

ARTICLE

**LARGE CONSTELLATIONS OF SMALL SATELLITES:
THE GOOD, THE BAD, THE UGLY, AND THE ILLEGAL**

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ABSTRACT

The most exciting and far-reaching contemporary developments regarding human activities in outer space arise from the recent drastic reductions in the costs of building, launching, and operating satellites, and from the concomitant sudden emergence of large constellations of small, inexpensive, privately-owned spacecraft. These satellites—devoted to highly remunerative functions such as communications (bringing high-speed, affordable internet to underserved constituencies), remote sensing (facilitating land use planning, weather forecasting, and emergency search and rescue), and support for military operations (in Ukraine and elsewhere)—already number in the thousands and will soon reach the tens of thousands.

But in addition to generating billions of dollars of revenue, these new constellations also raise a series of profound and unprecedented legal, economic, and social problems. The first concerns congestion of the most favored low-altitude orbital slots and the associated dangers of interference, collisions, and debris. This is a classic “tragedy of the commons,” where each participant is incentivized to exploit a shared resource too intensively, without husbanding it for the longer term. A second problem arises from the interference that the new satellite swarms cause for astronomy. An overflying satellite will disrupt an observatory’s ability to peer into far-distant space in pursuit of scientific discoveries. The satellite’s passage leaves an obnoxious white streak across the telescope’s images, obscuring the effort to collect and interpret faint data. Third, the growing armada of private satellites is increasingly used for military and intelligence purposes, obliterating the fundamental requirement under the longstanding international law of armed conflict to preserve a vital “distinction” between military and civilian objects and to achieve physical “separation” between those types of assets.

This Article examines the growing number of soon-to-be-ubiquitous constellations of small satellites and the three aforementioned special problems they pose. It also suggests some legal reforms to combat the dilemmas and temper an otherwise dangerous renewal of an unconstrained and unproductive international race to space. Among the recommendations are a call for the prompt development of

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additional legally-binding and non-legally-binding standards for allocating orderly access to shared space, measures of accommodation for rivalrous users of space, and greater separation of military and civilian space assets.

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INTRODUCTION

Large constellations of small, inexpensive satellites are suddenly and irreversibly transforming the political economy of outer space. Massive orbital fleets, mostly privately owned, are rapidly populating low-altitude trajectories, greatly expanding the opportunities for efficient, accelerated exploitation. These novel spacecraft promise multiple immense benefits for humanity; there is a lot of money to be made in this enterprise; and they surely represent the wave of the space future. But the sudden supremacy of this genre of spacecraft carries profound dangers and costs, and the world should not binge on the glories of the New Space revolution without being conscious of the price tag and without undertaking some sustained effort to mitigate its disadvantages.

This article begins by explaining—and mildly singing the praises of—large constellations of small satellites, acknowledging their myriad boons for society, the economy, national security, and diverse other applications. It then assesses three kinds of costs or problems generated by the sudden affinity for swarms of small, expendable, low-altitude satellites. First is the inevitable congestion of the most popular regions of space, with the attendant “tragedy of the commons” predicaments of pollution, collisions, and usurpation of opportunities by the first arrivals. The second problem is serious interference with astronomy, as ground-based and space-based observatories are impeded in peering past bright and noisy satellites to access faint, but important, scientific data from afar. Finally, the new reliance upon commercial satellites to perform military and intelligence functions undermines longstanding foundations of the international law of armed conflict (LoAC) and may help propel the world toward catastrophic arms racing and war in space. Each of these problems is important, urgent, and under-appreciated; together

they should cause us to pause and think hard before plunging forward on our current accelerating trajectory.

Finally, the article offers some recommendations for reimagining the current race to space to 1) make the process more orderly, equitable, and stable; 2) pursue updated and additional arms control measures in space; and 3) generally negotiate additional international agreements to flesh out the currently-inadequate legal infrastructure of space law. The sudden zeal for large constellations of small satellites provides an occasion to reflect more deeply upon the general paucity of space law and the need to supplement it to better cope with modern circumstances.

I. THE GOOD: LARGE CONSTELLATIONS OF SMALL SATELLITES

The most exciting, novel transformation in contemporary space operations has been the revolutionary reduction in the cost of building, launching, and operating satellites. Almost overnight, decades-old patterns for the exploration and exploitation of space have been reconstructed, with dramatic changes in *who* (the private sector) is putting *what* (inexpensive highly proliferated, single-purpose satellites) *where* (in popular low-altitude orbits).¹

First, regarding the “who,” the most aggressive, innovative space actors are now private commercial entities: space is no longer reserved for governments and their public missions. SpaceX, for example, has suddenly become the world’s most prolific launcher, with over five thousand Starlink communications satellites already constituting the most numerous orbiting constellation the world has ever seen.² A leading competitor, OneWeb, currently has deployed more than six

¹ See generally Sarah Kreps, Avishai Melamed, and Ray Jayawardhana, *The Promise and Perils of the New Space Boom*, BROOKINGS (Nov. 2, 2022), <https://www.brookings.edu/articles/the-promise-and-peril-of-the-new-space-boom-us-china-competition-spacex-international-law> [<https://perma.cc/XF7W-LD8Z>]; Sophie Goguichvili, *The New Space Era Will Drive the Economy of Tomorrow*, WILSON Q., (2023), https://www.wilsonquarterly.com/quarterly/_/the-new-space-era-will-drive-the-economy-of-tomorrow [<https://perma.cc/WV8X-TJU8>]; COMMITTEE FOR THE ASSESSMENT OF PARTNERSHIP OPTIONS FOR A SMALL SATELLITE SYSTEM FOR COLLECTING SCIENTIFIC QUALITY OCEANIC AND COASTAL DATA, LEVERAGING COMMERCIAL SPACE FOR EARTH AND OCEAN REMOTE SENSING (The National Academies Press 2022), <https://nap.nationalacademies.org/catalog/26380/leveraging-commercial-space-for-earth-and-ocean-remote-sensing> [<https://perma.cc/6ZZU-YP5U>] (discussing the New Space revolution and the move toward a hybrid space architecture combining new and legacy systems); CONGRESSIONAL BUDGET OFFICE, LARGE CONSTELLATIONS OF LOW-ALTITUDE SATELLITES: A PRIMER (May 2023), <https://www.cbo.gov/system/files/2023-05/58794-satellite-primer.pdf> [<https://perma.cc/G4UZ-5574>] [hereinafter CBO].

² *Starlink Statistics*, JONATHAN’S SPACE PAGES, <https://planet4589.org/space/con/star/stats.html> [<https://perma.cc/XQ9A-QFD8>] (last visited Nov. 29, 2023). As of November 2023, there were 5,513 Starlink satellites launched, 5,143 of which were still in orbit and 5,103 of which were operational; *Largest Satellite Constellation*, GUINNESS WORLD RECORDS, <https://www.guinnessworldrecords.com/world-records/628755-largest-satellite-constellation>

hundred operational satellites,³ and other for-profit enterprises, including Amazon, Telesat, and Astra, are only a few steps behind.⁴ The global space economy now generates over \$500 billion per year.⁵

Equally revolutionary is the “what,” as the primary vehicles for these private operators have been small, relatively inexpensive, single-function satellites, which operate in large co-flying networks⁶—far different from the legacy systems that typically rested upon only a few large, technically exquisite, expensive bespoke monoliths. SpaceX, for example, has plans and regulatory authority for a mega-constellation of forty thousand satellites,⁷ and observers now anticipate a total

[<https://perma.cc/N9N7-98QL>] (last visited Feb. 21, 2024). See also *UCS Satellite Database*, UNION OF CONCERNED SCIENTISTS, <https://www.ucsusa.org/resources/satellite-database> [<https://perma.cc/B6RP-NGGW>].

³ *Enormous (“Mega”) Satellite Constellations*, JONATHAN’S SPACE PAGES <https://planet4589.org/space/con/conlist.html> [<https://perma.cc/YG25-4MT2>] (last visited Feb. 21, 2024). As of November 2023, OneWeb had launched 640 satellites, of which 594 were still operational. A total second-generation constellation of 6,372 is planned.

⁴ JONATHAN’S SPACE PAGES, *supra* note 3 (reporting that Amazon is planning 3,232 satellites, Telesat 300, Astra 13,620, and Guanwang 12,992).

⁵ Theresa Hitchens, *Led by US, Global Spending on Military Space Jumped to \$54B in 2022*: *Space Foundation*, BREAKING DEFENSE (July 26, 2023), <https://breakingdefense.com/2023/07/led-by-us-global-spending-on-military-space-jumped-to-54b-in-2022-space-foundation/#:~:text=WASHINGTON%20%E2%80%94%20The%20Space%20Foundation's%20a%20test,majority%20of%20the%20known%20expenditure> [<https://perma.cc/G3X4-5Q4L>] (discussing report from the Space Foundation that the global space economy grew to \$546 billion in 2022, an eight percent rise over 2021); Amy Borrett, *Satellite Broadband Is the Future of the \$1trn Space Economy*, TECH MONITOR (Mar. 31, 2023), <https://techmonitor.ai/technology/cloud/satellite-broadband-future-1trn-space-economy> [<https://perma.cc/3HHL-NFUT>] (reporting that the race to provide low-cost, high-speed internet service is fueling the space economy, expected to reach one trillion dollars globally by 2040).

⁶ There is no official or authoritative definition of “small” satellites, but the general usage refers to spacecraft weighing a few hundred pounds or less. See *What Are SmallSats and CubeSats?*, NASA (Feb 26, 2015), <https://www.nasa.gov/content/what-are-smallsats-and-cubesats> [<https://perma.cc/T9ZA-R3N2>] (defining small satellites as generally less than 180 kilograms, and about the size of a refrigerator); NICHOLAS EFTIMIADIS, *SMALL SATELLITES: THE IMPLICATIONS FOR NATIONAL SECURITY* 4–5 (May 2022), https://www.atlanticcouncil.org/wp-content/uploads/2022/05/Small_satellites-Implications_for_national_security.pdf [<https://perma.cc/BK42-T4W7>] (estimating that seventy-five percent of the satellites launched from 2011 to 2020, and ninety-four percent of the satellites launched in 2020, were in the small category). Likewise, there is no clear definition for what constitutes a “large” constellation of satellites, but general practice focuses on cooperating collections embracing approximately 500 or more satellites. JASON, *THE IMPACTS OF LARGE CONSTELLATIONS* 11 (2021) https://www.nsf.gov/news/special_reports/jasonreportconstellations/JSR-20-2H_The_Impacts_of_Large_Constellations_of_Satellites_508.pdf [<https://perma.cc/W4C4-E5MA>] [hereinafter JASON]; CBO, *supra* note 1, at 10–17.

⁷ Tereza Pultarova & Elizabeth Howell, *Starlink Satellites: Everything You Need to Know about the Controversial Internet Megaconstellation*, SPACE.COM (Nov. 22, 2022), <https://www.space.com/spacex-starlink-satellites.html> [<https://perma.cc/6LN4-V3HC>]. *But see*

orbital population approaching a hundred thousand spacecraft within the next decade.⁸ In contrast, there were fewer than one thousand operational spacecraft of all types, by all users, in orbit as recently as 2010.⁹

The “where” refers to low-Earth orbit (LEO), generally seen as less than two thousand kilometers above the surface. For example, Starlink orbits at about 550 kilometers, and OneWeb orbits at 1,200 kilometers. The choice of altitude has important consequences: in a geosynchronous Earth orbit (GEO), at 36,000 kilometers, a satellite will appear to hover perpetually over a particular spot on the surface of the Earth. Thus, a constellation of only three spacecraft could have direct line-of-sight coverage of almost every location on the planet simultaneously. In contrast, a LEO satellite traverses the sky very rapidly, so a much larger constellation would be necessary to provide continuous coverage—but the greater proximity of LEO carries offsetting advantages.¹⁰

This combination of factors demarcating the New Space revolution offers revolutionary benefits. For one, LEO satellites can provide near-real-time Earth-monitoring capabilities, applicable to weather forecasting, land-use planning, agricultural assessments, military reconnaissance, and emergency search and rescue.¹¹ Even larger fleets of communications satellites promise low-cost, high-speed global internet access, narrowing the digital divide by serving remote communities and far-flung military units, as well as aircraft in flight and ships on

Agence France Presse, *SpaceX Says Likely Won't Need 42,000 Satellites for Starlink Internet*, BARRON'S (Sept. 12, 2022), <https://www.barrons.com/news/spacex-says-likely-won-t-need-42-000-satellites-for-starlink-internet-01663009507> [<https://perma.cc/QX8N-NV9T>].

