2022-2023, the orbital use fee model legislation provided in this previous work, as well as the principal arguments in favor of it, are antiquated). *See* Env't Prot. Agency, 142 S. Ct. at 2610–16; *see also* Khari Johnson, *Russian Missiles and Space Debris Could Threaten Satellites*, Wired Magazine (March 16, 2022), https://wired.me/science/space/space-debris-russia-satellites/ (explaining that "in a series of policy solutions published by the American Bar Association in

provide this model legislation within the context of the new space age.[36] This article proceeds in three central Parts.

January . . .." Runnels "wants the [FCC] to levy a tax on private space companies that would fund space debris cleanup projects handled by other private companies").

[36] *See, e.g.*, *xTech Futures: SpaceTech*, DELOITTE **1, 5** (June 14, 2023) (detailing only a few contours of this new space age, the Deloitte report argues that "[f]rom agriculture companies using satellite data to optimize crop yields to pharmaceutical companies using the advantages of microgravity to develop lifesaving solutions, we'll demonstrate how industries can leapfrog to the next opportunity by leveraging space-based technology advances and providing products and services to the growing space industry."); *Space: Investing in the Final Frontier***,** MORGAN STANLEY (July 24, 2020), https://www.morganstanley.com/ideas/investing-in-space [https://perma.cc/J96Q-HM3G] (estimating that the global space industry could generate revenue of more than $1 trillion or more in 2040, up from the then $350 billion); *Capital Flows as Space Opens for Business*, MORGAN STANLEY (July 21, 2020), https://www.morganstanley.com/ideas/future-space-economy [https://perma.cc/5FNH-8NWE] (describing the nascent space economy as demonstrable fertile grounds for private investment). The article notes that this new "space race is being powered not just by government but by a new crop of startups and visionaries . . . [E]ntrepreneurs, strategic partnerships, and venture capital have been leading the charge on funding" for these ventures and that, for some of these investments, "the exit plans can be 50 years out." The article further discusses that "[we're] seeing a tremendous amount of interest in this area from angel investors, venture capital and private-equity firms" and that much of this is real passion in the industry, though "some of it is simply fear of being late to the party. Things are changing at such a rapid pace that investors are saying they have to keep up with the times . . . [and] [b]ecause success in space promises to be a multidecade endeavor - with returns on some lofty endeavors that could be many years away - this new economy requires patient investors. One sign of investors' willingness to wait is the increasing reliance on permanent and long-term capital funds." *Id.*; *ESA Space Resources Strategy*, EUR. SPACE AGENCY (May 23, 2019), https://sci.esa.int/documents/34161/35992/1567260390250-ESA_Space_Resources_Strategy.pdf [https://perma.cc/P3B5-Y6NZ] (concluding that 88 billion to 206 billion dollars over the 2018–2045 period are expected from space resource utilization); *Opportunities for Space Resources Utilization: Future Markets & Value Chains*, LUX. SPACE AGENCY 1, 9 (Dec. 2018), https://space-agency.public.lu/dam-assets/publications/2018/Study-Summary-of-the-Space-Resources-Value-Chain-Study.pdf [https://perma.cc/WNY5-ZS6C] (noting that the nascent space resources utilization industry is expected to generate a market revenue of 88 billion to 206 billion dollars over the 2018–2045 period, supporting a total of 845,000 to 1.8 million full time employees. The report further notes that the "[i]ncorporation of space resources into exploration missions will reduce costs and improve their economic viability" and that, as such, "[s]pace resources will play a foundational role in the future of in-space economies"); Noah Poponak et al., *Space: The Next Investment Frontier*, GOLDMAN SACHS EQUITY RSCH. REP. **1, 4** (April 4, 2017), http://www.fullertreacymoney.com/system/data/files/PDFs/2017/October/4th/space%20-%20the%20next%20investment%20frontier%20-%20gs.pdf [https://perma.cc/L2DJ-J4ZD] (noting that "[w]hile relatively small markets today, rapidly falling costs are lowering the barrier to participate in the space economy, making new industries like space tourism, asteroid mining, and on-orbit manufacturing viable.").

Part II, drawing from studies conducted by NASA,[37] the Government Accountability Office (GAO),[38] the CBO,[39] and other government agencies, details the relationship between the growth of orbital debris and the exponential growth of satellite constellations in LEO, and then summarizes NASA's cost-benefit analysis of removing orbital debris from LEO. Part III briefly details how the OST provides the FCC jurisdiction for the regulation of satellite constellations and critiques the FCC's regulation of satellites as potentially in violation of the OST. Part IV then tackles the question of who should pay when orbital debris "trickles down"[40] in a manner that compromises Earth's information-based and satellite-reliant infrastructure,[41] and explains that under the OST and the recently proposed ORBITS Act, the American taxpayer would pay for this foreseeable damage. Therefore, Part IV concludes by recommending specific language to amend Title III of the Communications Act of 1934 (the Act),[42] which created and

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[37] *See, e.g.*, NASA Off. of Inspector Gen.**,** *supra* note 4.

[38] *See, e.g.*, U.S. Gov't Accountability Off., GAO-22-105166, *Large Constellations of Satellites: Mitigating Environmental and Other Effects* (2022), https://www.gao.gov/assets/gao-22-105166.pdf [https://perma.cc/XD7B-93L3].

[39] *See* Cong. Budget Off.**,** *supra* note 6.

[40] *See* Robert Reich, *Why is Trickle-Down Economics Still With Us?*, The Guardian (October 9, 2022, 10:04 PM), https://www.theguardian.com/commentisfree/2022/oct/09/why-is-trickle-down-economics-still-with-us [https://perma.cc/Z5Z9-C5HM] (defining "trickle-down economics" as an "abiding faith on the political right that tax cuts and deregulation are good for an economy, Reich argues that "this gonzo economic theory continues to live on, notwithstanding its repeated failures"). While this article's focus is on addressing the damage caused to the in-orbit infrastructure that provides the technologies that many developed countries depend upon, this article's recommendations are equally applicable to orbital debris falling back to Earth in a manner that causes damage to persons and property.

[41] *See* Robert S. Wilson et al., *The Value of Space*, Ctr. for Space Pol'y & Strategy 1, 1–2 (2020), https://aerospace.org/sites/default/files/2020-05/Gleason-Wilson_ValueOfSpace_20200511.pdf [https://perma.cc/P5DQ-EQNP] (highlighting satellite services for precision agriculture, ocean monitoring, weather forecasting, and other essential applications); U.S. Dep't of Def., Defense Space Strategy Summary 3 (2020) ("[t]oday, U.S. reliance upon space has increased to the point where space capabilities not only enhance, but enable our way of life and way of war"); Exec. Off. of the President, National Space Policy of the United States of America 1 (June 28, 2010), https://obamawhitehouse.archives.gov/sites/default/files/national_space_policy_6-28-10.pdf [https://perma.cc/9JUT-KRJ2] ("[s]pace systems allow people and governments around the world to see with clarity, communicate with certainty, navigate with accuracy, and operate with assurance"); Timothy J. Hall et. al., *Clearing Skies in the Forecast for the Nation's Weather Satellites, Aerospace* 1, 1 (June, 2021) (emphasizing the value of space weather data).

[42] *See* Communications Act of 1934, Pub. L. No. 73-416, 48 Stat. 1064, 1064 (1934) (codified as amended in multiple sections of 47 U.S.C.).

charged the FCC with regulating commercial satellite systems[43] to establish a satellite constellation OUF that will fund orbital debris remediation projects, related research, and otherwise remediate the environmental impacts of satellite constellations.

Given that the U.S. leads the world in the total number of satellites in space per country,[44] and SpaceX will own more satellites than each country in the world combined once it fully deploys its Starlink satellite constellation,[45] this article concludes by arguing that the U.S. is uniquely positioned to engage its allies in forging the foundation of customary international space law. First, through passing into law the types of model legislation provided in this article, which will then form the basis of bilateral and multilateral treaty negotiations with both current and potential space-faring nations. This legislative and diplomatic strategy will help to establish space as the "province of all mankind,"[46] operationalizing the proclamation by the OST, and promote its peaceful use and exploration for the "benefit and in the interests of all countries."[47]

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[43] *See* Communications Satellite Act of 1962, Pub. L. No. 87-624, § 101, 76 Stat. 419, 419; *Bill Signing, H.R. 11040 Public Law 87-624, Communications Satellite Act of 1962, 9:45AM*, JOHN F. KENNEDY PRESIDENTIAL LIBR. & MUSEUM (1962), https://www.jfklibrar y.org /asset-viewer/archives/JFKWHP/1962/Month%2008/Day%2031/JFKWHP-1962-08-31-A [https://Perma.cc/ZN2D-7YTL (photograph). The Communications Satellite Act of 1962, which delegates the regulation of commercial satellites to the FCC, is subject to Title III of the Act. *See The Communications Satellite Act of 1962*, 76 HARV. L. REV. 388, 390 (1962).

[44] *See, e.g.*, Kelly Kizer Whitt, *Who Owns all the Satellites?*, EARTHSKY (Feb. 8, 2022), https://earthsky.org/space/who-owns-satellites-company-country/ [https://perma.cc/RL2A-AKZE].

[45] *See, e.g.*, Rebecca Heilweil, *Elon Musk's Starlink is Only the Beginning*, VOX (Jan. 10, 2023, 1:10 PM), https://www.vox.com/recode/2023/1/10/23548291/elon-musk-starlink-space-internet-satellites-amazon-oneweb [https://perma.cc/8F58-QSDQ] (detailing the advent of satellite constellations in LEO and how the increasing congestion of LEO with these projects exacerbates Earth's orbital debris problem); *World's Most Advanced Broadband Satellite Internet*, STARLINK **(2023)**, https://www.starlink.com/technology [https://perma.cc/VYP5-LPRL] (describing Starlink as "the world's first and largest satellite constellation using a low Earth orbit to deliver . . . high-speed, low-latency internet to users all over the world").

[46] *See* Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies, *supra* note 21, at art. I.

[47] *Id.*

II. NASA & OTHER GOVERNMENT AGENCIES ON THE RELATIONSHIP BETWEEN ORBITAL DEBRIS & SATELLITE CONSTELLATIONS IN LEO

A. On Orbital Debris & Satellite Constellations

NASA defines orbital debris as "any human-made object in orbit about the Earth that no longer serves any useful purpose,"[48] such as "abandoned [rocket] vehicle stages, non-functional satellites, and fragments resulting from collisions or explosions,"[49] which "lingers [in Earth orbits] for years until it decays, deorbits, explodes, or collides with another object thus creating more debris."[50] This debris includes: approximately 36,500 pieces, the size of a softball or larger, which can destroy a satellite on impact; over one million pieces, the size of a marble and big enough to cause significant damage to spacecraft; and over 130 million pieces,[51] the size of a grain of salt, which are too small to track though large enough to penetrate a spacesuit.[52] All of this debris "hinders the use of space upon which critical infrastructure of the U.S. economy relies, such as communications, national security, financial exchanges, transportation, and climate monitoring."[53] NASA goes on to argue that orbital debris "increases the costs of space operations by requiring efforts to shield against or maneuver around it, threatens the safety of astronauts and satellites, limits the ability to launch spacecraft, and may eventually make entire orbits unusable."[54] Indeed, the Russian Federation recently underscored this point in November 2021 through its anti-satellite missile strike against its own satellite in LEO,[55] which created an

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[48] *See, e.g.*, Eileen K. Stansbery, *Frequently Asked Questions: What is Orbital Debris?*, NASA ARES, https://www.orbitaldebris.jsc.nasa.gov/faq/# [https://perma.cc/SR7W-AHER].

[49] *See* Colvin, *supra* note 2, at 2.