⁸ Jingrui Zhang, et al., *LEO Mega Constellations: Review of Development, Impact, Surveillance, and Governance*, SPACE: SCIENCE AND TECHNOLOGY 1–4 (2022) (surveying planned launches of large constellations by several companies).

⁹ *Number of Active Satellites from 1957 to 2022*, STATISTA (published Dec. 1, 2023), <https://www.statista.com/statistics/897719/number-of-active-satellites-by-year> [<https://perma.cc/8U86-969S>].

¹⁰ U.S. GOV'T ACCOUNTABILITY OFF., GAO-22-105166, LARGE CONSTELLATIONS OF SATELLITES: MITIGATING ENVIRONMENTAL AND OTHER EFFECTS, TECHNOLOGY ASSESSMENT 3–5 (Sept. 29, 2022) <https://www.gao.gov/assets/gao-22-105166.pdf> [<https://perma.cc/892H-7YJ9>] [hereinafter LARGE CONSTELLATIONS OF SATELLITES] (describing LEO and GEO); CBO, *supra* note 1, at 5–9.

¹¹ Francis Lyall and Paul B. Larsen, *SPACE LAW: A TREATISE* 359–86 (2d ed., 2018) (discussing remote sensing satellites and applicable international law); Todd Harrison and Matthew Strohmeier, *Commercial Space Remote Sensing and Its Role in National Security*, CENTER FOR STRATEGIC & INT'L STUDIES (Feb. 2, 2022) <https://www.csis.org/analysis/commercial-space-remote-sensing-and-its-role-national-security> [<https://perma.cc/PW8Q-F3Y8>]; Catherine Amirfar, et al., *Remote Sensing from Space: What Norms Govern?* JUST SECURITY (May 5, 2023), <https://www.justsecurity.org/86114/remote-sensing-from-space-what-norms-govern> [<https://perma.cc/C2ZZ-3F6G>] (underscoring the proliferation of remote sensing satellites, now totaling 1,100 active satellites, and projecting that the market for remote sensing will reach \$4.6 billion annually by 2026); EFTIMIADES, *supra* note 6, at 6–9 (describing diverse functions of small satellites).

the high seas where cell towers and fiber optic cables do not reach.¹² Linking the world electronically portends faster, more secure, less expensive virtual services of all types, carrying boundless benefits for consumers, corporations, and governments around the world.¹³ The profusion of constellations promises greater reliability of service and competitive pricing, via redundancy, resilience, and fleet survivability.¹⁴

¹² Sylvester Kaczmarek, *Why Are Satellite Communications Crucial for Organizations and Individuals?* <https://sylvesterkaczmarek.com/blog/why-are-satellite-communications-crucial-for-organisations-and-individuals> [<https://perma.cc/7PPK-WMQY>] (last visited Feb. 21, 2024); Marcin Frackiewicz, *Communication Satellites: How They Work and Their Importance*, TS2 SPACE (May 15, 2023), <https://ts2.space/en/communication-satellites-how-they-work-and-their-importance/> [<https://perma.cc/85K2-QAMG>]; Aparna Venkatesan, et. al., *The Impact of Satellite Constellations on Space as an Ancestral Global Commons*, 4 NATURE ASTRONOMY 1043, 1043 (Nov. 2020) (acknowledging the benefits of LEO constellations in breaching the global digital divide).

¹³ A LEO constellation can offer more rapid and accessible communications than are currently available via ground-based cable links (because light travels faster through the vacuum of space than through an optical fiber cable, and because cable lines do not reach everywhere) or via a GEO satellite (which is much further away). For example, bouncing a signal off a LEO satellite may involve a delay (latency) of twenty-five to forty milliseconds; going via a GEO satellite, on the other hand, would entail a delay of about 600 milliseconds. CBO, *supra* note 1, at 14. That minute difference in latency would hardly be noticeable for many applications, but for some (e.g., video gaming and stock trading), aficionados would appreciate the greater speed. See Stuart Eves, Opinion, *Congested, Contested... Under-Regulated and Unplanned*, ROOM (2021), <https://room.eu.com/article/congested-contested-under-regulated-and-unplanned> [<https://perma.cc/28A9-6NS2>]; Ben Gan, *Is Starlink Better Than Viasat?* SATELLITE INTERNET (June 22, 2023), <https://www.satelliteinternet.com/resources/starlink-vs-viasat/> [<https://perma.cc/SN6P-YZCD>]; Lauren Hannula, *Starlink Internet vs. Fiber Internet*, WHISTLE OUT (July 13, 2022), <https://www.whistleout.com/Internet/Guides/fiber-internet-vs-starlink-satellite-internet> [<https://perma.cc/992P-6PHP>]; Brian Westover, *Starlink vs. HughesNet vs. Viasat: Which Satellite Internet Provider Is Best?*, PC MAGAZINE (Mar. 14, 2023), <https://www.pcmag.com/news/starlink-vs-hughesnet-vs-viasat-which-satellite-internet-provider-is-best> [<https://perma.cc/G3CA-WXSE>].

¹⁴ ROBERT PRESTON, DISTRIBUTED SATELLITE CONSTELLATIONS OFFER ADVANTAGES OVER MONOLITHIC SYSTEMS 1 (Rand, 2004), https://www.rand.org/content/dam/rand/pubs/research_briefs/2005/RAND_RB92.pdf [<https://perma.cc/UJ6W-MW6F>] (noting cost, performance, and survivability benefits); EOS Data Analytics, *Satellite Constellations: Existing and Emerging Swarms* (Nov. 28, 2022), <https://eos.com/blog/satellite-constellation/> [<https://perma.cc/5MRH-Y6J7>]; Soumyaa Rawat, *What Is a Satellite Mega-Constellation? Advantages and Disadvantages*, ANALYTIC STEPS (May 8, 2021), <https://www.analyticssteps.com/blogs/what-satellite-mega-constellation-advantages-and-disadvantages> [<https://perma.cc/QZ64-69VA>]; Courtney Albon, *US Space Force Wants New Commercial Imagery Tool to Boost Resiliency*, C4ISRNET (July 8, 2022), <https://www.c4isrnet.com/battlefield-tech/space/2022/07/08/us-space-force-wants-new-commercial-imagery-tool-to-boost-resiliency> [<https://perma.cc/6XHU-ZDHZ>] (citing Space Force leaders who seek to rapidly diversify the national security space architecture, to favor use of small, distributed commercial spacecraft); EFTIMIADIS, *supra* note 6, at 10–15 (discussing positive and negative disruptive influence of small satellites).

II. THE BAD: CONGESTION IN SPACE

Yet all is not well with this new proliferation of satellites: at least three distinct clusters of issues must be parsed for a proper evaluation. This section addresses the first problem, arising from physical congestion due to the exorbitant increase in the volume of space traffic. Three related sub-aspects can be discerned. For each, the technical or logistical dimensions are presented first, followed by a marshalling of the (too scant) international law.

A. Overcrowding

First, the sheer number of orbiters threatens to overcrowd the resource. Space is, of course, a very big place, but not all regions are equally valuable, and the carrying capacity of the most popular orbital shells is limited. For safety purposes, and to minimize electronic interference, satellites must be at least somewhat separated, but maintenance of a suitable standoff distance becomes difficult when tens of thousands will seek to occupy the LEO domain. At some point, the density of existing orbital items will inhibit new accretions, as there would not be sufficient elbow room remaining. Even launching through the existing shells, to reach higher altitudes, could become tricky, as there would be fewer optimal launch windows for penetrating through the cloud of existing orbiters.¹⁵

¹⁵ Ethan Siegel, *How to Save the Night Sky from Satellite Megaconstellations*, FORBES (July 22, 2021), <https://www.forbes.com/sites/startswithabang/2021/07/22/how-to-save-the-night-sky-from-satellite-megaconstellations/?sh=45727d227c50> [<https://perma.cc/54VP-SYLM>] (calculating that every minute or two today, two LEO satellites pass within two kilometers of each other at 22,400 miles per hour; when the satellite population rises exponentially in coming years, “there are a number of existential risks to orbital overcrowding.”); Tereza Pultarova, *How Many Satellites Can We Safely Fit in Earth Orbit?*, SPACE.COM (Feb. 27, 2023), <https://www.space.com/how-many-satellites-fit-safely-earth-orbit> [<https://perma.cc/Z8ED-D47E>] (quoting astronomer Jonathan McDowell expressing apprehension about the growing population of LEO satellites and the danger of collisions); Thomas Taverney, *Proliferated LEO Is Risky But Necessary*, SPACE NEWS (Mar. 5, 2020), <https://spacenews.com/op-ed-proliferated-leo-is-risky-but-necessary/> [<https://perma.cc/R3JG-K8TF>] (highlighting the congestion dangers of a “gold rush” toward proliferated LEO satellites); Letter from Samantha Fonder, NASA Representative to the Commercial Space Transportation Interagency Group, to Marlene Dortch, Secretary, Federal Communications Commission, (Feb. 7, 2022), available at <https://www.scribd.com/document/557924666/NTIA-NASA-NSF-letter-to-FCC-regarding-Starlink-Gen-2> [<https://perma.cc/6R32-Z8KW>] [hereinafter NASA letter] (expressing concern about LEO congestion and increased danger of collisions, and stating that “NASA is also concerned with an increasing unavailability of safe launch windows, especially for missions requiring instantaneous or short launch windows, such as planetary missions like Europa Clipper, which would be significantly affected due to a lost launch opportunity.”); Zhang, *supra* note 8, at 1 (observing that LEO includes only 0.3% of space below GEO, but contains eighty percent of the total space objects).

This congestion is not only a problem for technology: it has legal dimensions, too. The 1967 Outer Space Treaty (OST),¹⁶ the foundational legal instrument in the field, joined by almost all the spacefaring states, and accepted as customary international law, provides that space “shall be free for exploration and use by all States without discrimination of any kind” and that the exploration and use of space “shall be carried out for the benefit and in the interests of all countries, irrespective of their degree of economic or scientific development.”¹⁷ Moreover, the treaty specifies that outer space “is not subject to national appropriation by claim of sovereignty, by means of use or occupation, or by any other means.”¹⁸

For the first time, the world has to contemplate the implications of some wealthy, technologically-developed countries and companies so intensively exploiting the optimal LEO orbital shells that, as a practical matter, they constitute an impermissible disruption to the abilities of subsequent users to enjoy their rights to the free exploration and use of space. Even if the first user did not officially “claim” exclusive rights to a particular orbital regime, if that party populates the sector so comprehensively that latecomers are *de facto* precluded from entering the area, could that usurpation of opportunities constitute an illegal “appropriation” by “other means” of a slice of space? Does the current system impermissibly “discriminate” against future belated space entrants, based on their current “degree of economic or scientific development”?¹⁹

B. Debris

The second aspect of the problem of congestion concerns debris, the miasma of human-created, but no longer functional, junk that is inevitably produced by space operations and that can remain in orbit as a hazard to others for extended periods. Debris includes large items like spent rocket bodies and no-longer-

¹⁶ Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies, OST, Jan. 27, 1967, 18 U.S.T. 2410 [hereinafter Outer Space Treaty or OST]. See Lyall and Larsen, *supra* note 11, at 49–73 (addressing the importance and contents of the OST); see generally 1 STEPHEN HOBE, ET. AL., COLOGNE COMMENTARY ON SPACE LAW (2009) (analyzing the contents of the OST as the leading source of space law).

¹⁷ OST, *supra* note 16, art. I.

¹⁸ *Id.* art. II.

¹⁹ Christopher D. Johnson, *The Legal Status of MegaLEO Constellations and Concerns about Appropriation of Large Swaths of Earth Orbit*, in HANDBOOK OF SMALL SATELLITES: TECHNOLOGY, DESIGN, MANUFACTURE, APPLICATIONS, ECONOMICS AND REGULATION 3 (Joseph N. Pelton and Scott Madry eds. 2020) (quoting OST, *supra* note 16, art. I). See also DARK & QUIET SKIES FOR SOCIETY, DARK & QUIET SKIES FOR SCIENCE AND SOCIETY II ON-LINE CONFERENCE WORKING GROUP REPORTS 107–14 (Jan. 2022), https://www.iau.org/static/science/scientific_bodies/working_groups/286/dark-quiet-skies-2-working-groups-reports.pdf [<https://perma.cc/SZ4L-LXPL>]; Aaron C. Boley & Michael Byers, *Satellite Mega-constellations Create Risks in Low Earth Orbit, the Atmosphere, and on Earth*, 11 NATURE SCIENTIFIC REPORTS, May 20, 2021, at 5, <https://www.nature.com/articles/s41598-021-89909-7.pdf> [<https://perma.cc/6Z8F-BQKJ>].

operational satellites, as well as smaller objects like discarded bolts and abandoned astronaut tools.²⁰ The profligate testing of anti-satellite (ASAT) weapons, kinetically shattering a target into random fast-flying fragments, has been a particularly pernicious source of debris.²¹ The United States has identified and catalogued, and continuously tracks, some forty thousand such items, but there are hundreds of thousands of bits too small to detect, but hazardous nonetheless.²² Depending on the altitude and size of a fragment and the circularity of its orbit, the debris can remain aloft for years or decades—at GEO, even for centuries—before it naturally cascades down to Earth. There is currently no human capability for proactive removal of defunct material from space.²³

This debris is now widely recognized as a terrible hazard to space navigation and use. Even a small piece, traveling at immense orbital velocities, could puncture a hole in any spacecraft it hits. Depending on where on the satellite

²⁰ Orbital Debris Interagency Working Grp., Subcommittee on Space Weather, Security, and Hazards, NATIONAL ORBITAL DEBRIS IMPLEMENTATION PLAN 7 (National Science and Technology Council, July 2022) (establishing roster of actions the U.S. government will pursue to address the hazards of orbital debris); LARGE CONSTELLATIONS OF SATELLITES, *supra* note 10, at 38–52; Kai McNamee, et. al., *Astronauts Dropped a Bag of Tools in Space, and You Can See It with Binoculars*, NPR (Nov. 12, 2023), <https://www.npr.org/2023/11/13/1212737786/astronauts-dropped-a-bag-of-tools-in-space-and-you-can-see-it-with-binoculars> [<https://perma.cc/2HDX-AD2E>].

²¹ Theresa Hitchens, *Debris from ASAT Tests Creating “Bad Neighborhood” in Low Earth Orbit*, BREAKING DEFENSE (June 16, 2023), <https://breakingdefense.com/2023/06/debris-from-asat-tests-creating-bad-neighborhood-in-low-earth-orbit-analyst> [<https://perma.cc/TB5D-5FYB>] (reporting large danger of collisions in LEO due to fragments from ASAT testing); Sandra Erwin, *Space Force Juggles Roles as Warrior and Protector of the Space Environment*, SPACE NEWS (July 10, 2023), <https://spacenews.com/space-force-juggles-roles-as-warrior-and-protector-of-space-environment/> [<https://perma.cc/QB94-TD6P>] (reporting comments by U.S. Space Command’s deputy chief, Lt. Gen. John Shaw, that the military will emphasize the sustainability of the space environment, such as by avoiding the creation of additional debris in military tests and operations).

²² Hitchens, *supra* note 21; Pultarova, *supra* note 15 (reporting estimates that in LEO, there are 36,500 pieces of space debris larger than ten centimeters, about a million objects one to ten centimeters in size, and 130 million fragments smaller than one centimeter); LARGE CONSTELLATIONS OF SATELLITES, *supra* note 10, at 39; *Space Debris by the Numbers*, EUROPEAN SPACE AGENCY (last visited Feb. 21, 2024), https://www.esa.int/Space_Safety/Space_Debris/Space_debris_by_the_numbers [<https://perma.cc/C75P-6VDN>] (reporting about 35,150 items tracked by space surveillance networks, and a total of 11,500 tonnes of human-made objects in orbit).

²³ LARGE CONSTELLATIONS OF SATELLITES, *supra* note 10, at 40–41, 50–52 (discussing lifespan of debris at different altitudes and current inability to remove debris from space); JASON, *supra* note 6, at 85–104; Ralph Cooney, *Harpoons, robots and lasers: how to capture defunct satellites and other space junk and bring it back to Earth*, THE CONVERSATION (Sept. 12, 2022), <https://theconversation.com/harpoons-robots-and-lasers-how-to-capture-defunct-satellites-and-other-space-junk-and-bring-it-back-to-earth-189698> [<https://perma.cc/9994-RCJG>] (assessing potential future methods for active removal of space debris); Zhang, *supra* note 8, at 10–12 (evaluating limited potential capacity for retrieving debris).

the impact occurs, the harm could be fatal. Certainly, a collision with a larger fragment would devastate any satellite.²⁴ And the harm does not end with a first collision: an initial impact would create more knock-on debris, with each piece then speeding along its own azimuth, potentially striking other space objects in a continuous chain reaction. That scenario, known as the Kessler Syndrome, posits a never-ending cascade of reverberating impacts and debris, rendering vast reaches of space uninhabitable. Ominously, some experts now posit that the LEO world has already reached the saturation point at which the Kessler effect would be irreversible—and, as more satellites are launched, the odds of fatal collisions inexorably and irreversibly mount.²⁵

The legal dimension of the debris problem features the 1972 Liability Convention,²⁶ another broad multilateral treaty, which establishes a novel two-tiered tort regime requiring compensation for harm inflicted by space activities. For damage experienced on the surface of the Earth (as when a spacecraft or a fragment crashes to the surface) the state that launched the offending space object is “absolutely” liable.²⁷ In contrast, where the harm is done to another spacecraft in flight, the state is liable only “if the damage is due to its fault.”²⁸ The treaty does not define “fault,” and there is no experience in applying this pregnant provision in practice. The difficulties in establishing who was at fault in a collision between two orbiters may be insurmountable, and if the damage was inflicted by a collision with random debris, it may be impossible to conclusively prove the origin and national affiliation of that fragment of space junk.²⁹

²⁴ *Space Debris and Human Spacecraft*, NASA (May 26, 2021), https://www.nasa.gov/mission_pages/station/news/orbital_debris.html [<https://perma.cc/DP3Z-5CZR>] (last visited Feb. 21, 2024); *Frequently Asked Questions*, NASA <https://orbitaldebris.jsc.nasa.gov/faq/> [<https://perma.cc/H7V7-WEU3>] (last visited Feb. 21, 2024) (describing the hazards of space debris); LARGE CONSTELLATIONS OF SATELLITES, *supra* note 10, at 41 (noting that even a loose fleck of dried paint, traveling at such high speeds, can damage a satellite); Raffi Khatchadourian, *The Trash Nebula*, NEW YORKER (Sept. 28, 2020), <https://www.newyorker.com/magazine/2020/09/28/the-elusive-peril-of-space-junk> [<https://perma.cc/57LQ-TNQU>]; Isobel Whitcomb, *How Do Tiny Pieces of Space Junk Cause Incredible Damage?*, SPACE.COM (Mar. 19, 2021), <https://www.space.com/tiny-space-junk-damage> [<https://perma.cc/C9NA-T9RD>].

²⁵ Mike Wall, *Kessler Syndrome and the Space Debris Problem*, SPACE.COM (July 14, 2022), <https://www.space.com/kessler-syndrome-space-debris> [<https://perma.cc/4FVX-28T7>]; Jakub Drmola & Tomas Hubik, *Kessler Syndrome: System Dynamics Model*, 44-45 SPACE POL. 29 (2018); LARGE CONSTELLATIONS OF SATELLITES, *supra* note 10, at 42 (noting that the likelihood of collisions in space rises with the square of the number of objects in orbit); MICHAEL BYERS & AARON BOLEY, WHO OWNS OUTER SPACE? INTERNATIONAL LAW, ASTROPHYSICS, AND THE SUSTAINABLE DEVELOPMENT OF SPACE 46–76 (Cambridge Univ. Press 2023).

²⁶ Convention on International Liability for Damage Caused by Space Objects, Mar. 29, 1972, 961 U.N.T.S. 187.

²⁷ *Id.* art. II.

²⁸ *Id.* art. III.

²⁹ The OST, like any treaty, establishes rights and responsibilities only for states. Article VI of the OST, however, creates an unusual rule through which a state “shall bear international responsibility for national activities in outer space . . . whether such activities are carried on by

C. Pollution

The third special aspect of the congestion problem is pollution. Each space launch is powered by noxious rocket fuel (of different sorts) and each deposits a quantity of metals, other particulates, and gases into the upper atmosphere and space, with inadequately understood environmental consequences.³⁰ Any human-made debris that drops out of orbit and burns up upon re-entering the Earth's atmosphere—currently estimated at a total of eighty tonnes per year—will also liberate a quantity of chemicals, some of which can have important and still imperfectly known adverse effects on the biosphere.³¹ The emerging practice of deliberately relying upon inexpensive, disposable satellites means that LEO will experience an even more massive quantity of transits, each carrying detrimental

governmental agencies or by non-governmental entities.” Therefore, for example, the United States is internationally responsible for SpaceX's space activities and the consequences of those activities, including congestion, collisions, and the generation of debris. *See Long-term Sustainability of Outer Space Activities*, U.N. OFF. FOR OUTER SPACE AFFAIRS <http://www.unoosa.org/oosa/en/ourwork/topics/long-term-sustainability-of-outer-space-activities.html>

[<https://perma.cc/9M5H-WVPT>] (last visited Feb. 21, 2024) (successful development of non-legally-binding code of conduct for space topics not related to weapons).

³⁰ LARGE CONSTELLATIONS OF SATELLITES, *supra* note 10, at 10 (anticipating sharp increases in numbers of space launches from the United States and globally), at 11 (listing rocket propellants and their atmospheric emissions), at 12–16 (describing launch emissions of alumina, black carbon, and other materials that could change the temperature of the stratosphere and deplete the ozone layer); J. A. Dallas, et. al., *The Environmental Impact of Emissions from Space Launches: A Comprehensive Review*, 255 JOURNAL OF CLEANER PRODUCTION (2020); Martin N. Ross and Karen L. Jones, *Implications of a Growing Spaceflight Industry: Climate Change*, 9 JOURNAL OF SPACE SAFETY ENGINEERING 469 (June 2022) (focusing on particulates, rather than gases, as the chief environmental danger from space activities); MARTIN ROSS & JAMES A. VEDDA, CTR. FOR SPACE POL. AND STRAT., *THE POLICY AND SCIENCE OF ROCKET EMISSIONS* (Apr. 2018), https://aerospace.org/sites/default/files/2018-05/RocketEmissions_0.pdf [<https://perma.cc/H5WW-8JZ4>]; Jeff Foust, *What Is the Environmental Impact of a Supercharged Space Industry?*, SPACE REV. (Feb. 6, 2023), <https://www.thespacereview.com/article/4527/1> [<https://perma.cc/63MU-8S37>] (reporting scientific concerns about long-lived black carbon and other pollutants introduced into the upper atmosphere, even if cleaner-burning fuels are used for launching).