[50] *See, e.g.*, NASA Off. Inspector Gen., *supra* note 4, at 3.

[51] *See Space Debris by the Numbers*, Eur. Space Agency (Sept. 12, 2023), https://www.esa.int/Space_Safety/Space_Debris/Space_debris_by_the_numbers [https://perma.cc/CFG6-ASZF].

[52] *See* NASA Off. Inspector Gen., *supra* note 4, at 3.

[53] *See* Colvin, *supra* note 2, at 2.

[54] *Id.*

[55] Press Release, United States Space Command, Russian Direct-Ascent Anti-Satellite Missile Test Creates Significant, Long-Lasting Space Debris (Nov. 15, 2021), https://www.spacecom.mil/Newsroom/News/Article-Display/Article/2842957/russian-direct-ascent-anti-satellite-missile-test-creates-significant-long-last/ [https://perma.cc/54GG-YAJ8] (explaining that "Russia has demonstrated a

orbital debris cloud that sent astronauts scrambling for safety aboard the ISS in October 2022.[56]

In a September 2022 report concerning the orbital debris-related environmental impacts from the operation of satellite constellations in LEO,[57] the GAO argued that the "anticipated growth of large constellations of satellites is affecting the space and terrestrial environments in several ways."[58] The GAO then contextualized these environmental impacts through a basic arithmetic truth, explaining that, "[a]s the number of objects in orbit increases, such as by launching satellites, so does the number of potential collisions between two objects,"[59] and further explaining that the number of potential collisions largely "scales with the square of the number of objects; that is, if the number of objects doubles, the number of potential collisions will approximately quadruple."[60] While acknowledging that satellites provide essential services to Earth, the GAO argued that the advent of satellite constellations in LEO will potentially lead to an "increase in orbital debris"[61] and noted the lack of any substantive regulations to mitigate this debris risk.[62] Indeed, in an acknowledgement that satellite constellations "pose a significant risk for collision and degradation of the space environment[,]"[63] the GAO concluded that the multiple experts, government officials, and commercial

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deliberate disregard for the security, safety, stability, and long-term sustainability of the space domain for all nations." U.S. Army Gen. James Dickinson, U.S. Space Command commander, further argued that the LEO "debris created by Russia's [ASAT] will continue to pose a threat to activities in outer space for years to come, putting satellites and space missions at risk, as well as forcing more collision avoidance maneuvers. Space activities underpin our way of life, and this kind of behavior is simply irresponsible.").

56 *See* Pearson, *supra* note 20 and accompanying text; *see also* United States Space Command, *supra* note 55 (noting that the U.S. government's "initial assessment is that the debris will remain in orbit for years and potentially for decades, posing a significant risk to the crew on the [ISS] and other human spaceflight activities, as well as multiple countries' satellites." The United States Space Command goes on to quote the commander of the U.S. Space Command's argument that "Russia is developing and deploying capabilities to actively deny access to and use of space by the United States and its allies and partners" . . . and that "Russia's tests of direct-ascent anti-satellite weapons clearly demonstrate that Russia continues to pursue counterspace weapon systems that undermine strategic stability and pose a threat to all nations.").

57 *See* U.S. GOV'T ACCOUNTABILITY OFF., *supra* note 38, at 50.

58 *Id.* at 53.

59 *Id.* at 42.

60 *Id.*

61 *Id.* at 3.

62 *Id.* at 58–59; *see also, e.g.*, Runnels, *supra* note 12, at 194.

63 *See* Long, *supra* note 24, at 109.

satellite operators, whom they consulted with, all "stressed the urgent need for policy action to mitigate the potential effects as large constellations of satellites are rapidly deployed."[64]

Yet, commercial satellite operators continue launching their payloads into this regulatory void. Indeed, the CBO's May 2023 report notes that the "number of satellites in all three orbital regimes grew slowly but consistently through the mid-2010s, [though beginning] around 2018, the number of satellites operating in LEO began to grow sharply"[65] and now accounts for about "85 percent of operational satellites . . . in LEO."[66] The CBO further noted that the catalyst for this growth can be traced to satellite constellations built by companies such as SpaceX, whose Starlink constellation "accounted for more than half of the launches of LEO satellites in 2020 and 2021."[67] Additionally, a May 2023 United Nations (U.N.) report on outer space governance detailed that "a decade ago, the number of satellites launched into [LEO] began to increase at an exponential rate, from 210 in 2013, to 600 in 2019, to 1,200 in 2020 and, most recently, to 2,470 in 2022."[68] These realities were echoed in a June 2023 NASA report on orbital debris, which determined that satellite constellation "launches have placed a relatively steady number of objects into orbit for most of the last two years and comprise more than half of all payloads launched."[69] NASA further detailed a breakdown of all payloads launched from the second quarter of 2021 to the first quarter of 2022, which "clearly indicates the recent trend towards large [satellite] constellations, . . . [as] nearly three quarters of all payloads are members of a large constellation."[70]

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[64] *See* U.S. Gov't Accountability Off., *supra* note 38, at 62.

[65] *See* Cong. Budget Off., *supra* note 6, at 12. The CBO explains that Earth "orbits are separated into three categories: Low-Earth orbits (LEOs) range from 300 km to 2,000 km above the Earth's surface; medium-Earth orbits (MEOs) range from 2,000 km to about 35,000 km; and geosynchronous orbits (GEOs) operate at 35,786 km." *Id.* at 2.

[66] *Id.* at 6.

[67] *Id.* at 12.

[68] *See, e.g.*, United Nations, *Our Common Agenda Policy Brief 7, For All Humanity: The Future of Outer Space Governance* at 4 (May, 2023), https://www.unoosa.org/res/oosadoc/data/documents/2023/a77/a77crp_1add_6_0_html/ our-common-agenda-policy-brief-outer-space-en.pdf [https://perma.cc/A6NU-ULN2].

[69] B. Greene, *Two Years of Space Traffic: Current Trends in New Payloads and Debris in Orbit*, 27 Orbital Q. News **1, 5** (June 2023), https://orbitaldebris.jsc.nasa.gov/quarterly-news/pdfs/odqnv27i2.pdf [https://perma.cc/2C4D-6KUP].

[70] *Id.* at 6.

Underscoring the dangers of launching thousands of satellites into a finite orbital space with no environmental regulation,[71] SpaceX reported[72] that, from December 2022 to May 2023, Starlink had to perform 25,299 collision avoidance[73] maneuvers in LEO.[74] This number of collision avoidance maneuvers is double the number of maneuvers reported by SpaceX during the previous six-month period.[75] This is a worrying trend for experts, as it follows an exponential curve. That is, in only two years, Starlink maneuvers have risen by a factor of ten, which if projected into the future, results in Starlink performing one million maneuvers every six months by 2028.[76] Similar to SpaceX,[77] who now accounts for over half of close encounters between two spacecrafts in LEO,[78] other companies also have plans to launch large

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[71] *See, e.g.*, Peter Elkind, *The FCC Is Supposed to Protect the Environment. It Doesn't*, ProPublica (May 2, 2023, 5:00 AM), https://www.propublica.org/article/fcc-environment-cell-towers-failures [https://perma.cc/TKG7-5Q3V] (arguing that "the FCC has approved Musk's space armada [Starlink], and many other satellite constellations, without requiring an environmental assessment, on the premise that, even cumulatively, they present no serious risk. (Musk has also argued that NEPA rules [should not] apply to space)."); U.S. Gov't Accountability Off., GAO-23-105005, *Satellite Licensing: FCC Should Reexamine Its Environmental Review Process for Large Constellations of Satellites* 2 (Nov. 2022), https://www.gao.gov/assets/730/723690.pdf [https://perma.cc/DBC9-ETKS] (arguing that the FCC "has not sufficiently documented its decision to [exclude satellites from environmental review] when licensing large constellations of satellites.").

[72] This report arises from an agreement between SpaceX with NASA through the USSPACECOM-facilitated sharing agreement program. Notably, SpaceX volunteers to publicize this data, as these disclosures are not required under U.S. law, the critical importance of a sustainable LEO environment notwithstanding. *See* NASA & Space Expl. Techs. Corp., Nonreimbursable Space Act Agreement Between National Aeronautics and Space Administration and Space Explorations Technologies Corp. for Flight Safety Coordination with NASA Assets (Jan. 7, 2021) https://www.nasa.gov/sites/default/files/atoms/files/nasa-spacex_starlink_agreement_final.pdf [https://perma.cc/2DFR-YMCR].

[73] *See generally*, NASA, Spacecraft Conjunction Assessment and Collision Avoidance Best Pracs. Handbook **1** (2020), https://nodis3.gsfc.nasa.gov/OCE_docs/OCE_50.pdf [https://perma.cc/9A4N-SL95] (discussing the increasing congestion of LEO orbits with satellites and debris and detailing the SSA data needed to assess and adapt to this increased congestion).

[74] *See* SpaceX, Constellation Status Rep. **2** (June 30, 2023).

[75] *See, e.g.*, Tereza Pultarova, *SpaceX Starlink Satellites had to Make 25,000 Collision-Avoidance Maneuvers in Just 6 Months – and it Will Only Get Worse*, Space.com (July 6, 2023), *https://www.space.com/starlink-satellite-conjunction-increase-threatens-space-sustainability [https://perma.cc/B7LF-2D7F].*

[76] *See id.*

[77] *See* Colvin, *supra* note 2, tbl. 1 (noting SpaceX's potential constellation size as 29,988 satellites).

[78] *See, e.g.*, Tereza Pultarova, *SpaceX Starlink Satellites Responsible for Over Half of Close Encounters in Orbit, Scientist Says*, Space.com (Aug. 20, 2021), *https://www.space.com/*

constellations of satellites into LEO, including Amazon,[79] Astra,[80] Boeing,[81] China SatNet,[82] and OneWeb.[83] As Kessler argues, "[w]e are entering a new era of debris control … an era that will be dominated by a slowly increasing number of random catastrophic collisions. These collisions will continue in [LEO], but will eventually spread to other [orbital] regions."[84]

B. NASA's Orbital Debris Cost-Benefit Analysis & Remediation Recommendations

In July 2022, the U.S. government issued its National Orbital Debris Implementation Plan (Orbital Debris Plan),[85] which declared that "the challenges posed by orbital debris to the sustainability of outer space have inherent similarities to other human-made global environmental challenges,"[86] and tasked several Federal agencies, including NASA and the FCC,[87] with reviewing the ef-

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spacex-starlink-satellite-collision-alerts-on-the-rise [https://perma.cc/77JV-GZB5]. Quoting Professor Hugh Lewis, Head of the Aeronautics Research Group at the University of Southampton and Europe's leading expert on space debris, Pultarova writes:

> I have looked at the data going back to May 2019 when Starlink was first launched to understand the burden of these [satellite] constellations. . . . Since then, the number of encounters picked up by the Socrates database has more than doubled and now we are in a situation where Starlink accounts for half of all encounters.

Id.

[79] *See generally* Elizabeth Howell, *Amazon's 1st Kuiper Megaconstellation Satellites will Launch on a ULA Atlas V Rocket,* Space.com (Apr. 20, 2021), https://www.space.com/amazon-kuiper-megaconstellation-atlas-v-rockets [https://perma.cc/FBB4-YAMX]; *see also* Colvin, *supra* note 2, at 9 (noting Amazon's potential constellation size as 4,538 satellites).

[80] *See* Colvin, *supra* note 2, at 9 tbl.1 1 (noting Astra's potential constellation size as 13,620 satellites).

[81] *Id.* (noting Boeing's potential constellation size as 5,670 satellites).

[82] *Id.* (noting China SatNet's potential constellation size as 12,992 satellites).