³¹ LARGE CONSTELLATIONS OF SATELLITES, *supra* note 10, at 15–16 (discussing exotic materials including paints, resins, epoxies, and others that would be released during re-entry); Cooney, *supra* note 23 (citing eighty tonnes of space debris reentering the atmosphere per year); Ross & Jones, *supra* note 30; Boley & Byers, *supra* note 19; Tereza Pultarova, *Mega-constellations, Rockets and Supersonic Aircraft Could Thwart Ozone Layer's Recovery*, SPACE.COM (Jan. 23, 2023), <https://www.space.com/supersonic-aviation-megaconstellations-new-threats-ozone> [<https://perma.cc/Z697-9NS4>] (reporting scientists' apprehensions that the reentry and consequent vaporization of large numbers of LEO satellites and the firing of so many rocket propulsion systems could jeopardize the Earth's protective ozone layer); Daniel M. Murphy, et. al., *Metals from Spacecraft Reentry in Stratospheric Aerosol Particles*, PNAS, Sept. 7, 2023, <https://www.pnas.org/doi/10.1073/pnas.2313374120> [<https://perma.cc/4X85-CJ79>].

(and not fully studied or appreciated) environmental implications.³² In addition, injecting that increasing volume of short-lived material into LEO inevitably raises the prospect of occasional losses of control, and the possibility that more large, dense items may survive their reentry and catastrophically strike objects or persons upon return to Earth.³³

International environmental law regarding space activities is still under construction. There is no broad-based treaty that explicitly regulates pollution in space,³⁴ nor is there any specific international law obligation to undertake rigorous

³² Siegel, *supra* note 15 (calculating that the anticipated 100,000 satellites will deposit fourteen tons of aluminum into the Earth's atmosphere daily—thirty times the naturally occurring amount—possibly contributing to adverse climatic effects); U.S. GOV'T ACCOUNTABILITY OFF., GAO-23-105005, SATELLITE LICENSING: FCC SHOULD REEXAMINE ITS ENVIRONMENTAL REVIEW PROCESS FOR LARGE CONSTELLATIONS OF SATELLITES 5–7 (2002), <https://www.gao.gov/assets/gao-23-105005.pdf> [<https://perma.cc/4AXD-LS8Q>] [hereinafter SATELLITE LICENSING]; Robert Lea, *A Satellite Will Fall to Earth This Week in a 1st-of-its-Kind Reentry. Here's What You Need to Know*, SPACE.COM (July 24, 2023), <https://www.space.com/aeolus-satellite-will-return-to-earth-this-week> [<https://perma.cc/QQD7-2MGJ>] (reporting that typically eighty percent of a returning satellite's mass will burn in the atmosphere and twenty percent will crash to the Earth's surface; also noting that the 2,000 nonfunctional satellites currently in orbit amount to 11,000 tons of matter, and that large objects reenter the atmosphere about once per week).

³³ AARON BOLEY, ET. AL., REPORT ON MEGA-CONSTELLATIONS TO THE GOVERNMENT OF CANADA AND THE CANADIAN SPACE AGENCY 12–13 (2021), <https://arxiv.org/abs/2104.05733> [<https://perma.cc/P2WN-P3QA>] (calculating that there was a forty-five percent chance of one or more casualties on Earth over five years due to uncontrolled satellite re-entries; this risk has been abated via better Starlink designs); LARGE CONSTELLATIONS OF SATELLITES, *supra* note 10, at 18–21 (critiquing U.S. standards that assess the risk of reentry impacts on a per-satellite basis without adequately taking into account the size of the large constellations); *International Open Letter on Reducing Risks from Uncontrolled Reentries of Rocket Bodies and Other Space Objects*, OUTER SPACE INST. (Dec. 19, 2022), https://outerspaceinstitute.ca/osisite/wp-content/uploads/OSI-Open-Letter-on-Uncontrolled-Reentries19_12_2022.pdf [<https://perma.cc/D3CC-9GL9>] (highlighting the potential harm inflicted by space objects that fall uncontrolled to Earth); BYERS & BOLEY, *supra* note 25 (also highlighting the adverse cumulative environmental effect of thousands of rocket stages splashing into the oceans); Carmen Pardini and Luciano Anselmo, *Uncontrolled Re-Entries of Spacecraft and Rocket Bodies: A Statistical Overview of the Last Decade*, 6 JOURNAL OF SPACE SAFETY ENG'G 30, 30 (Mar. 2019) (reporting that since the beginning of the space age, 24,400 catalogued orbiting objects have reentered the Earth's atmosphere, amounting to almost thirty thousand metric tons, creating significant risks on the ground); RICHARD GREEN, ET AL., SATCON2 POLICY WORKING GROUP REPORT 163–187 (Oct. 2021), <https://noirlab.edu/public/media/archives/techdocs/pdf/techdoc033.pdf> [<https://perma.cc/6ZLB-QLND>]; Jason Rainbow, *SpaceX Slams FAA Report on Falling Space Debris Danger*, SPACE NEWS (Oct. 9, 2023), <https://spacenews.com/spacex-slams-faa-report-on-falling-space-debris-danger/> [<https://perma.cc/Z7NQ-MATD>] (reporting controversy about recent expert report calculating the probability that debris falling from space could cause injuries on the Earth or to aircraft in flight).

³⁴ LARGE CONSTELLATIONS OF SATELLITES, *supra* note 10, at 13 (assessing that the Montreal Protocol on Substances That Deplete the Ozone Layer does not apply to rocket emissions in the stratosphere); Ross & Jones, *supra* note 30, at 8–9. *See also* Andy Lawrence, et. al., *The Case for*

“environmental assessments” of space activities. Under U.S. law, the Federal Communications Commission, which is responsible for licensing satellite operations, has given itself a blanket “categorical exclusion” from most of the usual environmental assessment requirements of the National Environmental Policy Act.³⁵

Nonetheless, the proposition is well-established in international law that no state may allow its territory to be used in a manner that inflicts serious injury on “areas beyond national jurisdiction,” and the proscription against the spread of significant transborder pollution is abundantly clear.³⁶ Non-legally-binding provisions, such as the Space Debris Mitigation Guidelines, promulgated by the U.N. Committee on the Peaceful Use of Outer Space, are influential, if not

Space Environmentalism, 6 NATURE ASTRONOMY PERSPECTIVE 428, 428 (April 2022) (assembling a case in favor of extending terrestrial environmental law into orbital space). Cf. *1979 Convention on Long-Range Transboundary Air Pollution*, U.S. DEP’T OF STATE, <https://www.state.gov/key-topics-office-of-environmental-quality-and-transboundary-issues/convention-on-long-range-transboundary-air-pollution/> [<https://perma.cc/7X72-VQPJ>] (explaining the international agreement, joined by fifty-one states, embracing eight protocols addressing specific pollutants and establishing agreed international standards to abate pollution of the atmosphere).

³⁵ Space Exploration Holdings, LLC, 36 FCC Rcd. 7995, 8035–47 (2021) [hereinafter FCC Order] (providing FCC’s views of its responsibilities under the National Environmental Policy Act, particularly regarding debris, pollution, and interference with astronomy); SATELLITE LICENSING, *supra* note 32, at 22–28 (challenging the FCC’s basis for applying its categorical exclusion from the ordinary NEPA procedures when considering license applications for large LEO constellations); GREEN, ET AL., *supra* note 33, at 192–195; Leighton Brown and Paul Stimers, *The FCC’s Authority in Regulating Orbital Debris*, SPACE REV. (Nov. 6, 2023), <https://www.thespacereview.com/article/4687/1> [<https://perma.cc/PJ38-ZFEN>] (discussing FCC’s negotiating a consent decree with Dish, which agree to pay a \$150,000 civil penalty for failing to adhere to FCC rules regarding orbital debris). See also Exec. Order No. 12114, 44 Fed. Reg. 1957 (Jan. 4, 1979) (requiring some form of environmental assessment for “major Federal actions significantly affecting the environment of the global commons outside the jurisdiction of any nation”).

³⁶ Trail Smelter (U.S. v. Can.), 3 R.I.A.A. 1905 (Mar. 11, 1941); Legality of the Threat or Use of Nuclear Weapons, Advisory Opinion, 1996 I.C.J. 226, para. 29 (determining that “the general obligation of States to ensure that activities within their jurisdiction and control respect the environment of other States or of areas beyond national control is now part of the corpus of international law relating to the environment.”); U.N. Conference on Environment and Development, *Rio Declaration on Environment and Development*, Principles 2, 3, U.N. Doc. A/CONF.151/26/Rev.1 (Vol. 1), annex I (Aug. 12, 1992) (states have “the responsibility to ensure that activities within their jurisdiction or control do not cause damage to the environment of other States or of areas beyond the limits of national jurisdiction” and “the right to development must be fulfilled so as to equitably meet developmental and environmental needs of present and future generations.”); DARK & QUIET SKIES FOR SOCIETY, *supra* note 19, at 122–29; International Institute of Space Law, Keeping the Night Sky Clear: IISL Working Group on the Light Pollution of the Night Sky from a Space Law Perspective Final Report 24–26 (June 2023), https://www.researchgate.net/publication/372308025_The_IISL_Working_Group_identified_and_examined_existing_legal_regulation_already_in_place_that_may_be_relevant_for_this_problem_and_also_explored_the_possible_emergence_of_new_rules_of_international_s [<https://perma.cc/8F2Y-RDEE>] [hereinafter IISL] (summarizing international environmental law applicable to light pollution in space).

dispositive, in reinforcing those norms—but these seek only to minimize, not to eliminate, the pollution problem.³⁷

Multiple variables will affect the malign power of each of these three problematic factors. For example, many satellites are maneuverable; they carry onboard sensors, thrusters, and fuel, empowering them to take evasive maneuvers to avoid a collision – but many others do not.³⁸ Moreover, current capabilities are far from perfect for monitoring spacecraft positions and detecting debris, and for projecting exactly what their future trajectories will be—the ability to anticipate future “conjunctions” between space objects is highly imperfect (even while the number of such potentially destructive events is surely mounting).³⁹ In addition, any satellite that remains in orbit long after its functionality ends will pose an enduring (and at that point, wholly unproductive) danger.⁴⁰ The U.S. government has recently tightened its rules to require deorbit within five years (instead of the prior twenty-five years) after the orbiter’s useful life ends – but many defunct spacecraft will remain sitting ducks for collisions in space for much longer.⁴¹ Some

³⁷ U.N. OFF. FOR OUTER SPACE AFFAIRS, SPACE DEBRIS MITIGATION GUIDELINES OF THE COMM. ON THE PEACEFUL USES OF OUTER SPACE (2010), available at https://www.unoosa.org/pdf/publications/st_space_49E.pdf [<https://perma.cc/D45S-DZH4>]. See also Robert Lea, *NASA Scientists Push for a Treaty to Tackle Risky “Space Junk,”* SPACE.COM (Mar. 9, 2023), <https://www.space.com/nasa-scientists-space-junk-treaty> [<https://perma.cc/B6QP-Q8LD>] (reporting scientists’ call for enhanced legal constraints on the generation of additional space debris).

³⁸ Pultarova, *supra* note 7 (noting that each Starlink satellite “has a sufficient amount of fuel on board to perform 350 collision-avoidance maneuvers over its expected five-year lifetime”); Jason Rainbow, *Project Kuiper Urges Regulators to Focus on Satellite Maneuverability Rules,* SPACE NEWS (Jun. 15, 2023), <https://spacenews.com/project-kuiper-urges-regulators-to-focus-on-satellite-maneuverability-rules/> [<https://perma.cc/9RUN/H68P>] (reporting industry experts recommending national regulations to require that LEO satellites be maneuverable).

³⁹ Hitchens, *supra* note 21 (noting that there were 1486 conjunction warnings for the International Space Station in 2022); Pultarova, *supra* note 7 (quoting British astronomer Hugh Lewis stating that “the overall number of conjunctions predicted for 2022 was 134% higher than the number for 2020 and 58% higher than 2021, exceeding 4 million.” Likewise, Starlink’s autonomous collision-avoidance system performed 26,037 orbital avoidance maneuvers in the two-year period between December 1, 2020 and November 30, 2022, rising to 25,299 such maneuvers during the six month period between December 1, 2022 and May 31, 2023); 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 (Jul. 6, 2023), <https://www.space.com/starlink-satellite-conjunction-increase-threatens-space-sustainability> [<https://perma.cc/9WZW-L5R9>]; LARGE CONSTELLATIONS OF SATELLITES, *supra* note 10, at 43–48 (discussing the need for improved “space situational awareness,” to monitor debris and active satellites); Zhang, *supra* note 8, at 5–9 (evaluating capabilities for surveillance of space objects).

⁴⁰ Siegel, *supra* note 15 (noting that Starlink has an admirable failure rate of only one percent, but with a high rate of launches, that amounts to a substantial quantity of dead satellites, which may linger in space); FCC Order, *supra* note 35, at 8026–35 (FCC assesses that SpaceX’s plans are adequate regarding Starlink’s risks for collisions, satellite failures, and debris).

⁴¹ In 2022, the FCC adopted a “Five Year Rule,” requiring quicker de-orbit of LEO satellites that are licensed in the United States or that serve U.S. markets, to be effective in two years, replacing the longstanding twenty-five-year rule. Press Release, Fed. Communications Comm’n, *FCC*

satellites are “demisable” —designed so that all components will burn up entirely upon re-entry through the Earth’s atmosphere—but others are hardier and therefore more dangerous.⁴²

In sum, this aspect of modern space life offers a disheartening version of the tragedy of the commons.⁴³ Multiple competitive users seek to exploit a shared space vigorously; each has little incentive to husband the resources or to avoid general harms that will afflict everyone. The first to arrive will seek to entrench their favored position; over-crowding and pollution will inevitably follow. In the absence of effective international regulation, each country experiences an incentive to assert only the lightest touch of national regulation, in order to avoid discouraging private entrepreneurs and driving them to incorporate abroad.⁴⁴ Sooner or later, the enormous potential advantages of inexpensive access to space may lead to wild over-use, causing the system to collapse, to the profound and enduring detriment of all.⁴⁵

Adopts New ‘5-Year Rule’ for Deorbiting Satellites to Address Growing Risk of Orbital Debris

(Sept. 29, 2022) <https://docs.fcc.gov/public/attachments/DOC-387720A1.pdf>

[<https://perma.cc/PJ3E-ASDX>]; Jeff Foust, *FCC Approves New Orbital Debris Rule*, SPACE NEWS (Sept. 29, 2022), <https://spacenews.com/fcc-approves-new-orbital-debris-rule/>

[<https://perma.cc/KGH4-2B7B>]. See also Cooney, *supra* note 23 (assessing that approximately sixty percent of the satellites now in orbit are non-functional).

⁴² Mirko Trisolini, Hugh G. Lewis, & Camilla Colombo, *On the Demisability and Survivability of Modern Spacecraft*, Proc. of the Seventh European Conference on Space Debris (2017)

<https://conference.sdo.esoc.esa.int/proceedings/sdc7/paper/450/SDC7-paper450.pdf>

[<https://perma.cc/6JL5-8ZB>].

⁴³ Garrett Hardin, *The Tragedy of the Commons*, 162 SCIENCE 1243, 1243 (1968) (discussing the recurrent problem of over-use of a shared resource, resulting in its depletion, with harm to all); Boley & Byers, *supra* note 19.

⁴⁴ Scott Pace, Exec. Sec’y, Nat’l Space Council, Space Development, Law, and Values, Keynote Address at IISL Galloway Space Law Symposium 3 (Dec. 13, 2017),

<https://spacepolicyonline.com/wp-content/uploads/2017/12/Scott-Pace-to-Galloway-Symp-Dec-13-2017.pdf> [<https://perma.cc/F6JD-9THR>] (asserting that “the United States should strive to be

the most attractive jurisdiction in the world for private sector investment and innovation in outer space. This requires a transparent, efficient, and minimally burdensome domestic regulatory mechanism for U.S. companies conducting space activities. This Administration embraces meeting U.S. international obligations through a “light-touch” regulatory approach that maximizes industry’s ability to innovate and national freedom of action.”); Kevin O’Connell, Dir., Off. Space Com., U.S. Dep’t Com., *Advancing Space Commerce: What Does “Light Touch, Permissive Regulation” Mean?*, Keynote Address at Galloway Space Law Symposium (Dec. 5, 2018), <https://www.space.commerce.gov/advancing-space-commerce-what-does-light-touch-permissive-regulation-mean/> [<https://perma.cc/5MGZ-EY44>].

⁴⁵ It is beyond the scope of this Article to mediate the persistent debate about whether outer space is a true “global commons.” See generally HOBE ET. AL., *supra* note 16, at 27–29 (comparing space to other common areas); U.N. Secretary-General, *Our Common Agenda*, 17–18, 48, U.N. Doc. A/75/982 (Aug. 5, 2021) (listing outer space, along with the high seas, the atmosphere, and Antarctica, as global commons, and calling for improved protection of them); Henry R. Hertzfeld, Brian Weeden, and Christopher D. Johnson, *How Simple Terms Mislead Us: The Pitfalls of Thinking about Outer Space as a Commons*, SECURE WORLD (2015), <https://swfound.org/media/205390/how-simple-terms-mislead-us-hertzfeld-johnson-weeden-iac->

III. THE UGLY: INTERFERENCE WITH ASTRONOMY

Not only may the legions of new satellites jeopardize each other, but they also pose a different kind of interference problem: disrupting astronomy.

Astronomy is an ancient science and art, attempting to gather faint electromagnetic emissions and reflections from distant celestial bodies, to unlock the secrets of the origins of the universe and the Earth's tiny place within it. Breath-taking scientific discoveries regarding the Big Bang, black holes, and other ethereal phenomena are attributable to astronomy, and additional breakthroughs are surely on the horizon. Astronomy also constitutes a critical enabling technology for all other space exploration and use—now including, ironically, modern satellite applications that threaten to subvert further activities of this “origin science.”⁴⁶

There are multiple types of technologies and facilities for conducting painstaking celestial searches, but the two most relevant here are optical astronomy (using familiar large telescopes to access visible light) and radio astronomy (detecting faint invisible radio signals from distant sources). Observatories of both types dot the planet, and are also deployed in space, as astronomers attempt to avoid the competing terrestrial glare and noise that would obscure their data.⁴⁷

2015.pdf [<https://perma.cc/4TV9-C6L4>] (noting that the term “commons” does not appear in any space related treaties, but is frequently applied by governments and other commentators in discussing space and arguing that space does not fit the historical concept of a commons); DANIEL PATTON, IS SPACE A GLOBAL COMMONS? SECURE WORLD FOUNDATION SPACE SUSTAINABILITY BRIEF (2022)

https://swfound.org/media/207517/swf_brief_is_space_a_global_commons_pp2301_final.pdf [<https://perma.cc/KEU2-D58A>] (quoting contradictory U.S. government statements about whether space is a global commons); Exec. Order No. 13914, § 1, 85 Fed. Reg. 20381 (Apr. 6, 2020) (“the United States does not view [outer space] as a global commons”); Pace, *supra* note 44, at 4 (asserting that space is not a global commons and that the United States has consistently taken the position that the legal status of space should not be described by that legal construct); John S. Goehring, *Why Isn't Outer Space a Global Commons?*, 11 JOURNAL OF NATIONAL SECURITY LAW AND POLICY 573 (2021); Venkatesan, *supra* note 12 (arguing that space is an ancestral global commons); IISL, *supra* note 36, at 86–94.

⁴⁶ Marissa Rosenberg, et. al., *Astronomy in Everyday Life*, Int'l Astronomical Union (Oct. 2013), https://www.iau.org/public/themes/astronomy_in_everyday_life/ [<https://perma.cc/A2RL-V33H>] (summarizing tangible and intangible benefits of astronomy for science, industry, medicine, and daily life); Paul Sutter, *Why Astronomy Remains Relevant Today*, SPACE.COM (Jan. 7, 2021), <https://www.space.com/why-astronomy-is-important-today> [<https://perma.cc/AP3Q-NR5U>]; PUSHPA KHARE, NOBEL PRIZES IN ASTRONOMY (2023) (discussing eleven Nobel Prizes in physics awarded to astronomers); Robert Lea, *World's Biggest Radio Telescope Could Tease Out Secrets of Dark Matter, Universe's 1st Galaxies*, SPACE.COM (Jul. 18, 2023), <https://www.space.com/dark-matter-universe-first-galaxies-cosmic-dawn-forest> [<https://perma.cc/JS32-4PFP>] (anticipating that a new radio telescope now under construction will enable the first definitive studies of dark matter created at the beginning of the universe.).

⁴⁷ *Science of Radio Astronomy*, NATIONAL RADIO ASTRONOMY OBSERVATORY, <https://public.nrao.edu/radio-astronomy/the-science-of-radio-astronomy/> [<https://perma.cc/WPH7-7MBT>] (last visited Mar. 27, 2024); *Radio Telescope vs. Optical Telescope – The Differences Between Them*, SCOPE THE GALAXY <https://scopethegalaxy.com/radio-vs-optical-telescope/>

The perpetual search for suitably dark and quiet skies can be complicated by the increasing light and radio pollution from modern life—streetlights, sports stadiums, microwave ovens, and overflying airplanes can jeopardize astronomers’ scientific inquiries.⁴⁸ Satellites, too, pose a challenge—and today, this is a suddenly growing and possibly fatal threat to the future of astronomy.

When an optical telescope stares up through the night sky, it seeks to capture images of faint points of light that may represent far distant stars or other celestial bodies. However, when a LEO satellite overflies, it will leave a bright streak across the observatory’s images, obscuring the view of whatever lies behind. When there were only a few such intervening overflights, the intrusions were a mere annoyance—akin to a bug splat on a car windshield. But when thousands of satellites appear nightly, the proliferation of occluding streaks drowns out more pixels in each photograph, degrading the telescope’s ability to gather and interpret the data essential to its scientific mission.⁴⁹ As one chilling example, at the soon-

[<https://perma.cc/NE7F-Q6EV>] (last visited Mar. 22, 2024); *Observatory Locations*, SPACE FM, <https://www.space.fm/astronomy/planetarysystems/observatories.html> [<https://perma.cc/6DPW-MR2F>] (last visited Mar. 22, 2024).

⁴⁸ Richard F. Green, et. al., *The Growing Threat of Light Pollution to Ground-based Observatories*, 30 ASTRONOMY AND ASTROPHYSICS REVIEW 1, 2 (2022) (“The growth of artificial light at night (ALAN) worldwide has drastically diminished the accessibility of dark skies to all members of modern cultures, and for professional astronomy, and threatens even remote professional observatory sites with increased anthropogenic skyglow.”); DARK & QUIET SKIES FOR SOCIETY, *supra* note 19, at 15–73; Antonia M. Varela Perez, *The Increasing Effects of Light Pollution on Professional and Amateur Astronomy*, 380 SCIENCE 1136 (2023); Siegel, *supra* note 15.