[83] *See generally* Jonathan Amos, *OneWeb Lays Path to Commercial Broadband Services*, BBC News (July 1, 2021), https://www.bbc.com/news/science-environment-57674882 [https://perma.cc/Q9XA-R7ED]; *see also* Colvin, *supra* note 2, at 9 (noting OneWeb's potential constellation size as 6,372 satellites).

[84] *See* Kessler, *supra* note 15.

[85] *See* Nat'l Sci. and Tech. Council, National Orbital Debris Implementation Plan (2022), https://www.whitehouse.gov/wp-content/uploads/2022/07/07-2022-NATIONAL-ORBITAL-DEBRIS-IMPLEMENTATION-PLAN.pdf [https://perma.cc/KYG6-7PWT].

[86] *Id.* at 5.

[87] The Orbital Debris Plan details several Federal agencies as engaged in orbital debris risk management, explaining that:

> [n]umerous U.S. Government departments and agencies are involved in orbital debris risk management. The National Aeronautics and Space Administration (NASA) uses radars, telescopes, and in situ measurements to statistically sample debris too small to be tracked but still large enough to threaten human spaceflight and robotic missions. NASA also leads the development of the U.S. Government

ficacy of U.S. policies regarding the expanding risks of Earth's orbital debris. The Orbital Debris Plan also called for "an economic and strategic risk assessment [that] would describe the near-term harm—quantified in dollars and probabilities—to provide an expected value for costs imposed by orbital debris and, by extension, the potential size of the market for active debris removal (ADR) services."[88] NASA's Cost-Benefit Analysis is a direct response to the Orbital Debris Plan's call for an economic risk assessment of the near-term costs imposed by the fastest-growing danger in LEO—and the benefits of remediating it.[89]

Using data from only U.S.-operated satellites, U.S.-authorized satellites, or both,[90] NASA concluded that 23 million dollars in damage can be averted each time 100,000 pieces of small debris, measured between one and ten centimeters, are removed from LEO.[91] Further concluding that the costs orbital debris imposes on satellite operators to be 58 million dollars per year,[92] NASA argued that the most cost-efficient remediation option is the use of ground and space-based pulsed lasers to nudge large debris off a collision course with another object,[93] rather than removing

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Orbital Debris Mitigation Standard Practices (ODMSP), which are directly applicable to U.S. Government operators. NASA also maintains an office to monitor the space environment for its own satellites. The Department of Defense (DOD) collects data on and tracks space objects and notifies spacecraft operators of possible collision. DOD is transitioning the responsibility of providing notifications for civil and commercial operators to the Department of Commerce (DOC). The Federal Aviation Administration (FAA) and the Federal Communications Commission (FCC) have policies or regulations that are intended to limit the creation or accumulation of debris.

Id. at 7.

88 *Id.* at 13.

89 *See* Colvin, *supra* note 2, at 1. To create the report, NASA devised a model specifying the economic risks orbital debris imposes on commercial satellite operators, based upon the time it takes to match the cost dedicated to the remediation, and the method of remediation used. NASA then applied the model to two scenarios: 1) prioritizing the removal of the 50 largest objects in LEO; and 2) targeting 100,000 pieces of small debris for removal. *See generally id.* at ii.

90 *See id.* at 13.

91 *See id.* at IV fig. ES-2.

92 *See id.* at 54, tbl. 6.

93 *See, e.g.*, *NASA Proposes Use of Lasers to Clear and Nudge Orbital Debris*, PHOTONICS MEDIA (June 2023), https://www.photonics.com/Articles/NASA_Proposes_Use_of_Lasers_to_Clear_and_Nudge/a68915/ [https://perma.cc/HKV9-HLYG] (describing the process of using lasers to nudge large orbital debris, the author explains that "[w]hen directed energy irradiates a piece of debris, it generates thrust on the object. The thrust is too weak to move the debris, but enough to potentially nudge it out of the way of a collision" which is the option "NASA presents for large debris."). This nudge can also be used to alter the course of a satellite that does not have the capability to maneuver. *See id.*

the large debris from orbit.[94] These laser-based nudging options, which NASA estimates to cost up to $6,000 per debris removed with ground-based lasers and $300 per debris removed with space-based lasers, are also available for de-orbiting small pieces of debris.[95] While acknowledging the perception that using laser systems in space raises a fear of weaponization, NASA argues that these fears are unfounded, as lasers used for debris remediation are roughly 1000 times less powerful than a laser used to destroy a spacecraft.[96] Moreover, the power level required for damaging a satellite's sensors is in the same power level range of a "laser guide star," which is commonly used by astronomy observatories.[97] For these reasons, NASA concluded that using a laser system to remediate orbital debris poses about as much of a weaponization risk as does ground-based astronomical observations.[98]

The NASA report further argued that taking immediate action will have "minimal financial drawbacks as high debris-cleaning impact[s] [are possible] within [only] a few years,"[99] and concluded that using laser systems would generate benefits exceeding their costs within a decade.[100] In contrast, the fastest financial break-even times for other remediation systems studied occur in twenty years at the earliest, and nearly a century at the latest.[101] Accordingly, NASA argued that "the near-term benefits of debris remediation may be significant enough on their own to incentivize immediate action . . . [and that these] benefits are small for each space operator, but when aggregated across all the operators in

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94 *See* Colvin, *supra* note 2, at 65.

95 *See id.* at v, 101, 102; *see also, e.g.*, *NASA Proposes Use of Lasers to Clear and Nudge Orbital Debris*, *supra* note 93 (describing the process of using lasers to "ablate" orbital debris, the author explains that, "in ablation, a laser strikes an object that is ejected approximately perpendicular to the surface and generates thrust in the opposite direction. Generally, the ejected material is a combination of hot gas and plasma and therefore does not contribute new debris to the environment.").

96 *See* Colvin, *supra* note 2, at 35–36 (arguing that "[l]asers in the power range appropriate for debris remediation have limited potential use as weapons . . . [as they] could still be used for dazzling or damaging satellite sensors." NASA explains, however, that "doing so requires lower power lasers that are already commonly available. Specifically, ground-based lasers as weak as 10 W can dazzle a satellite, while a 40 W laser guide star commonly used by astronomy observatories can permanently damage satellite sensors."). Therefore, NASA argues, "lasers [used] for debris remediation pose approximately as much weaponization risk as ground-based optical astronomy observatories." *Id.* at 36.

97 *Id.*

98 *Id.*

99 *See* Iyer, *supra* note 3.

100 *See* Colvin, *supra* note 2, at V.

101 *See id.* at 6 fig.16.

the U.S. space enterprise, their sum becomes meaningful."[102] While acknowledging that orbital debris in LEO will continue to increase even if no new satellites are launched, NASA sounded a note of caution of relying too heavily on the growth of commercial satellite constellations as a policy-making motivation, arguing that "[a]ttempts in the 1990s to establish large [satellite] constellations for communication services saw every constellation operator go bankrupt … [and] only one operator (Motorola / Iridium) launched their constellation prior to bankruptcy."[103] NASA further acknowledged, however, that even if "only one or two of these constellations materialize, they represent a substantial increase in the number of operational satellites in space and therefore an increase in the number of pieces of debris that can result from satellite failures or poor post-mission disposal procedures."[104]

Indeed, since NASA released its Cost-Benefit Analysis,[105] SpaceX launched an additional 1,815 Starlink satellites into orbit,[106] which represent a remarkable 174% increase of SpaceX's footprint in LEO. Additionally, several recent studies underline that the risk of LEO collisions will be increased by the deployment of satellite constellations, which includes the collision risk between individual constellations.[107] Because the Starlink and OneWeb constellations are the only constellations closest to full deployment, and therefore provide the most publicly available information for analysis,[108] one study found the Starlink constellation increased the total LEO collision probability by 5%,[109] and regarding OneWeb, concluded that the full deployment of its 48,000 second generation satellites would be altogether "hazardous in terms

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[102] *Id.* at 66.

[103] *Id.* at 9.

[104] *Id.*

[105] *Id.* at 94, tbl. 26 (noting the number of satellites in Starlink's constellation at the filing of the report at 1,815).

[106] *See id.*; *see generally, e.g.*, *West Coast Falcon 9 Launches SpaceX's 100th Starlink Mission*, SpaceFlight Now (Aug. 22, 2023), https://spaceflightnow.com/2023/08/22/west-coast-falcon-9-launches-spacexs-100th-starlink-mission/ [https://perma.cc/2ZFG-V649].

[107] *See generally, e.g.*, Chuan Chen & Wulin Yang, *The Impact of Large Constellations on Space Debris Environment and its Countermeasures*, 8th Eur. Conf. for Aeronautics and Space Scis. 1, 2–6 (2019); S. Le May et al., *Space Debris Collision Probability Analysis for Proposed Global Broadband Constellations*, 151 Acta Astronautica 445, 445-55 (2018); Jonas Radtke et al., *Interactions of the Space Debris Environment with Mega Constellations—Using the Example of the OneWeb Constellation*, 131 Acta Astronautica **55**, 67 (2017).

[108] *See, e.g.*, C. Parejo et al., *Effect of Mega Constellations on Collision Risk in Space*, 8th Eur. Conf. Space Debris (2021).

[109] *Id.*

of collision probability."[110] Moreover, a 2023 study argued that the maximum number of satellites that LEO can accommodate before triggering the Kessler syndrome is 72,000.[111] Underscoring the risks that satellite constellations pose to the sustainability of LEO, industry experts note that the global space market grew by 8% to $424 billion in 2022, and is expected to be valued at more than $737 billion by 2030,[112] which is a market that will certainly be impacted if LEO is enshrouded in an impenetrable maelstrom of orbital debris moving at speeds seven-times faster than a bullet.[113]

Given the current growth of the satellite constellation industry, and that the current population of satellites in LEO is 11,330, which represents a 37.94% increase since January 2022,[114] and the FCC's 2021 launch authorization[115] of an additional 30,000 Starlink satellites, and that the FCC is currently considering applications for an additional 64,000 satellites in LEO,[116] it is unwise to discount the growth of the commercial satellite constellation industry as a sufficient incentive to forge new orbital debris regulations. Accordingly, there is an "immediate need to address the [orbital] debris problem,"[117] as U.S. government and commercial infrastructure in LEO are at risk, and "[t]he faster [orbital] debris is addressed, the more space innovation and invention we will see in the coming decades."[118] Indeed, as the European Space Agency (ESA) argued in their June 2023 Annual Space Environment

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110 *Id.*

111 *See, e.g.*, Aneli Bongers & José L. Torres, *Orbital Debris and the Market for Satellites*, 209 Ecological Econs. 1, 3 (2023).

112 *See* United Nations**,** *supra* note 68, at 6; *see also* Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies, *supra* note 46 and accompanying text.

113 *See* The Week Staff, *supra* note 16.

114 *See* Andy, *How Many Satellites are Orbiting the Earth in 2023?*, Pixalytics (July 5, 2023), https://www.pixalytics.com/satellites-orbiting-earth-2023/ [https://perma.cc/6WXN-QLUP].

115 *See* Space Exploration Holdings, LLC, FCC 21 at 43–44 (2021) https://docs.fcc.gov/public/attachments/FCC-21-48A1.pdf [https://perma.cc/8KYU-EFDH].

116 *See, e.g.*, Press Release, Jessica Rosenworcel, Chairwoman, FCC, Rosenworcel Statement on Plan to Modernize the FCC by Establishing a Space Bureau and Office of International Affairs (Nov. 3, 2022), https://docs.fcc.gov/public/attachments/DOC-388826A1.pdf [https://perma.cc/7AC8-TH42] (noting that the "satellite industry is growing at a record pace, but here on the ground our regulatory frameworks for licensing them have not kept up," FCC Chairwoman, Jessica Rosenworcel, explained that "[o]ver the past two years the agency has received applications for 64,000 new satellites.").