⁴⁹ DARK & QUIET SKIES FOR SOCIETY, *supra* note 19, at 74–92; PRZEMEK MROZ, ET. AL., IMPACT OF THE SPACE X STARLINK SATELLITES ON THE ZWICKY TRANSIENT FACILITY SURVEY OBSERVATIONS (2022) <https://arxiv.org/abs/2201.05343> [<https://perma.cc/QNK5-KKPY>] (detailing streaks on observatory’s images due to satellite overflights); Patrick Seitzer & J. Anthony Tyson, *Large LEO Constellations, Astronomy, and Space Debris Mitigation*, Proc. of the Eighth European Conference on Space Debris (2021) <https://conference.sdo.esoc.esa.int/proceedings/sdc8/paper/112/SDC8-paper112.pdf> [<https://perma.cc/XM6T-FFWF>] (describing five types of problems that satellite trails pose for observatories’ photographic images); LARGE CONSTELLATIONS OF SATELLITES, *supra* note 10, at 22–37 (describing astronomical functions that are being inhibited by satellite interference); BYERS & BOLEY, *supra* note 25, at 46–76; Margaret Davis, *The Bluewalker 3 Satellite Is Officially One of the Brightest Objects in the Sky*, SPACE.COM (Oct. 3, 2023), <https://www.space.com/bluewalker-3-prototype-satellite-brightest-objects-sky#> [<https://perma.cc/R92V-QQ3X>] (describing the first of a planned constellation of ninety exceptionally bright satellites). Placing telescopes in space can mitigate, but not eliminate, the effects of satellite interference, but space-based observatories are extremely expensive. Comm. on the Peaceful Uses of Outer Space, *Recommendations to Keep Dark and Quiet Skies for Science and Society*, Conf. Room Paper submitted by Chile, Ethiopia, Jordan, Slovakia, Spain and the International Astronomical Union, U.N. Doc. A/AC.105/C.1/2021/CRP.17*, at 5 (2021) [hereinafter Chile, et. al., Conf. Room Paper] (noting that the interference from LEO satellites affects space-based telescopes, too, “and in those cases, mitigations are more challenging to implement.”); LARGE CONSTELLATIONS OF SATELLITES, *supra*

to-be-completed Vera C. Rubin Observatory in Chile, anticipated to provide (at a cost of half a billion dollars) the most advanced capability to image large sectors of the night sky, thirty to forty percent of the images are likely to be indelibly polluted by satellite streaks.⁵⁰

These intrusions generate multiple disruptions for astronomy by obstructing access to vital data, forcing expensive repetition of observations, complicating the interpretation of results, and compelling professionals and institutions to divert their energies into trying to invent adaptations, rather than proceeding with their underlying science missions.⁵¹ Leading astronomers fear the collapse of their profession and the consequent loss of scientific data essential for the exploration and understanding of space.⁵² Some also emphasize the special impediment that

note 10, at 38–52; U.S. GOV'T ACCOUNTABILITY OFF., GAO-23-105565, SPACE SITUATIONAL AWARENESS: DOD SHOULD EVALUATE HOW IT CAN USE COMMERCIAL DATA 28 (Apr. 2023), <https://www.gao.gov/assets/gao-23-105565.pdf> [<https://perma.cc/6RF7-DRJ5>] (observing that satellites in orbit currently affect two to eight percent of the images collected by the Hubble space telescope, and anticipating that in the future, sixteen percent of the images will be harmed).

⁵⁰ *About*, VERA C. RUBIN OBSERVATORY, <https://rubinobservatory.org/about> [<https://perma.cc/W76A-47GE>] (last visited Feb. 22, 2024); Lawrence, *supra* note 34, at 430 (explaining that the problem of intrusive satellite streaks will be worse for those observatories, such as Rubin, that are designed to scan broad areas of the sky nightly, and asserting that the interference “can render some scientific analyses impossible”); JASON, *supra* note 6, at 41–43; Siegel, *supra* note 15 (noting that, in addition to creating individual streaks on astronomical images, the growing LEO satellite population will also contribute to a more diffuse illumination of the night sky, causing a general, pervasive degradation in observatories’ capabilities).

⁵¹ John C. Barentine, et. al., *Aggregate Effects of Proliferating Low-Earth-Orbit Objects and Implications for Astronomical Data Lost in the Noise*, 7 NATURE ASTRONOMY 252 (2023); Luc H. Riesbeck, Roger C. Thompson, & Josef S. Koller, THE FUTURE OF THE NIGHT SKY: LIGHT POLLUTION FROM SATELLITES, AEROSPACE CENTER FOR SPACE POLICY AND STRATEGY (Oct. 2020), https://csp.aerospace.org/sites/default/files/2021-08/Koller-Thompson_LightPollution_20201026.pdf [<https://perma.cc/YC2Q-V4TN>] (describing several highly-reflective satellites); Alexandra Witze, ‘Unsustainable’: How Satellite Swarms Pose a Rising Threat to Astronomy, SCI. AM. (June 2., 2022), <https://www.scientificamerican.com/article/lsquo-unsustainable-rsquo-how-satellite-swarms-pose-a-rising-threat-to-astronomy/> [<https://perma.cc/TFY2-6PB4>]. See generally IISL, *supra* note 36.

⁵² See Alexandra Witze, *How Satellite “Megaconstellations” Will Photobomb Astronomy Images*, NATURE (2020), <https://www.nature.com/articles/d41586-020-02480-5> [<https://perma.cc/3AGB-QP6L>] (quoting astronomer Tony Tyson saying, “There’s no place to hide in the middle of the night from such a satellite constellation”); Rebecca Boyle, *Satellite Constellations Are an Existential Threat for Astronomy*, SCI. AM. (Nov. 7, 2022) <https://www.scientificamerican.com/article/satellite-constellations-are-an-existential-threat-for-astronomy/> [<https://perma.cc/8QUK-K5SX>] (quoting Harvard-Smithsonian astronomer Jonathan McDowell calling satellite interference “an existential threat” to astronomy); DARK & QUIET SKIES FOR SOCIETY, DARK & QUIET SKIES FOR SCIENCE AND SOCIETY ON-LINE WORKSHOP REPORT AND RECOMMENDATIONS 143 (2020), <https://www.iau.org/static/publications/dskies-book-29-12-20.pdf> [<https://perma.cc/3WAG-D4TY>] (astronomy experts assess that “[a]t present, the situation for astronomy is reaching a point of no return from continuous interference with observations and loss of science.”); Chile, et. al., Conf. Room Paper, *supra* note 49, para. 15 (concluding that “[w]ithout action from the international community, policymakers and industry, abundant LEO satellites will increasingly tarnish the pristine view of the natural night sky from our planet, and will increasingly imperil astronomical science.”).

satellite interference can cause for planetary defense—the task of monitoring the skies for evidence of any potentially hazardous earthbound large asteroids and comets, which must be detected, tracked, and characterized in time to mount an effective human response for deflection.⁵³

There have been nascent efforts to mitigate this interference by reducing the light reflectivity of the satellites, developing software and data manipulation techniques to scrub the offending streaks from images, and inventing other accommodations. But none of those adjustments will be sufficient to cope with the monumental surge in the satellite population, and purely spontaneous self-restraint is unreliable. SpaceX has voluntarily expended considerable engineering talent and money to reduce Starlink’s visibility; nonetheless, the necessary faintness has not been achieved, and other space participants may not match even that level of *noblesse oblige*.⁵⁴

⁵³ NASA letter, *supra* note 15 (expressing concern that the large and growing LEO constellations will interfere with NASA’s ground-based and space-based telescopes, and stating “NASA estimates that there would be a Starlink in every single asteroid survey image taken for planetary defense against hazardous asteroid impacts, decreasing asteroid survey effectiveness by rendering portions of images unusable.”); Stefanie Waldek, *Asteroid Hunters Worry Megaconstellations Might Interfere with Planetary Defense*, SPACE.COM (Sept. 1, 2022), <https://www.space.com/asteroid-detection-interference-from-satellites> [<https://perma.cc/GY8Z-97DJ>] (reporting that satellite interference can be most problematic for ground-based observatories at twilight and low on the horizon, which are especially important conditions for planetary defense searches).

⁵⁴ SpaceX has been particularly active in developing and deploying, at its own cost, possible adaptations, such as DarkSat (a Starlink satellite painted black, to reduce brightness); VisorSat (a Starlink equipped with a hood to diminish reflectivity); and several newer accommodations such as dielectric film coating, ultra-black paint, and twisting the satellite’s orientation. *See* SpaceX, Space Sustainability, May 7, 2022 (discussing mechanisms for reducing satellite brightness, including paint, visors, stickers, and altering the satellite’s angle toward the Earth); DARK & QUIET SKIES FOR SOCIETY, *supra* note 52, at 30 (concluding that “[l]imited observations of DarkSat and VisorSat indicate that the brightness-reduction mitigation measures implemented in the modified designs are effective but do not achieve the recommended brightness goals stated in this report in all operational phases and geometries.”); *id.* at 247 (concluding that the DarkSat and VisorSat mitigations, along with Starlink’s efforts to align the satellites better to achieve less reflection, did diminish their apparent brightness, but not sufficiently to meet recommended standards); ANTHONY MALLAMA, THE BRIGHTNESS OF VISORSAT-DESIGN STARLINK SATELLITES (2021), <https://arxiv.org/ftp/arxiv/papers/2101/2101.00374.pdf> [<https://perma.cc/6T6N-2D8K>]; Jeff Foust, *Astronomers Renew Concerns About Starlink Satellite Brightness*, SPACE NEWS (Jun. 17, 2022) <https://spacenews.com/astronomers-renew-concerns-about-starlink-satellite-brightness/> [<https://perma.cc/A3H3-JXJB>] (reporting that the new Starlink satellites are brighter than those equipped with visors, and quoting one astronomer saying, “In a real sense, we’re going backwards here.”); Brad Young & Jay Respler, *Effect of Upgrades to Starlink Generation 2 Satellites on Visual Brightness*, SPACE REV. (Aug. 7, 2023) <https://www.thespacereview.com/article/4634/1> [<https://perma.cc/AB33-NPYM>]; LARGE CONSTELLATIONS OF SATELLITES, *supra* note 10, at 26–28 (discussing mitigation efforts, and concluding that even in combination they would be inadequate to resolve the problem of satellite interference with astronomy).

A similar, perhaps even more profound, disruption afflicts radio telescopes. For those observatories, wayward light is not a problem, but radio emissions are—and the massive new LEO constellations are prolific emitters of radio noise for communications. In some instances, “the emissions from satellites can easily be a trillion times louder than the astronomical targets,” and they may sabotage an entire observation, not confined to a single streak across an optical image.⁵⁵ Legal restrictions (internationally, from the International Telecommunication Union,⁵⁶ and domestically, from the Federal Communications Commission⁵⁷) specify who can broadcast on which frequencies, and they preserve some slices of the radio spectrum for observatories. But the growing appetite for commercial applications, and the inherent indiscriminateness of radio broadcasting and receiving, mean that protected frequencies are subject to poaching and interference. Again, some astronomers view the coming diminution of radio astronomy as fatal to their scientific inquiries.⁵⁸

The international law of outer space should provide some relief here, but the applicable provisions are vague and difficult to enforce. The OST specifies that parties’ space activities “shall be guided by the principle of cooperation and mutual assistance” and shall be conducted “with due regard to the corresponding interests

⁵⁵ Lawrence, *supra* note 34, at 431.

⁵⁶ See Lyall & Larsen, *supra* note 11, at 189–225 (describing ITU responsibilities regarding regulation of states’ and companies’ use of the radio spectrum for satellites); *Regulation of Satellite Systems*, INT’L TELECOMM. UNION (Feb. 2022) <https://www.itu.int/en/mediacentre/backgrounders/Pages/Regulation-of-Satellite-Systems.aspx> [<https://perma.cc/EA8A-8PKX>] (last visited Feb. 27, 2024); Joanne Wheeler, *The Space Law Review: International Telecommunication Union and Access to Spectrum*, ALDEN LEGAL LIMITED (Jan. 5, 2023), <https://www.lexology.com/library/detail.aspx?g=0bdd5183-d7f1-453f-b264-b93604bd4dbf>, <https://perma.cc/J8SC-98VA>].

⁵⁷ See SATELLITE LICENSING, *supra* note 32, at 11–18; JASON, *supra* note 6, at 19 (assessing that “the requirement of an FCC license to operate in the lucrative US market appears to be the only effective formal regulation of satellite vendors.”); FCC Order, *supra* note 35, at 8005–26 (discussing potential effects of new Starlink constellation on radio astronomy).

⁵⁸ DARK & QUIET SKIES FOR SOCIETY, *supra* note 19, at 269–83; Jeff Hecht, *Will Satellites Cripple Ground-Based Astronomy?*, OPTICS & PHOTONICS NEWS (May 2021) (quoting astronomer Harvey Liszt saying, “these beams are like death rays for radio astronomy receivers.”); LARGE CONSTELLATIONS OF SATELLITES, *supra* note 10, at 32–37 (describing damaging effects of overflying satellites on radio astronomy; emphasizing that radio transmissions inherently involve a degree of “side beam” energy, so even a radio observatory that is not directly beneath an overflying satellite will be affected by it); Eves, *supra* note 13 (describing multiple problems of radio interference); JASON, *supra* note 6, at 49–71 (concluding that the existing domestic and international legal regulatory mechanism is not sufficient to protect radio astronomy in the era of large constellations of satellites); F. Di Vruno, *Unintended Electromagnetic Radiation from Starlink Satellites Detected with LOFAR between 110 and 188 MHz*, 676 ASTRONOMY & ASTROPHYSICS, Aug. 2023 (reporting additional radio interference arising from the internal functioning of Starlink satellites, separate from the satellite’s intentional emissions); Tereza Pultarova, *SpaceX’s Starlink Internet Satellites “Leak” So Much Radiation That It’s Hurting Radio Astronomy, Scientists Say*, SPACE.COM (Jul. 6, 2023), <https://www.space.com/starlink-electronics-hum-disturbs-radio-astronomy> [<https://perma.cc/4XUC-XF4W>].

of all other States Parties to the Treaty.”⁵⁹ The key terms “cooperation,” “mutual assistance,” and “due regard” are not defined in the treaty, and to date, the high-minded rhetoric has not been translated into effective operational restraints.⁶⁰

The OST also deals with the possibility of conflicting applications and operations in space, providing that if a state “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.”⁶¹ On the flip side, a state that “has reason to believe that an activity or experiment planned by another State Party in outer space . . . would cause potentially harmful interference with activities in the peaceful exploration and use of outer space . . . may request consultation concerning the activity or experiment.”⁶² Unfortunately, the treaty again fails to define the content of “harmful interference” and no state has ever operationalized this provision of the treaty by seeking or offering the envisioned “international consultations.”⁶³

⁵⁹ OST, *supra* note 16, art. IX.

⁶⁰ DARK & QUIET SKIES FOR SOCIETY, *supra* note 19, at 93–119 (analyzing international law relevant to satellite interference with astronomy); IISL, *supra* note 36, at 32–54 (construing the terms of OST art. IX in application to satellite interference); Hitoshi Nasu & Michael Schmitt, *A Threat or a Warning: Russia’s Weapons Testing in Space*, JUST SEC. (Jul. 31, 2020) <https://www.justsecurity.org/71783/a-threat-or-a-warning-russias-weapons-testing-in-space/> [<https://perma.cc/A55X-E64Q>] (highlighting the ambiguity in OST terms such as due regard and harmful interference); GREEN, ET AL., *supra* note 33, at 27–30; BYERS & BOLEY, *supra* note 25, at 105–09.

⁶¹ OST, *supra* note 16, art. IX. See Rafael Moro-Aguilar, *Mega-Constellations of Satellites and their Impact on Astronomy: Exploring the Role of Article IX of the Outer Space Treaty*, 64 Proc. of the Int’l Institute of Space L. 209, 210–12 (2024) (emphasizing the absence of definitions of key terms in the OST); Comm. on the Peaceful Uses of Outer Space, *Survey of the Problem of Discretion Exercised by States in Interpreting Basic Legal Principles and Norms Related to Safety and Security in Outer Space*, Working Paper submitted by the Russian Federation, U.N. Doc. A/AC.105/2018/CRP.17, para. 1–6 (2018) [hereinafter *Russia Working Paper*] (noting ambiguities in the Outer Space Treaty, leading to differing national interpretations).

⁶² OST, *supra* note 16, art. IX. The OST does not define “interference,” but ITU Radio Regulations define “harmful interference” as any “interference which endangers the functioning of a radionavigation service . . . or seriously degrades, obstructs, or repeatedly interrupts a radiocommunication service operating in accordance with these [Radio] Regulations.” INT’L TELECOMM. UNION, RADIO REGULATIONS § 1.169 (2016), <https://search.itu.int/history/HistoryDigitalCollectionDocLibrary/1.43.48.en.101.pdf> [<https://perma.cc/N8G9-Y832>]. Domestic U.S. law contains a parallel definition in 47 C.F.R. § 2.1(c) (2015).

⁶³ John Goehring, *The Russian ASAT Test Caps a Bad Year for the Due Regard Principle in Space*, JUST SEC. (Jan. 12, 2022), <https://www.justsecurity.org/79820/the-russian-asat-test-caps-a-bad-year-for-the-due-regard-principle-in-space/> [<https://perma.cc/56XV-XNLN>] (observing that states have never invoked OST art. IX in situations where it might have been useful); Christopher J. Borgen, *Russia’s ASAT Test and the Development of Space Law*, ARTICLES OF WAR (Nov. 21, 2021), <https://lieber.westpoint.edu/russia-asat-test-development-space-law/>

The international astronomy community has begun to rally around the imperative of preserving the dark and quiet skies, enlisting the full array of available political and legal tools. Again, the key starting concept is to recognize that even in its current underdeveloped state, the law of outer space can offer the prospect of some relief—the deck is not stacked inexorably in favor of the unrestrained exploitation of space by hordes of satellites. But the challenge is severe; the prospect of high-speed, low-cost ubiquitous internet and remote sensing services holds great allure, and the value of astronomy may seem abstract and long-term in contrast.⁶⁴ Even the U.N. Committee on the Peaceful Uses of Outer Space, the natural home for discussion and debate on topics of this sort, has been hesitant to embrace the issue fully.⁶⁵

Therefore, there is a very real prospect that the coming hordes of LEO constellations will so substantially injure the whole field of astronomy that the world's significant investment in ground- and space-based observatories will be undercut, and the scientific enterprise will be truncated. Some commentators may be inclined to minimize this development, opining that the world's march toward global connectivity, enabled by LEO constellations, is just another example of a modern technology displacing a prior pattern of life—it is another iteration of the type of revolutionary social and economic change that has occurred episodically and disruptively through history.

There is, admittedly, an element of Luddism in the antipathy to LEO satellite constellations—a certain congruity with calls for preserving the beauty and peacefulness of the dark and quiet night sky of a simpler pastoral era, and in revering humanity's ancient awe of the pristine heavens.⁶⁶ The disappearance of an

[<https://perma.cc/G9ZS-MUBF>]; Russia Working Paper, *supra* note 61, para. 12 (discussing the ambiguity in determining what constitutes “harmful interference”), para. 13 (discussing ambiguities in the obligation under OST art. IX to consult); GREEN, ET AL., *supra* note 33, at 30–31.

⁶⁴ See IAU CENTRE FOR THE PROTECTION OF THE DARK AND QUIET SKY FROM SATELLITE CONSTELLATION INTERFERENCE, <https://cps.iau.org/> [<https://perma.cc/RX4Y-2ZAS>] (last visited Feb. 23, 2024) (group established in 2022 by the National Science Foundation's NOIRLab and the SKA Observatory); IISL, *supra* note 36, at 72–94; Yana Yakushina, *National Approaches to the Protection of Dark and Quiet Sky*, Proc. of IAU Symposium (2023), https://www.iau.org/public/videos/detail/yana-yakushina_national-approaches-to-the-protect/ [<https://perma.cc/52L3-KB9E>].

⁶⁵ Daniel Clery, *Astronomers Stumble in Diplomatic Push to Protect the Night Sky*, SCIENCE (Feb. 27, 2023) <https://www.science.org/content/article/astronomers-stumble-diplomatic-push-protect-night-sky> [<https://perma.cc/VYF4-745Y>] (reporting the failure to achieve consensus in COPUOS for the creation of an experts' group to develop new guidelines to protect astronomy).

⁶⁶ Sara Goudarzi, *Rage against the Machine Owners: Luddite Lessons for the 21st Century*, BULL. OF THE ATOMIC SCIENTISTS (Oct. 16, 2023) <https://thebulletin.org/2023/10/rage-against-the-machine-owners-luddite-lessons-for-the-21st-century/> [<https://perma.cc/5N6T-G33J>]; Jathan Sadowski, *I'm a Luddite. You Should Be One Too*, THE CONVERSATION (Aug. 9, 2021), <https://theconversation.com/im-a-luddite-you-should-be-one-too-163172> [<https://perma.cc/T8K8-JMRZ>]; Richard Conniff, *What the Luddites Really Fought Against*, SMITHSONIAN MAG. (Mar.

antiquarian way of life, with a particular kind of direct connection to the natural world, resonates with millennia-old traditional religious values and indigenous practices, as well as connecting with the importance of natural darkness for healthy human, animal, and plant circadian rhythms.⁶⁷ But there is also an important difference: unlike Luddism, astronomy is intensely scientific and forward-looking; it seeks new discoveries that could upend our conventional understandings of the world and our place in it. Astronomy vigorously promotes social, technical, and economic progress, but it will have a very hard time living comfortably with the suddenly intrusive, rivalrous uses of the space milieu.

IV. THE ILLEGAL: VIOLATING THE LAW OF ARMED CONFLICT

The third problem with the emerging space population arises from a particular, sometimes predominant, use to which the small satellites are put, and the resulting incompatibility with longstanding international law regulating military combat.

These LEO satellites are inherently dual-capable, being applicable for both civilian operations and military campaigns. Rapid, global communications, for example, can support both civilian uses (e.g., internet searches, telemedicine, and videogaming) and warfighting (e.g., the engagement of Starlink in support of Ukraine in the war against Russia). Capabilities for remote sensing, likewise, are multi-purpose: weather forecasting, geo-locating, and traffic monitoring, for example, have obvious implications for battlefield management as well as for peacetime pursuits.⁶⁸

2011), <https://www.smithsonianmag.com/history/what-the-luddites-really-fought-against-264412/> [<https://perma.cc/86AF-GRUL>].

⁶⁷ DARK & QUIET SKIES FOR SOCIETY, *supra* note 19, at 136–39 (evaluating societal impact of loss of dark night skies); Venkatesan, *supra* note 12 (describing importance of unimpeded access to dark night sky for religious and cultural traditions); VENKATESAN, ET. AL., SATCON2 COMMUNITY ENGAGEMENT WORKING GROUP REPORT 73–115 (Oct. 2021), <https://noirlab.edu/public/media/archives/techdocs/pdf/techdoc033.pdf> [<https://perma.cc/6ZLB-QLND>] (emphasizing value of dark and quiet skies for astro-tourism, amateur astronomy, indigenous communities, and environmental interests); YongMin Cho, et. al., *Effects of Artificial Light Night on Human Health: A Literature Review of Observational and Experimental Studies Applied to Exposure Assessment*, 32, CHRONOBIOLOGY INT’L 1294, 1298 (2015); International Dark-Sky Association, *Artificial Light at Night: State of the Science 2022* 3–5 (2022), <https://www.darksky.org/wp-content/uploads/2022/06/SOTS-post-final-version-220527.pdf> [<https://perma.cc/C6HQ-JVE5>] (highlighting adverse consequences of artificial light at night on migratory birds, pollinating insects, and human health); Michelle Z. Donahue, *80 Percent of Americans Can’t See the Milky Way Anymore*, NAT’L GEOGRAPHIC (Jun. 10, 2016), <https://www.nationalgeographic.com/science/article/milky-way-space-science> [<https://perma.cc/FZ7P-7N62>] (regretting how the rise in artificial light at night has polluted the skies sufficiently to obscure views of once-familiar stellar scenes).