117 *See* Iyer, *supra* note 3.

118 *Id.*

Report, "[t]he effect of adherence to [orbital] debris mitigation guidelines and regulations on a global level has a direct influence on the avoidance of the Kessler syndrome in [LEO]."[119]

III. HOW THE OUTER SPACE TREATY CONFERS JURISDICTION UPON THE FCC TO REGULATE ORBITAL DEBRIS

The OST, which was ratified by the U.S. Senate and therefore has the force of law,[120] forms the bedrock of the international community's efforts to regulate space activities and has nearly received universal acceptance among spacefaring nations.[121] In a desire "to contribute to broad international cooperation in the scientific as well as the legal aspects of the exploration and use of outer space,"[122] Article I of the OST provides that outer space must be explored and used "for the benefit and in the interests of all countries" and, therefore, "shall be the province of all mankind."[123] Article I further provides that all nations must be free to use and explore outer space "on a basis of equality," and that they must

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119 *See, e.g.*, EUR. SPACE AGENCY, ESA'S ANN. SPACE ENV'T REP. 116 (2023), https://www.sdo.esoc.esa.int/environment_report/Space_Environment_Report_latest.pdf [https://perma.cc/2PND-VLSY].

120 *See, e.g.*, U.S. DEPT. OF STATE, TREATY ON PRINCIPLES GOVERNING THE ACTIVITIES OF STATES IN THE EXPLORATION AND USE OF OUTER SPACE, INCLUDING THE MOON AND OTHER CELESTIAL BODIES (1967) (noting that the OST received unanimous consent in the U.S. Senate) https://2009-2017.state.gov/t/isn/5181.htm [https://perma.cc/E3US-MVUF].

121 *See* Runnels, *supra* note 12, at 198 (describing the OST as the "centerpiece of the international community's efforts at regulating space activities and has received near universal acceptance among spacefaring nations"); *see* Colin B. Picker, *A View from 40,000 Feet: International Law and the Invisible Hand of Technology*, 23 CARDOZO L. REV. 149, 177 (2001) (describing the OST as "the 'Magna Carta' of space."); Ricky J. Lee, *Reconciling International Space Law with the Commercial Realities of the Twenty-First Century*, 4 SING. J. INT'L & COMPAR. L. 194, 197 (2000) (noting that the OST has "the widest acceptance in the international community" and "must be regarded as the basic charter of international space law"); Jennifer M. Seymour, Note, *Containing the Cosmic Crisis: A Proposal for Curbing the Perils of Space Debris*, 10 GEO. INT'L ENV'T L. REV. 891, 899 (1998); Heidi Keefe, Essay, *Making the Final Frontier Feasible: A Critical Look at the Current Body of Outer Space Law*, *in* 11 SANTA CLARA COMPUT. & HIGH TECH. L.J. 345, 349 (1995) (arguing that the OST is the "cornerstone of all space law"); Harminderpal Singh Rana, Note, *The "Common Heritage of Mankind" & the Final Frontier: A Revaluation of Values Constituting the International Legal Regime for Outer Space Activities*, 26 RUTGERS L.J. 225, 250 (1994) (arguing that "[t]he legitimacy of the [OST] is unquestioned in international space law.").

122 *See* Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies, *supra* note 21, at Preamble.

123 *See id.* at art. I.

"facilitate and encourage international cooperation in [scientific] investigation."[124] Accordingly, Article II provides that "[o]uter space . . . is not subject to national appropriation by claim of sovereignty, by means of use or occupation, or by other means."[125] Article III addresses the adverse environmental impacts caused by space operations and provides that signatory nations shall conduct their activities in outer space "in accordance with international law";[126] the environmental aspects of which were later clarified by the U.N.'s Guidelines for the Long-Term Sustainability of Outer Space Activities (LTSG),[127] which was adopted by the United States in 2019.[128]

The LTSG reemphasizes the principle contained in Article III of the OST that national activities "in the exploration and use of outer space shall be carried out in accordance with international law, including the Charter of the United Nations. Accordingly, [nations] should build on these principles when developing and conducting their national activities in outer space."[129] Therefore, the LTSG recommends that in drafting national legislation implementing the OST, nations should address risks to the environment associated with in-orbit operating and "support the idea of minimizing the impacts of human activities on Earth as well as on the outer space environment."[130] Moreover, the

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[124] *Id.*

[125] *Id.* at art. II.

[126] *See id.* at art. III (prescribing that "States Parties to the Treaty shall carry on activities in the exploration and use of outer space, including the Moon and other celestial bodies, in accordance with international law, including the Charter of the United Nations, in the interest of maintaining international peace and security and promoting international co-operation and understanding.").

[127] *See* Comm. On the Peaceful Uses of Outer Space, Guidelines for the Long-Term Sustainability of Outer Space Activities, U.N. Doc. A/AC.105/2018/CRP.20, at I, ¶ 1 (2018), https://www.unoosa.org/res/oosadoc/data/documents/2018/aac_1052018crp/aac_1052018crp_20_0_html/AC105_2018_CRP20E.pdf [https://perma.cc/5VFQ-E4QH] [hereinafter LTSG].

[128] *See* Comm. On the Peaceful Uses of Outer Space, U.N. Doc. A/74/20, ¶ 163 (2019).

[129] LTSG, *supra* note 127, ¶ 7.

[130] *Id.* at II.A.2, ¶ 2(d). The relevant enabling provisions of the LTSG recommend that when enacting regulatory frameworks, States should:

> (c) Address, to the extent practicable, risks to people, property, public health and the environment associated with the launch, in-orbit operation and re-entry of space objects;
>
> (d) Promote regulations and policies that support the idea of minimizing the impacts of human activities on Earth as well as on the outer space environment. They are encouraged to plan their activities based on the Sustainable Development Goals, their main national requirements and international considerations for the sustainability of space and the Earth.

Id. ¶ (II)(A)(2)(c)-(d).

background text accompanying the LTSG makes clear that the guidelines were developed with the adverse impacts of satellite constellations on the sustainable development of Earth orbits in mind, explaining that "Earth's orbital space environment constitutes a finite resource," and that "[t]he proliferation of [orbital] debris, . . . the emergence of large [satellite] constellations and the increased risks of collision and interference with the operation of space objects may affect the long-term sustainability of space activities."[131]

Regarding the regulation of commercial satellite operators, Article VI of the OST provides that "[p]arties to the treaty shall bear international responsibility for [their] activities in outer space" whether "carried on by governmental agencies or by non-governmental entities,"[132] and therefore requires the "authorization and continuing supervision"[133] of commercial operators. Article VIII of the OST further provides that nation signatories, "on whose registry an object launched into outer space is carried shall retain jurisdiction and control over such object . . . while in outer space."[134] Additionally, under Article VII, parties to the treaty will be held "internationally liable" for damages caused by an object launched into outer space.[135] For these reasons, when the U.S. creates regulations regarding the commercial space industry, it is also creating domestic implementing legislation of the OST.[136]

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131 *See id.* at I, ¶ 1.

132 *See* Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies, *supra* note 21, at art. VI.

133 LTSG, *supra* note 130, at II.A, ¶ A.3.2.

134 Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies, *supra* note 21, at art. VIII. The issue of each nation's jurisdiction is addressed under a transnational law through a system of registration. The 1976 Registration Convention requires a launching nation to maintain a registry of launched space objects. The convention provides that "[w]hen a space object is launched into earth orbit . . . the launching State shall register the space object by means of an entry in an appropriate registry which it shall maintain." *See* Convention on Registration of Objects Launched into Outer Space art. II, ¶ 1, Nov. 12 ,1974, S. TREATY Doc. No. 94-18, 1023 U.N.T.S. 15.

135 *See* Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies, *supra* note 21, at art. VII; *see also* Convention on International Liability for Damage Caused by Space Objects art. 2, Mar. 29, 1972, 24 U.S.T. 2389, 961 U.N.T.S. 187 (adopted to clarify the intent of art. VII of the OST); Meghan R. Plantz, Note, *Orbital Debris: Out of Space*, 40 GA. J. INT'L & COMP. L. REV. 585, 603 (2012).

136 *See* Major John S. Goehring, *Properly Speaking, the United States Does Have an International Obligation to Authorize and Supervise Commercial Space Activity*, 78 A.F. L. Rev. 101, 104 (2018) (identifying the need for Congress to fill in regulatory

The FCC's authority to regulate commercial satellites derives from the U.S.'s signatory status to the International Telecommunication Union Treaty, which requires commercial entities to obtain a license from their host government before installing or operating a transmitting station.[137] To comply with the treaty, Congress amended the Act to delegate the authority to process satellite license applications and otherwise regulate commercial satellites to the FCC.[138] "[U]nder its mandate to regulate radio communications in the public interest,[139] the FCC provides the most comprehensive regulatory oversight among U.S. agencies regarding commercial satellite" activity in Earth orbits.[140] While the OST provides no specific language regarding orbital debris, Article IX requires that signatory nations must conduct their exploration and use of outer space in manners that do not cause a "potentially harmful interference" with the use of outer space by other nations.[141] Given

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mechanisms in order to fulfill U.S. obligations pertaining to "authorization and continuing supervision" of outer space activities under the OST).

[137] *See* 1995 Revision of Radio Regulations art. S18.1, Nov. 17, 1995, S. Treaty Doc. No. 108-28 (2008). For more information on ITU regulatory publications see the ITU Radiocommunication Sector (ITU-R) webpage at: https://www.itu.int/en/ITU-R/Pages/default.aspx. The United States is bound by ITU documents and implements many of the specific technical obligations through regulations, such as those promulgated by the FCC. *See generally* Lawrence D. Roberts, *A Lost Connection: Geostationary Satellite Networks and the International Telecommunication Union*, 15 Berkeley Tech. L.J. 1095, 1106, 1111 (2000).

[138] *See generally* Communications Satellite Act of 1962, Pub. L. No. 87-624, § 101, 76 Stat. 419.

[139] *See* Communications Act of 1934, Pub. L. No. 73-416, 48 Stat. 1064, at § 307(a) (1934); *see also* Jordan L. Regenie, *On-Orbit Services Are Ready for Lift Off: Existing U.S. Regulations Can Usher in a New Era of Commercial Space Activity*, 18.1 Colo. Tech. L.J. 227, 240–41 (2020) (regarding commercial satellites, arguing that the U.S. meets its obligations under the OST through FCC regulation).

[140] Jordan L. Regenie, *On-Orbit Services Are Ready for Lift Off: Existing U.S. Regulations Can Usher in a New Era of Commercial Space Activity*, 18.1 Colo. Tech. L.J. 227, 240–41 (2020); *see generally* Runnels, *supra* note 140, at 201.

[141] Regarding the environmental protection arising from Article IX of the OST, the OST provides, in relevant part, that:

> [i]n the exploration and use of outer space . . . States Parties to the Treaty . . . shall conduct all their activities in outer space . . . with due regard to the corresponding interests of all other States Parties to the Treaty. States Parties to the Treaty shall pursue studies of outer space, including the Moon and other celestial bodies, and conduct exploration of them so as to avoid their harmful contamination . . . If a State Party to the Treaty has reason to believe that an activity or experiment planned by it or its nationals in outer space . . . would cause potentially harmful interference with activities of other States Parties in the peaceful exploration and use of outer space . . . it shall undertake appropriate international consultations before proceeding with any such activity or experiment.

See Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies, *supra* note 21, at art. IX; *see also* Michael S. Dodge, *Regulating Orbital Debris: The Federal*

the U.S.'s adoption of the LTSG,[142] the creation of orbital debris constitutes an example of "harmful interference" with the use of the outer space environment by other nations.[143] Accordingly, the catalyst for the FCC's first orbital debris rules in 2004 was an acknowledgment from the U.S. government that orbital debris poses a significant risk to operational spacecraft,[144] noting that the definition of "space object" under the OST includes the "component parts of a space object,"[145] which arguably "incorporate[s] orbital debris resulting from satellite operations."[146] However, while FCC rules may appear to closely adhere to the OST, their rules in practice reveal that they do not.

Indeed, the FCC's regulatory practice of assigning orbital shells[147] to satellite constellation operators on a first-come, first-served basis,[148] without any formal assessment of the effects on the use of LEO by other nations[149] or the likely orbital debris-related

Communications Commission Tackles Space Junk, 96 N.D. L. Rev. 181, 187 (2021) (arguing that FCC regulations governing orbital debris can be traced back to U.S. obligations under the OST).

142 *See generally* The National Space Policy, 85 Fed. Reg. 81755 (Dec. 9, 2020).

143 *See generally* Richard Green et al., SATCON**2:** Policy Working Group Report 17(2021), https://baas.aas.org/pub/q099he5g [https://perma.cc/8LKQ-CRF8] (discussing how the FCC's "first-come, first-served" allocation practice harmfully interferes with ground-based astronomy).

144 *See* Mitigation of Orbital Debris, 19 FCC Rcd. 1, 5, 9 (June 21, 2004) (explaining that between 2000 and 2003 the FCC adopted orbital debris mitigation disclosure for certain classes of satellites. The FCC further explains that robotic spacecraft are typically controlled through radiocommunications links, and thus there is a direct connection between the satellite's radiocommunications functions and the physical operations of spacecraft); *see also* Establishment of Domestic Communications-Satellite Facilities by Nongovernmental Entities, 22 F.C.C.2d 86, 129, 133 (1970) (explaining the Commission's opinion that the Act "clearly include[s] non-Government satellite and earth station facilities used for interstate communication or transmission of energy by radio" and concluding that the Act provides the Commission with the requisite legal authority to "authorize domestic communications satellite facilities upon finding that such facilities would serve the public convenience, interest, or necessity").

145 *See* Mitigation of Orbital Debris, *supra* note 144, at 46, para. 109.

146 *Id.*

147 An "orbit" is the orbital path that any given object orbits the Earth. *See generally What Is an Orbit?*, NASA (Aug. 7, 2017), https://www.nasa.gov/audience/forstudents/5-8/features/nasa-knows/what-is-orbit-58.html [https://perma.cc/5BN9-SALX].

148 *See, e.g.*, FCC, IB Docket No. 16-408, Fact Sheet, Updating Rules for Non-Geostationary-Satellite Orbit Fixed-Satellite Service Constellations 17 (2017), https://transition.fcc.gov/Daily_Releases/Daily_Business/2017/db0907/DOC-346584A1.pdf [https://perma.cc/W6CV-EJNQ]; *see generally* Runnels, *supra* note 31 (discussing how the FCC's "first-come, first-served" allocation practice may violate the OST).

149 *See* Runnels, *supra* note 35 (noting the FCC's lack of consideration of how its LEO assignment procedures interferes with the use of outer space by other nations).

environmental impacts to those orbits,[150] likely violates Article I of the OST, which declares that outer space must be explored and used "for the benefit and in the interests of all countries."[151] Although FCC regulators have not claimed sovereignty over these LEO shells, they have certainly enabled commercial satellite operators to saturate them with satellites; these saturated shells, accompanied by the likely resulting orbital debris,[152] could make any further satellite launches into LEO prohibitively dangerous.[153] Such a de facto occupation of orbital shells may, in the long-term, constitute a "national appropriation" of outer space "by means of use or occupation, or by other means,"[154] which would violate Article II of the OST, in addition to Article IX, which requires nations to conduct their activities in outer space in a way that does not cause "potentially harmful interference" with the use of outer space by other nations.[155] For these reasons, the FCC cannot continue its current practice of maintaining the conditions for a safe, stable, accessible, and sustainable LEO environment by ignoring the environmental impacts that FCC-licensed satellite constellations may have on other space users, which only serves to compound the looming dangers of the Kessler syndrome.[156]

IV. WHO SHOULD PAY WHEN ORBITAL DEBRIS "TRICKLES-DOWN" IN A TRAGIC LEO COMMONS?

A. Our Tragic LEO Commons

As is true for many environmental problems, the control of the orbital debris environment may initially be expensive, but failure

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150 *Id.*; *see also* Long, *supra* note 24, at 6.

151 *See* Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies, *supra* note 21, at art. I.

152 *See supra* notes 84–93 and accompanying text; *see also* discussion *supra* Section II.B.

153 *See, e.g.*, discussion *supra* Section II.B; *see also* John Gapper, *Elon Musk's SpaceX Is Seizing Power in Space with Satellites*, Fin. Times (Apr. 29, 2021), https://www.ft.com/content/49514bb1-fed0-4efe-8d86-b314ca66df40 [https://perma.cc/LT54-UHG3] (claiming that "Musk intends to boldly go where no regulator can reach him" and detailing how, as a consequence of the number of Starlink satellites in orbit, "there will not be much orbital space left without a satellite in it").

154 *See* Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies, *supra* note 21, at art. II.

155 *See id.* at art. IX.

156 *See generally* Runnels, *supra* note 12; *see also* Runnels, *supra* note 32 and accompanying text.

to control leads to disaster in the long-term. Catastrophic collisions between catalogued objects in [LEO] are now an important environmental issue that will dominate the debris hazard to future spacecraft.[157]

NASA argues that "LEO is an orbital space junk yard"[158] that is "now viewed as the World's largest garbage dump,"[159] all of which is underwritten by the fact that "there are no international space laws to clean up debris in our LEO."[160] In lieu of no international laws governing the environmental impacts to LEO, there are voluntary orbital debris mitigation guidelines, which NASA rightly considers as ineffective due to their voluntary nature.[161] Aligned with NASA's skepticism of voluntary guidelines is Donald Kessler,[162] who argues that "commercial organizations seek to provide services as inexpensively as possible to maximize profit . . . [but] following guidelines adds cost,"[163] so there is an economic incentive

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157 Kessler, *supra* note 15.

158 *See Space Debris*, NASA (Sept. 27, 2023), *https://www.nasa.gov/headquarters/library/find/bibliographies/space-debris/ [https://perma.cc/933P-F3D6]* (noting the origin and steps needed to effectively address orbital debris in LEO).

159 *Id.*

160 *Id.*

161 *See, e.g.*, NASA Off. Inspector Gen., *supra* note 4, at 16. Detailing the conditional effectiveness of voluntary orbital debris mitigation guidelines, the report notes that:

> [A]t the February 2020 United Nations Committee on the Peaceful Uses of Outer Space meeting in Vienna, Austria, the United States urged all spacefaring nations, emerging space nations, international organizations, and non-government organizations to implement orbital debris mitigation guidelines to limit the generation of debris. However, adopting voluntary guidelines does not ensure compliance, as demonstrated when China and India—both signatories of the Inter-Agency Debris Coordination Committee—conducted their anti-satellite tests in 2007 and 2019, respectively, resulting in the creation of additional orbital debris. At a September 2020 congressional committee hearing, NASA's Administrator commented, "[T]here has been a lot of activity from our international friends who don't necessarily follow the guidelines. While countries sign on to the guidelines, it does not necessarily mean they fully adhere to the guidelines."

Id.; see also generally Pearson & Schmitt, *supra* note 20 and accompanying text regarding the environmental impacts of Russia's October 2022 anti-satellite test.

162 *See* 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/ [https://perma.cc/D5QS-VKSX]; *see also* Union of Concerned Scientists, *UCS Satellite Database, In-Depth Details on the 1,957 Satellites Currently Orbiting Earth*, Union Concerned Scis. (Nov. 30, 2018), https://www.ucsusa.org/nuclear-weapons/space-weapons/satellite-database#.W7kmW5NkhmA [https://perma.cc/7GGE-7DE7].

163 *See* Debra Werner, *Will Megaconstellations Cause a Dangerous Spike in Orbital Debris*, SpaceNews (Nov. 15, 2018), https://spacenews.com/will-megaconstellations-cause-a-dangerous-spike-in-orbital-debris/ [https://perma.cc/82YC-5BXK] (quoting Donald Kessler's arguments that our current regulatory regime is predictably leading to an orbital tragedy of the commons).

for corporations to not follow voluntary guidelines. This short-term wealth maximization behavior, particularly when it creates externalities,[164] like orbital debris, is not only typical of the modern American corporation[165] but is also a typical "tragedy of the commons"[166] dynamic.

Considering the economic dynamic created by this short-term behavior as a classical tragedy of the commons problem, Kessler argues that "[y]ou [economically] prosper the most if you do the most but it's not good for the environment. And the environment can be contaminated for everybody."[167] Garrett Hardin's

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[164] *See, e.g.*, Harold Demsetz, *Toward a Theory of Property Rights*, 57 AM. ECON. REV. 347, 347–50 (May 1967) (providing a foundational conception of property rights, Demsetz famously observed that property rights in a resource tend to emerge to help "internalize externalities when the gains of internalization become larger than the cost of internalization."). An externality arises when "the activity of one entity . . . directly affects the welfare of another in a way that is not transmitted by market prices." HARVEY S. ROSEN, PUBLIC FINANCE 86 (5th ed. 1999); *see also* Mario J. Rizzo, *Law Amid Flux: The Economic of Negligence and Strict Liability in Tort,* 9 J. LEGAL STUD. 291, 298 (1980) (describing a major purpose of tort law as a means of internalizing the cost of external harms, thereby incentivizing actors to find ways to reduce their cost by decreasing external harms); JOEL BAKAN, THE CORPORATION: THE PATHOLOGICAL PURSUIT OF PROFITS AND POWER 1–2 (Fred Hill, 2004) (discussing the behavioral characteristics of the corporate form and noting that the "corporation's legally defined mandate is to pursue, relentlessly and without exception, its own self-interest, regardless of the often harmful consequences it might cause to others"). As such, the fact that millions of pieces of unattributed space junk currently orbit Earth should be of surprise to no one. For an influential account, *see generally*, Robert C. Ellickson, *Property in Land*, 102 YALE L. J. 1315, 1334 (1993); Jared B. Taylor, Note, *Tragedy of the Space Commons: A Market Mechanism Solution to the Space Debris Problem*, 50 COLUM. J. TRANSNAT'L L. 253, 276 (2011).

[165] *See, e.g.*, LAWRENCE E. MITCHELL, CORPORATE IRRESPONSIBILITY: AMERICA'S NEWEST EXPORT 276 (2001) (highlighting that since American companies are legally incentivized to focus on the short-term wealth maximization of their shareholders, and that a defining feature of these companies are their limited liability, such companies are necessarily incentivized to become externalizing machines). Indeed, Mitchell argues that "[j]ust as evolution has made the shark a perfect eating machine . . . limited liability has allowed the corporation to perfect its function . . . [which permits] corporations to externalize the costs of stock price maximization, that is, to push those costs onto others. The corporation is the perfect externalizing machine." *Id.* at 53.

[166] *See generally* Garrett Hardin, *The Tragedy of the Commons*, 162 SCI. 1243, 1243–48 (1968). Garrett Hardin's essay of the same name, "Tragedy of the Commons," is one of the most cited policy articles of our time. KARLSON JAMES HARGROVES & MICHAEL H. SMITH, THE NATURAL ADVANTAGE OF NATIONS: BUSINESS OPPORTUNITIES, INNOVATION AND GOVERNANCE IN THE 21ST CENTURY 178 (2005); *see also* Holly Caggiano & Laura F. Landau, *A New Framework for Imagining the Climate Commons? The Case of a Green New Deal in the US*, 21(4) PLAN. THEORY 380, 381–82 (2021).

[167] *See* Werner, *supra* note 163 (quoting Donald Kessler's arguments that our current regulatory regime is predictably leading to an orbital tragedy of the commons).

often-cited tragedy of the commons scenario, which has framed environmental policy debates for decades,[168] deftly portrays this tragedy in its description of herders entering a pasture open to all other herders, i.e., a "commons," stating:

> Picture a pasture open to all. It is to be expected that each herdsman will try to keep as many cattle as possible on the commons. . . . As a rational being, each herdsman seeks to maximize gain. Explicitly or implicitly . . . he asks, "What is the utility to me of adding one more animal to my herd?" This utility has one negative and one positive component.
>
> 1) The positive component is a function of the increment of one animal. Since the herdsman receives all the proceeds from the sale of the animal, the positive utility is nearly + 1.
> 2) The negative component is a function of the additional overgrazing created by more than one animal. Since, however, the effects of overgrazing are shared by all the herdsmen, the negative utility for any particular decision-making herdsman is only a fraction of -1.
>
> Adding together the component partial utilities, the rational herdsman concludes that the only sensible course for him is to add another animal to his herd. And another, and another. . . . But this is the conclusion reached by each and every rational herdsman sharing a commons. Therein is the tragedy.[169]

LEO typifies Hardin's cattle pasture, as free access to LEO leaves it vulnerable to overuse,[170] an overuse that is quickly becoming a defining feature of SpaceX's Starlink.

Responding to critics that Starlink is squeezing out future satellite competitors through its de facto occupation of LEO orbital shells, Elon Musk demonstrated the utility of Hardin's analysis by arguing that "[s]pace is just extremely enormous, and satellites are very tiny . . . . This is not some situation where we're blocking others in any way . . . [so there is] room for tens of billions of satellites. A couple of thousand satellites is nothing."[171] While the universe may be practically infinite,[172] the Earth's or-

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168 *See generally* Mitchell, *supra* note 165 and accompanying text.

169 *See* Hardin, *supra* note 166, at 1244.

170 *See* Micheal B. Runnels, *Protecting Earth and Space Industries from Orbital Debris: Implementing the Outer Space Treaty to Fill the Regulatory Vacuum in the FCC's Orbital Debris Guidelines*, 60 Am. Bus. L.J. 175, 195 (Mar. 30, 2023).

171 *See* Richard Waters, *Elon Musk Rejects Claims He Is Squeezing out Rivals in Space*, Fin. Times (Dec. 29, 2021), https://www.ft.com/content/18dc896f-e92f-41f7-9259-69cfd8d61011 [https://perma.cc/DQ5E-KZ7X] (noting Elon Musk is the CEO and CTO of SpaceX).

172 *See* Rahul Rao, *10 Years Ago, a Stunning Sci-Fi Thriller Exposed a Growing Threat to Space Exploration*, Inverse (Oct. 31, 2023), https://www.inverse.com/science/

bital space is not.[173] And given that Musk's arguments are contradicted by multiple studies conducted by NASA,[174] in addition to other scientific studies demonstrating that the current trajectory of satellite constellation growth is endangering the exploration and scientific investigation of outer space,[175] it should be clear that commercial satellite operators are facing the same calculus as Hardin's farmers: the increased risks of triggering the Kessler syndrome caused by launching more satellites into LEO is spread among all users, though each operator reaps the full benefit of launching satellites in ways that will trigger the Kessler syndrome. Therein is the tragedy of the LEO commons.[176]

B. Under the OST & the Proposed ORBITS Act of 2023, the American Taxpayer Pays

As noted earlier,[177] the OST requires that signatories to the treaty bear international responsibility for national activities in space, whether carried out by governmental or nongovernmental entities,[178] and under Article VII, provides that each signatory launching or procuring the "launching of an object into outer space . . . is internationally liable for damage to another [signatory] to the Treaty or to its natural or juridical persons by such object or its component parts on the Earth, in air space or in outer space."[179]

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gravity-kessler-syndrome-real-danger-nasa-space (explaining that "[w]hile space might be practically infinite, the orbital space around our planet is not," Runnels argues that LEO should be regulated "as a finite space, as we do the oceans, as we do the air"); *see also* Khatchadourian, *supra* note 14 (noting the dynamics of LEO orbits and writing that "[t]he universe may be infinite—a 'big sky,' as some NASA officials have described it—but even an endless amount of space is too small if you can occupy only a tiny bit of it.").

173 *See* Nat'l Sci. and Tech. Council, *supra* note 85, at 5 (defining Earth orbits as "finite resources [that] can be threatened by the rapid, uncontrolled increase in orbital debris"); *see also, e.g.*, Miles Lifson & Richard Linares, *Is There Enough Room in Space for Tens of Billions of Satellites, as Elon Musk Suggests? We Don't Think So*, SpaceNews (Jan. 4, 2022), https://spacenews.com/op-ed-is-there-enough-room-in-space-for-tens-of-billions-of-satellites-as-elon-musk-suggests -we-don't-think-so/ [https://perma.cc/5YH8-86QJ].

174 *See, e.g.*, NASA Off. Inspector Gen., *supra* note 4, at 14.

175 *See* Cong. Budget Off. *supra* note 6, at 12, 16; *see also supra* notes 38, 107, 108, and 111; *see also* discussion, *supra* Section II.A.

176 *See* Lee Anne Fennell, *Common Interest Tragedies*, 98 Nw. U. L. Rev. 907, 914 (2004) (explaining that tragedies of the commons occur when necessary care of common resources is not undertaken).

177 *See, e.g.*, discussion *supra* Part III.

178 *See* Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies, *supra* note 21, at art. VI.

179 *Id.* at art. VII.

The Liability Convention clarifies the intent of Article VII in its provision that a "launching state shall be absolutely liable to pay compensation for damage caused by its space objects on the surface of the Earth or to aircraft flight."[180] Regarding damage caused somewhere other than on the surface of the Earth, such as to spacecraft of another nation, to persons, or to property on board of a spacecraft, the Liability Convention provides that the launching state[181] "shall be liable only if the damage is due to its fault or the fault of persons for whom it is responsible."[182] Accordingly, and given that the FCC interprets the OST's language: "component parts of a space object,"[183] to include orbital debris, the FCC argues that "under international law, the U.S. government could potentially be presented with a claim under the Liability Convention for certain damage that may result from private space station operations, including disposal, maneuvering, and the generation of orbital debris."[184] In addition to the FCC's interpretation of the OST as holding the U.S. government and therefore, the U.S. taxpayer, liable for claims arising from the activities of commercial satellite operators, the proposed ORBITS Act also leaves the U.S. taxpayer on the hook for damages arising from commercially caused orbital debris.[185]

The ORBITS Act, which enjoys wide bipartisan support:[186] (1) directs NASA and other federal agencies to publish and periodically update a list of identified orbital debris that pose the greatest immediate risk to the safety of LEO satellites and other on-orbit activities; (2) establishes a NASA demonstration program to encourage the development of technologies to remediate the debris on this list; (3) directs NASA to conduct research and other development activities to promote technologies for remediating orbital debris;[187] and (4) directs federal agencies, including

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180 *See* Liability Convention, supra note 135, at art. VII.

181 A "launching state" is defined as either 1) a State which launches or procures the launching of a space object; or 2) a State from whose territory or facility a space object is launched. *See id.* at art. I.

182 *See id.* at art. II.

183 *See* Mitigation of Orbital Debris, *supra* note 144, at 46, ¶ 109.

184 *See id.* at ¶ 110.

185 *See* discussion, *supra* Part I.

186 Press Release, Maria Cantwell & John Hickenlooper, ORBITS Act Would Support Techs. to Clear the Nearly 1 Million Pieces of Dangerous Orbital Debris That Endanger Astronauts and Satellites, U.S. S. Comm. Com., Sci., & Transp. (July 27, 2023), https://www.commerce.senate.gov/2023/7/cantwell-hickenlooper-orbits-act-to-clean-up-space-junk-heads-to-full-senate [https://perma.cc/X9LU-35NZ]; *see also supra* note 26.

187 *Id.*

the FCC, to update their regulations regarding orbital debris.[188] In support of these efforts, the bill authorizes NASA to acquire commercial, non-profit, or academic institution-provided orbital debris remediation services, and allocates $150 million in competitive grant awards for these efforts.[189] As noted earlier and just as is the case concerning liability arising under the OST,[190] the significance of this ORBITS Act funding provision "signals that the U.S. taxpayer, rather than commercial space companies themselves, may foot the bill for remediating the debris left behind by commercial satellites."[191] As it is uncontested that commercial satellite constellation operators are both the primary drivers of the increased collisional risk in LEO and the primary economic beneficiaries of their saturation of available LEO orbital shells,[192] levying a fee for the use of these finite valuable resources is a rational way to address the incentives that create more orbital debris. That is, without a mechanism to secure exclusive property rights to use the orbital resource, commercial satellite constellation operators will use the resource until it is no longer profitable to do so, which would be a tragic result for our LEO commons . . . a tragedy that lawmakers can avoid.[193]

C. Trickle-Down Economics Meets Physics & the Recommendation to Levy an "Orbital Use Fee" as a Requirement for Commercial Satellite Launch

"My fellow Americans, trickle-down economics has never worked."[194]

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188 *See supra* note 27.

189 *See* Hill, *supra* note 28.

190 *See* discussion, *supra* Part I.

191 *See* Hill, *supra* note 28.

192 *See* discussion, *supra* Section II.A; *see also* discussion, *supra* Section IV.A.

193 *See, e.g.*, discussion *supra* Section IV.A; *see also generally* Akhil Rao et al. *Orbital-Use Fees Could More Than Quadruple the Value of the Space Industry*, 117 Procs. Nat'l Acad. Scis. 12756, 12756 (2020) (framing the dynamic among commercial satellite operators in LEO as a tragedy of the commons, the authors provide an economic analysis in favor of creating an orbital-use fee).

194 *See* Joe Biden, President, First Joint Address to Congress, (Apr. 28, 2021) CNN (Apr. 28, 2021), https://edition.cnn.com/politics/live-news/biden-address-fact-check-updates-04-28-21/h_b99259226c5a2b76db1d83 d 415bd5ebe [https://perma.cc/7UMJ-M9WE] (quoting President Biden during his first address to a joint session of Congress as the President delivered a full-throated critique of trickle-down economics theory); *see also generally* Jacob S. Hacker & Paul Pierson, Winner-Take-All Politics: How Washington Made the and Turned Its Back on the Middle Class 20 (2010); *see, e.g.*, Paul Craig Roberts, The Breakdown of the Keynesian Model, in Supply-Side Economics: A Critical Appraisal 1-2 (University

While the current U.S. liability regime clearly leaves the U.S. taxpayer with footing the bill for damages caused by trickling down[195] commercial orbital debris,[196] it is similarly clear that the economic benefits gained by commercial satellite operators in LEO will not eventually trickle down to the same U.S. taxpayer.[197] This is mostly due to the intellectual bankruptcy of trickle-down economics theory, which is based on the notion that market success somehow trickles down to benefit the consumer because it reflects consumer interests.[198] As business practices in the LEO commercial satellite constellation industry have yet to normalize, lawmakers face a choice of whether the U.S. taxpayer should pay for these foreseeable corporate externalities, or whether

Publications of America, Inc. eds., 1982) (criticizing the Keynesian approach); *see* Paul Brietzke, *New Wrinkles in Law . . . And Economics*, 32 VAL. U. L. REV. 105, 125 (1997) (asserting that a neoclassical economics does not operate in developing countries or the ghettoes of U.S. cities; such equilibria as can be discovered usually perpetuate a stagnation); *Id.* at 129 (the inability of neoclassical economists to identify a coherent and compelling "public interest" will exacerbate democratic crises); *Id.* at 131 (describing the dehumanizing abstractions of neoclassical economics: a natural rate of unemployment, the advantages of a "balanced" budget, free trade, endowing welfare for the poor, and the downsizing and trickle-down distributions that are identified with efficiency—as opposed to an adequate number of jobs at a living wage and other recognitions of the dignity interest); *see* John B. Kirkwood & Robert H. Lande, *The Fundamental Goal of Antitrust: Protecting Consumers, Not Increasing Efficiency*, 84 NOTRE DAME L. REV. 191, 240 (2008). Kirkwood and Lande define "trickle-down economics" as "the hope that if we allow businesses to take from consumers in the short run, then eventually, somehow, in some indirect, uncertain and difficult to explain long-run manner, the money will find its way back to society as a whole . . . so that all told we will all be better off." *Id.* at 239; *see* Robert H. Frank, *In the Real World of Work and Wages, Trickle-Down Economics Doesn't Hold Up*, N.Y. TIMES (Apr. 12, 2007), http://www.nytimes.com/2007/04/12/business /12scene.html [https://perma.cc/NRG9-FUXH]; *see, e.g.*, LESTER THUROW, DANGEROUS CURRENTS: THE STATE OF ECONOMICS xvii (1983) (challenging a core principle of Keynesian economics, Thurow argues that he is "convinced that accepting the conventional supply-demand model of the economy is rather like believing that the world is flat, or that the sun revolves around the earth - you can make a rigorous case, on paper, for both propositions, but hard evidence is more than a bit scarce. Moreover, if you chose to act on either belief, you can get into a lot of trouble").

195 *See* Reich, *supra* note 40 and accompanying text.

196 *See* discussion, *supra* Section IV.B.

197 *See id.*; *see also* Frank, *supra* note 194 and accompanying text; *see also* William Lazonick, *Profits Without Prosperity*, HARV. BUS. REV., (Sept. 2014), https://hbr.org/2014/09/profits-without-prosperity [https://perma.cc/7AFQ-ANNL] (explaining that as corporations and executives raked in greater amounts of profits, job stability and wages floundered and declined, leading to an unequal and broken economy); *see also* Ronald Chen & Jon Hanson, *The Illusion of Law: The Legitimating Schemas of Modern Policy and Corporate Law*, 103 MICH. L. REV. 1, 31–32 (2004).

198 *See* Reich, *supra* note 40 and accompanying text; *see also generally* Kirkwood, *supra* note 194 and accompanying text.

the primary corporate driver of these orbital debris externalities should internalize them.[199] While focusing exclusively on the remediation of orbital debris may seem to be the most rational policy path forward, reducing debris and collision risk within a tragic LEO commons, characterized by unfettered open access,[200] actually incentivizes additional satellite launches that "eventually restores [both] the debris and risk."[201] For these reasons, "the core of the [orbital] debris problem is incentives, not technology."[202]

In other sectors of the U.S. economy, addressing the tragedy of the commons is often a game of catch-up with considerable social costs, which the fledging commercial satellite constellation industry can avoid before these costs surge and metastasize into the Kessler syndrome.[203] Cross-referencing the most current orbital debris numbers from the ESA[204] with NASA's estimated costs of $300 per debris removed with ground-based lasers and $6,000 per debris removed with space-based lasers;[205] the total estimated cost to remove the 1,036,500 trackable pieces of orbital debris from LEO is from 310 million to 6.2 billion dollars, while the cost to remove the estimated 130 million pieces of untraceable orbital debris from LEO is from 39 to 780 billion dollars; all of which is a sizeable liability for the U.S. government to allocate to the U.S. taxpayer. As argued by the FCC in their 2020 update to the 2004 Orbital Debris Order, Title III of the Act authorizes the licensing of satellite communications upon a finding that the "public

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199 *See* Rosen, *supra* note 164 and accompanying text regarding the corporate internalization of corporate externalities.

200 *See, e.g.*, discussion *supra* Section IV.A.

201 *See, e.g.*, Rao et al., *supra* note 193, at 12756.

202 *Id.*

203 *See e.g.*, *id.* at 12758 (detailing the escalating costs of inaction regarding orbital debris by analogy). Likewise, the authors argue that:

> Escalating costs of inaction are a common feature of the tragedy of the commons, evident in several other sectors in which it went unaddressed for lengthy periods. For example, tens of billions of dollars in net benefits are lost annually from open-access or poorly managed fisheries globally. Similarly, open access to oil fields in the United States at the turn of the century drove recovery rates down to 20 to 25% at competitively drilled sites, compared with 85 to 90% potential recovery under optimal management. Open access to roadways—somewhat analogous to orbits—is estimated to create traffic congestion costs in excess of $120 billion/y in the United States alone. In contrast, there is still time to get out ahead of the tragedy of the commons in the young space industry.

Id.

204 *See Space Debris by the Numbers*, *supra* note 51. The numbers are current as of August 11, 2023. *See id.*

205 *See* Colvin, *supra* note 2, at 101, 104.

convenience, interest, or necessity will be served thereby."[206] Accordingly, the FCC argued that they "consider an applicant's plan to mitigate orbital debris risks to be a relevant public interest factor in approving an applicant's space station operations."[207]

Indeed, and consistent with the FCC's mandate to protect the public interest in its licensing procedures for commercial satellites;[208] their OST-based responsibilities to authorize and continually supervise[209] their commercial satellite licensees; to conduct their procedures "in accordance with international law,"[210] the environmental aspects of which were clarified in the LTSG;[211] and to not cause "harmful interference"[212] with the use of space by other nations; current law should change to require the primary drivers of the looming Kessler syndrome to internalize their satellite constellation related externalities through the creation of an OUF. While such a fee might seem to represent an unreasonable restraint on the growth of this fledgling industry, a Pew study found that in the case of almost a dozen industries, the costs of implementing new environmental regulations were less than estimated while the economic benefits were greater than estimated.[213] Indeed, the report noted that:

> Regulatory requirements to protect the environment . . . often lead to innovation, increased productivity, and new businesses and jobs. Although an argument is sometimes made that the cost of complying with regulations is too high, that the societal benefits do not justify the investment, or that job losses will result, a review of past regulations reveals just the opposite. Historically, compliance costs have

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206 *See* Mitigation of Orbital Debris in the New Space Age, 85 Fed. Reg. 52461, at § 307(a) (April 24, 2020).

207 *See id.* at 4185 (voting to adopt additional, disclosure-based, orbital debris mitigation rules).

208 *See* Communications Act of 1934, *supra* note 42, at § 307(a).

209 *See* Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies, *supra* note 21, at art. VI. This jurisdiction includes the in-orbit operation of satellites. *See id.* at art. VIII.

210 *See id.* at art. III.

211 *See* Comm. On the Peaceful Uses of Outer Space, *supra* note 127.

212 *See* Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies, *supra* note 21, at art. IX.

213 *See Government Regulation: Costs Lower, Benefits Greater than Industry Estimates,* Pew Charitable Trs. (May 26, 2015), https://www.pewtrusts.org/en/research-and-analysis/fact-sheets/2015/05/government-regulation-costs-lower-benefits-greater-than-industry-estimates [https://perma.cc/ZF5K-TCKB].

been less and benefits greater than industry predictions, and regulation typically poses little challenge to economic competitiveness.[214]

Accordingly, and consistent with the FCC's mandate to protect the public interest through its licensing procedures for commercial satellites,[215] the authorization and supervision requirements under the OST,[216] NASA's Cost-Benefit Analysis,[217] reports from NASA,[218] the GAO,[219] the CBO,[220] the U.N.,[221] Congressional discussions of the impacts that satellite constellations have on the creation of LEO orbital debris,[222] and the Supreme Court holding in *West Virginia v. EPA*,[223] this article's proposed amendment to Title III of the Act is as follows:

SECTION 1. SHORT TITLE.

This Act may be cited as the ''Commercial Satellite Constellation Act'' or the ''COMSATCON Act."

SEC. 2. AUTHORITY REGARDING CERTAIN LICENSES.

(a) AMENDMENT: Part I of title III of the Communications Act of 1934 (47 U.S.C. 301 et seq.) is amended by adding at the end the following new section:

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214 *Id.*

215 *See* Mitigation of Orbital Debris in the New Space Age, *supra* note 144 and accompanying text.

216 *See* Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies, *supra* note 21, at art. VI.

217 *See generally* Colvin, *supra* note 2.

218 *See generally NASA* Off. Inspector Gen., *supra* note 4.

219 *See generally* U.S. Gov't Accountability Off., *supra* note 38.

220 *See generally* Congr. Budget Off., *supra* note 6.

221 *See generally* United Nations, *supra* note 68.

222 *See generally* JASON Report, *supra* note 24 and accompanying text; *see also* discussion *supra* Section II.A.

223 *See generally* West Virginia v. EPA, 142 S. Ct. 2587, 2610 (2022). Chief Justice John Roberts, writing for the Court in its reversal of EPA carbon dioxide regulations, articulated that the Clean Air Act does not explicitly authorize the EPA to regulate carbon dioxide emissions in a manner that triggers a nationwide transition away from the use of coal, and that Congress must clearly give the agency this authority before it can act, arguing that a "decision of such magnitude and consequence rests with Congress itself, or an agency acting pursuant to a clear delegation from that representative body." *Id.* at 2608, 2616. Congress passed the Clean Air Act in 1970 when the existence of global warming was a little-known phenomenon. *See id.* at 2952. Similarly, Congress passed NEPA in 1969 when orbital debris was little known. Notably, despite the FCC's oversight and authorization of satellite operations, Section 1.1307 neither refers to orbital debris nor the environmental considerations for operating in LEO. Finally, the regulation has not been significantly amended since 1986. *See* Michael B. Runnels, *On Launching Environmental Law into Orbit in the Age of Satellite Constellations*, 88 J. Air L. & Com. 181, 203 (2023).

SEC. 346. RADIOFREQUENCY LICENSING AUTHORITY REGARDING CERTAIN OPERATIONS.

(a) RULES:

1) The Federal Communications Commission shall issue rules to amend Title 47, Code of Federal Regulations to establish:

A. A Commercial Satellite Constellation Orbital Use Fee.[224] This fee shall function as a progressive tax[225] based upon the satellite's mass, the total number of satellites under the control of the operator, and the orbital characteristics of the constellation.[226] This fee will fund projects and research related to:

i. Orbital debris remediation in Earth orbits.

ii. Orbital debris tracking and characterization.[227]

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[224] *See e.g.*, Rao et al., *supra* note 193, at 12762. Based on the calculations in this study, which focuses on the source of the externality, which is the object in orbit:

> The optimal OUF starts at roughly $14,900 per satellite-year in 2020 and escalates at roughly 14% per year (aside from some initial transition dynamics) to around $235,000 per satellite-year in 2040. Rising optimal price paths are common in environmental pricing such as carbon taxes . . . although declining optimal price paths are also possible. The rising price path in this case partly reflects the rising value of safer orbits . . . [resulting] from the OUF. For comparison, the average annual profits of operating a satellite in 2015 were roughly $2.1 million. The 2020 and 2040 OUF values we describe amount to roughly 0.7 and 11% of average annual profits generated by a satellite in 2015.

Id. at 12767.

[225] *See* Aaron Boysen & Austin Humphrey, *Beyond Earth's Clutter: Unveiling the Orbital Debris Market – Global Policy, Challenges, and a Path Forward*, SPACEWORKS (Aug. 17, 2023), https://www.spaceworks.aero/beyond-earths-clutter-unveiling-the-orbital-debris-market-global-policy-challenges-and-a-path-forward/ [https://perma.cc/B2NL-YTH3] (noting that "[o]wners/operators with 13 or less satellites would pay a minimum or no tax while those in the larger satellite quantity tiers would pay higher rates." The authors go on to argue levying such a tax "would incentivize [commercial satellite operators] to deorbit inoperable satellites while creating a common pool to fund SSA and [debris remediation]."). *Id.*

[226] *Id.*

[227] *See* Colvin, *supra* note 2, at 64. Detailing the dual use of laser systems for orbital debris remediation and SSA, NASA explains that:

> [W]hen a high-threat conjunction with a piece of debris is identified by traditional SSA techniques, a laser can be tasked to remediate the conjunction. The laser system then locks its sights on the piece of debris by determining the orbit of the debris to high precision; however, a high-precision estimate of the orbit may clarify that the conjunction will not result in a collision. In this case, there is no need for the laser system to nudge the debris and the laser can be applied to other ongoing high-threat conjunctions. [In this way], [w]hen a laser system is not nudging debris, it can provide enhanced SSA services."

Id.

iii. Compositional changes to Earth's atmosphere caused by satellite reentry into and vaporization in Earth's atmosphere.[228]
iv. Orbital debris surviving reentry that causes terrestrial damage to persons and property.[229]
v. Impacts to ground-based astronomy caused by LEO satellite interference.[230]

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[228] *See* Press Release, Will Wiquist, FCC, FCC Adopts New '5-Year Rule' for Deorbiting Satellites to Address Growing Risk of Orbital Debris (Sept. 29, 2022), https://www.fcc.gov/document/fcc-adopts-new-5-year-rule-deorbiting-satellites [https://perma.cc/MP2T-WVCJ] (changing the FCC's satellite deorbiting policy from a recommendation to deorbit inoperable satellites within 25 years of satellite failure to a 5-year requirement to do so after failure. The deorbiting process requires the lowering of the satellite's orbit into Earth's upper atmosphere where it is expected to vaporize); *see also* Colvin, *supra* note 2, at VI (explaining the dynamics of satellite reentry into the Earth's atmosphere, NASA argues that "[r]eentering space debris can catalyze the creation of damaging chemicals due to atmospheric heating or deposit undesirable spacecraft materials into the upper atmosphere as the debris vaporizes"); *see also, e.g.*, Aaron C. Boley & Michael Byers, *Satellite Mega-Constellations Create Risks in Low Earth Orbit, the Atmosphere and on Earth*, 11 Sci. Reps. 1, 5 (May 2021) (noting that the exponential development of satellite constellations "risks multiple tragedies of the commons" to LEO orbits, the chemical makeup of Earth's upper atmosphere, and ground-based astronomy, due to the increased likelihood of orbital collisions and other externalities associated with such satellite launches. The article further argues that "international cooperation is urgently needed, along with a regulatory system that takes into account the effects of tens of thousands of satellites"); Lee Billings & Leonard David, *Space Junk is Polluting Earth's Stratosphere with Vaporized Metal*, Sci. Am. (Oct. 26, 2023), https://www.scientificamerican.com/article/space-junk-is-polluting-earths-stratosphere-with-vaporized-metal/ (detailing that in work sponsored by the National Oceanic and Atmospheric Administration in March and April 2023, "researchers sampled stratospheric air using specialized mass spectrometers . . . [and] discovered surprising amounts of many metals commonly used in rockets and satellites, often in ratios mirroring those found in specific high-performance aerospace alloys . . .. [that] are accumulating within sulfuric acid particles, which constitute most of the stratosphere's particulates and influence our world's ozone layer and climate.") *Id.*

[229] *See* Moriba Jah, *Space Debris Will Block Space Exploration Unless We Start Acting Sustainably*, Sci. Am. (Aug. 1, 2023), https://www.scientificamerican.com/article/space-debris-will-block-space-exploration-unless-we-start-acting-sustainably/ [https://perma.cc/G5ME-XFGN] (explaining the environmental impacts of satellites surviving reentry into Earth's atmosphere). Jah, an Associate Professor of Aerospace Engineering and Engineering Mechanics, who is also known as a "space environmentalist," argues:

> Objects that survive reentry pollute our oceans and lands at best and crash in populated areas at worst. We are now filling space with fleets of thousands of these objects the size of a phone booth, trash can or school locker without remembering that what goes up can come down.

Id.

[230] As Article I of the OST provides that all nations must be free to use and explore outer space "on a basis of equality," and that they must "facilitate and encourage international cooperation in [scientific] investigation," impacts to

V. CONCLUSION: AMERICAN ASTROPOLITIK

While the geopolitical will to forge enforceable international space laws may not seem forthcoming—particularly regarding an enforceable international OUF—these challenges need not be daunting,[231] as "[t]heory suggests countries could each collect and spend OUF revenues domestically, without losing economic efficiency, as long as the fee's magnitude was internationally harmonized."[232] Indeed, under Article VI, new rules can and should be formulated in conformity with the OST,[233] and it was for these reasons that the FCC voted unanimously in January 2023 to reorganize its International Bureau into a "Space Bureau"[234] (Bureau), arguing that the "satellite industry is growing at a record pace, but here on the ground our regulatory frameworks for li-

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ground-based astronomy caused by satellite interference constitutes a "harmful interference" with the use of outer space by other nations, which violates Article IX of the OST. *See* Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies, *supra* note21, at art. I, IX; *see also, e.g.*, Green et al., *supra* note 143 (noting how the advent of satellite constellations harmfully interferes with ground-based astronomy and the potential steps the U.S. government can take to mitigate this harmful interference); *see also generally* JASON Report, *supra* note 24, at 35–77 and accompanying text (discussing the harmful interference of satellite constellations on optical astronomy generally, infrared astronomy, radio astronomy, cosmic microwave background studies, and laser guide-star observations); *see also, e.g.*, Boley & Michael Byers, *supra* note 228 and accompanying text; *see also* Mathieu Isidro, *New Radio Astronomical Observations Confirm Unintended Electromagnetic Radiation Emanating from Large Satellite Constellations*, Int'l Astronomical Union (July 5, 2023), https://cps.iau.org/news/new-radio-astronomical-observations-confirm-unintended-electromagnetic-radiation-emana ting-from-large-satellite-constellations/ [https://perma.cc/463S-Y583] (Explaining how scientists used the "LOFAR telescope to observe low-frequency radio waves from satellites in large constellations for the first time . . . and discovered '[u]nintended electromagnetic radiation' emanating from onboard electronics in Starlink satellites, . . . which could impact astronomical research . . . [and that] further study is now ongoing.) *Id.*

231 *See* Major Adam G. Mudge, *Incentivizing 'Active Debris Removal' Following the Failure of Mitigation Measures to Solve the Space Debris Problem: Current Challenges and Future Strategies*, 82 A.F. L. Rev. 88, 147–48 (2022) (noting the geopolitical difficulties of successfully negotiating a successor to the OST and arguing that, in lieu of a new space treaty, States should lay the foundation of responsible international space laws through domestic implementing legislation of the OST).

232 *See* Rao et al., *supra* note 193, at 12758.

233 *See generally* Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies, *supra* note 212, at art. VI.

234 *See* Press Release, Paloma Perez, Commission Votes to Establish a Space Bureau and Office of International Affairs, (Jan. 9, 2023), https://docs.fcc.gov/public/attachments/DOC-390599A1.pdf.

censing them have not kept up."[235] The purpose of the Bureau is to "develop, recommend, and administer policies, rules, standards, and procedures for the authorization and regulation of domestic and international satellite systems."[236] Consistent with the 2020 National Space Policy of the U.S.'s declaration that "[t]o preserve the space environment for responsible, peaceful, and safe use, and with a focus on minimizing space debris, the [U.S.] shall: [c]ontinue leading the development and adoption of international and industry standards and policies,"[237] the purpose of the FCC's Bureau is to take a leadership position in implementing new policies for in-orbit environmental impacts that will allow America to influence other nations positively and engage them in an internationally constructive approach.[238]

Given the central role that the FCC plays in licensing commercial satellite constellations and the purpose of its newly-created Bureau, an American astropolitical strategy must be rooted in: (1) Congress first adopting domestic implementing legislation of the OST that is responsive to the looming dangers of the Kessler syndrome, which will then; (2) serve as the basis for bilateral and multilateral treaty negotiations with space-faring nations.[239] This resulting network of treaties would provide the basis for a customary international law that will mitigate orbital debris that poses potentially harmful interference with the use of outer space by

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[235] *See* Press Release, Paloma Perez, Chairwoman Rosenworcel Announces Plan to Modernize the FCC and Office of International Affairs (Nov. 3, 2022), https://docs.fcc.gov/public/attachments/DOC-388826A1.pdf [https://perma.cc/7FQ9-43FD].

[236] *See* ESTABLISHMENT OF THE SPACE BUREAU AND THE OFFICE OF INTERNATIONAL AFFAIRS AND REORGANIZATION OF THE CONSUMER AND GOVERNMENTAL AFFAIRS BUREAU AND OFFICE OF MANAGING DIRECTOR, 23-1 FCC §0.51(a) (2023), https://docs.fcc.gov/public/attachments/FCC-23-1A1.pdf [https://perma.cc/RP9R-E246].

[237] *See* The National Space Policy, *supra* note 142, at 81761; *see also, e.g.*, *United States Space Priorities Framework*, WHITE HOUSE, at 4 (2021), https://www.whitehouse.gov/wp-content/uploads/2021/12/United-States-Space-Priorities-Framework-_-December-1-2021.pdf [https://perma.cc/DG97-FUF6].

[238] *See* Green et al., *supra* note 143, at 81 (noting arguments concerning how satellites negatively impact ground-based astronomy, SATCON2 argues that the U.S. should demonstrate leadership on such matters through implementing domestic legislation based on the OST); *see also generally* Runnels, *supra* note 34, at 160.

[239] *See, e.g.*, Michael B. Runnels, *Rising to China's Challenge in the Pacific Rim: Reforming the Foreign Corrupt Practices Act to Further the Trans-Pacific Partnership*, 39 J. SEATTLE U. L. REV. 107, 109–110, 125 (2015) (arguing that bilateral and multilateral treaties regarding trade, i.e., free trade agreements, "have become a key foreign-policy plank used to structure the architecture of global trade . . . increase geopolitical influence . . . and are [now] evolving into an increasingly critical platform for writing the rules of the game, and [are] viewed as key instruments in establishing diplomatic relationships"); *see also generally* Runnels, *supra* note 34, at 159.

other nations.[240] In contrast to the general principles contained in the American-led Artemis Accords,[241] this strategy would seek the inclusion of specific regulations that will enhance the sustainability of LEO orbits. The OUF legislative and diplomatic strategy provided in this article meets these challenges by helping to operationalize the OST's proclamation establishing space as the "province of all mankind,"[242] and promoting its peaceful use and exploration for the "benefit and in the interests of all countries."[243]

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[240] Runnels, *supra* note 34, at 159–60.

[241] *See generally The Artemis Accords: Principles for Cooperation in the Civil Exploration and Use of the Moon, Mars, Comets, and Asteroids for Peaceful Purposes*, NASA (Oct. 13, 2020), https://www.nasa.gov/specials/artemis-accords/img/Artemis-Accords-signed-13Oct2020.pdf [https://perma.cc/7FFY-VV5J].

[242] *See* Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies, *supra* note 212, at art. I.

[243] *Id.*