⁶⁸ Almudena Azcarate Ortega, *Not a Rose by Any Other Name: Dual-Use and Dual-Purpose Space Systems*, LAWFARE (Jun. 5, 2023), <https://www.lawfaremedia.org/article/not-a-rose-by-any-other->

A corresponding modern political development has been the deliberate governmental policy of further interweaving these dual capabilities, to inextricably intertwine civilian and military assets, capacities, and operations. In the United States, it has long been official policy to “[r]ely to the maximum practical extent on U.S. commercial remote sensing space capabilities for filling imagery and geospatial needs for military, intelligence, foreign policy, homeland security, and civil users.”⁶⁹ U.S. military leadership has confirmed the outsourcing of other national security space services to the private sector, too, acknowledging that “the joint force is becoming increasingly dependent on the use of commercial space systems to provide communications; tagging, tracking, and locating; and other support.”⁷⁰

name-dual-use-and-dual-purpose-space-systems [https://perma.cc/MFD5-C5KF]; *Myriad Ways That Commercial Satellite Capabilities Augment DoD Space Assets*, BREAKING DEFENSE (Jan. 6, 2022), <https://breakingdefense.com/2022/01/myriad-ways-that-commercial-satellite-capabilities-augment-dod-space-assets/> [https://perma.cc/4MSC-44KF]; Jaspreet Gill, *DoD Launches New “Effort” to Rapidly Adopt Commercial Space Capabilities*, BREAKING DEFENSE (Apr. 18, 2023), <https://breakingdefense.com/2023/04/dod-launches-new-effort-to-rapidly-adopt-commercial-space-capabilities> [https://perma.cc/2SWD-MYJ2]; Julian E. Barnes, *Intelligence Agencies Pushed to Use More Commercial Satellites*, N.Y. TIMES (Sept. 27, 2021), <https://www.nytimes.com/2021/09/27/us/politics/intelligence-agencies-commercial-satellites.html> [https://perma.cc/KJ3E-PR9F]; Eric Talbot Jensen, *Cyber Attacks: Proportionality and Precautions in Attack*, 98 INT’L L. STUD. 89, 198, 213 (2013) (reporting estimates that ninety to ninety-eight percent of U.S. Department of Defense digital traffic uses civilian-owned and -operated infrastructure); G. Ryan Faith, *The Future of Space: Trouble on the Final Frontier*, WORLD AFFS., 82, 84 (arguing that “[a]ll space technologies are inherently dual-use”); Kestutis Paulauskas, *Space: NATO’s Latest Frontier*, NATO REV. (Mar. 13, 2020), <https://www.nato.int/docu/review/articles/2020/03/13/space-natos-latest-frontier/index.html> [https://perma.cc/5BEK-ELN7] (observing that “most satellites serve multiple civilian, commercial or security functions”).

⁶⁹ EXEC. OFF. OF THE PRESIDENT, NSPD-27, U.S. COMMERCIAL REMOTE SENSING POLICY 2 (2003), <https://www.nesdis.noaa.gov/s3/2021-08/Commercial%20Remote%20Sensing%20Policy%202003.pdf> [https://perma.cc/9KK9-ZCRG]; see also EXEC. OFF. OF THE PRESIDENT, NATIONAL SPACE POLICY OF THE UNITED STATES OF AMERICA 10 (2010), https://obamawhitehouse.archives.gov/sites/default/files/national_space_policy_6-28-10.pdf [https://perma.cc/5666-KMG9] (committing the U.S. government to “[p]urchase and use commercial space capabilities and services to the maximum practical extent when such capabilities and services are available in the marketplace and meet United States Government requirements”).

⁷⁰ U.S. JOINT CHIEFS OF STAFF, JP 3-14, SPACE OPERATIONS I-6 (2020) https://irp.fas.org/doddir/dod/jp3_14.pdf [https://perma.cc/6W9D-YFE3]; see also Gen. B. Chance Saltzman, Chief of Space Operations, U.S. Space Force, Keynote Address at the AFA Warfare Symposium: Guardians in the Fight (Mar. 7, 2023), in AIR & SPACE FORCES MAG. (Mar. 14, 2023), <https://www.airandspaceforces.com/watch-read-gen-b-chance-saltzman-guardians-fight/> [https://perma.cc/2DP2-3QEC] (emphasizing the importance of partnerships between the commercial sector and the Space Force); Sandra Erwin, *U.S. Sharpens Plan for Military Space Race*, SPACE NEWS (July 11, 2023), <https://spacenews.com/u-s-sharpens-plan-for-military-space-race/> [https://perma.cc/CWV9-QVDW] [hereinafter Erwin, *U.S. Sharpens Plan*] (noting Space

To some extent, the large and growing reliance upon private sector LEO constellations for the performance of national security space missions is grounded in economics. It may sometimes be cheaper to rely on corporations to drive costs down, and market incentives may speed the uptake of new space technology faster than a cumbersome military bureaucracy can muster.⁷¹ In addition, there can be warfighting inducements: the U.S. military and the intelligence community strategically prefer to rely on a “hybrid” space architecture, featuring dozens (or hundreds, or thousands) of small, expendable commercial satellites assisting a smaller number of large, expensive, hard-to-replace government satellites for the performance of key communications and reconnaissance missions. When the duties are so dispersed, the whole network becomes more resilient and survivable. An adversary that might be tempted to undertake damaging or destructive ASAT actions against a small set of juicy government targets might well be more deterred from initiating that sort of conflict when there so many potential private as well as public satellite aim-points, that it would be hopeless to try to cover them all simultaneously.⁷²

Force reliance upon private satellites, and the plan to develop a Commercial Augmentation Space Reserve fleet to supplement government spacecraft); Sandra Erwin, *Pentagon Looks to Commercial Space for an Edge*, SPACE NEWS (Nov. 27, 2023), <https://spacenews.com/pentagon-looks-to-commercial-space-for-an-edge/> [<https://perma.cc/YGU5-FVJQ>] (reporting that Deputy Secretary of Defense Kathleen Hicks is urging accelerated integration of commercial operations into defense programs).

⁷¹ See, e.g., Dean Cheng, *Space Invaders: The Rise of Commercial Firms*, GIS REPORTS (Jan. 5, 2023), <https://www.gisreportsonline.com/r/space-exploration/> [<https://perma.cc/T6R3-8FLG>] (describing scenarios for greater integration of civilian and military space assets); STEVEN KOSIAK, CTR. FOR NEW AM. SEC., *SMALL SATELLITES IN THE EMERGING SPACE ENVIRONMENT 1* (2019), <https://www.cnas.org/publications/reports/small-satellites-in-the-emerging-space-environment> [<https://perma.cc/GA82-6M8T>] (assessing that, “In coming years, constellations composed of large numbers of small, less complex, and less costly satellites are likely to become progressively more cost-effective relative to constellations made up of small numbers of large, more complex, and more expensive satellites.”); ELLEN PAWLIKOWSKI ET AL., AIR FORCE SPACE COMMAND, *RESILIENCY AND DISAGGREGATED SPACE ARCHITECTURES 10* (2013), <https://apps.dtic.mil/sti/pdfs/AD1077222.pdf> [<https://perma.cc/BL7U-LQUQ>] (concluding that reliance upon a diverse satellite structure offers advantages in increased affordability and opportunities to refresh technology); U.S. GOV'T ACCOUNTABILITY OFF., *GAO-18-493, DOD'S USE OF COMMERCIAL SATELLITES TO HOST DEFENSE PAYLOADS WOULD BENEFIT FROM CENTRALIZING DATA 4-5* (2018), <https://www.gao.gov/assets/gao-18-493.pdf> [<https://perma.cc/2634-NH59>] [hereinafter DOD'S USE OF COMMERCIAL SATELLITES].

⁷² See Matthew Mowthorpe, *Space Resilience and the Importance of Multiple Orbits*, SPACE REV. (Jan. 3, 2023), <https://www.thespacereview.com/article/4504/1> [<https://perma.cc/V3Z2-C4CJ>] (assessing how a proliferated, dispersed satellite constellation offers advantages in resiliency against enemy attack); see also Sandra Erwin, *Space Force Not Buying Large Satellites for the Foreseeable Future*, SPACE NEWS (Jan. 24, 2023), <https://spacenews.com/space-force-not-buying-large-satellites-for-the-foreseeable-future/> [<https://perma.cc/ZD95-W73E>] (reporting comments from the Department of Defense military space acquisitions chief favoring small, disaggregated satellite constellations); Erwin, *U.S. Sharpens Plan*, *supra* note 70; Nathan Strout, *Can Commercial Satellites Revolutionize Nuclear Command and Control?*, C4ISRNET (July 12, 2019), <https://www.c4isrnet.com/battlefield-tech/c2-comms/2019/07/12/can-commercial-satellites->

Other countries are avidly pursuing similar logic. In China, the concept of “civil-military fusion” makes it difficult to discern any reliable distinction between public and private space assets, actors, and activities.⁷³ In Russia, it may no longer be possible to disentangle the role of the government and the military establishment in the private space industry.⁷⁴

An underappreciated, but central, legal problem with this erasure of the line between public and private space activities arises from LoAC, the critical body of international law that attempts to regulate the conduct of war, in the name of protecting the shared interests of humanity. A cardinal LoAC principle is distinction (or discrimination), requiring that during war, a belligerent is privileged to direct

revolutionize-nuclear-command-and-control/ [https://perma.cc/P53Q-HLUL] (“We want to get to a point both in conventional and unconventional, or conventional and nuclear, where if some portion of the network is taken out, our answer ought to be ‘Peh, I’ve got five other pathways. And if you want to take out 1,000 satellites of my constellation, of which I have five? Knock yourself out.’”) (quoting Gen. David Goldfein, Chief of Staff, U.S. Air Force); Robert Work, Deputy Sec’y, U.S. Dep’t of Def, Remarks at the Space Symposium (Apr. 12, 2016), <https://www.defense.gov/Newsroom/Speeches/Speech/Article/723498/remarks-at-the-space-symposium/> [https://perma.cc/8LG4-T7ST] (explaining how U.S. government reliance upon commercial spacecraft can enhance deterrence: “[It’s] one thing to have to deny the U.S. the use of a few government owned imagery systems; it’s quite another to take on tens or even hundreds of allied and U.S. government and commercial remote sensing systems all at the same time.”); David Roza, *Experts Warn of Blurring Line Between Military, Commercial Satellites*, AIR & SPACE FORCES MAG. (July 27, 2023), <https://www.airandspaceforces.com/military-commercial-satellites-blurring-line/> [https://perma.cc/V755-Z6PA] (expressing concern about intermingling commercial and national security space systems).

⁷³ See Masaaki Yatsuzuka, *The Complex Impact of China’s Military-Civil Fusion in Space*, THINK CHINA (July 4, 2022), <https://www.thinkchina.sg/complex-impact-chinas-military-civil-fusion-space> [https://perma.cc/HLR3-UTPY]; see also Junhua Zhang, *Eyeing Taiwan, China Builds Its Own Starlink*, GIS REPORTS (June 27, 2023), <https://www.gisreportsonline.com/r/china-starlink/> [https://perma.cc/5LZF-F3US] (reporting on China’s plans to create one or more huge satellite constellations for military and commercial uses). See generally Xiaodan Wu & Jie Long, *Assessing the Particularity and Potentiality of Civil-Military Integration Strategy for Space Activities in China*, 62 SPACE POLICY, Oct. 1, 2022; MARK STOKES ET AL., CHINA’S SPACE AND COUNTERSPACE CAPABILITIES AND ACTIVITIES 59–100 (2020), https://www.uscc.gov/sites/default/files/2020-05/China_Space_and_Counterspace_Activities.pdf [https://perma.cc/7NT2-DWZZ]; Patrick Tucker, *China’s Commercial Space Ventures Pose a Variety of Threats, DoD Officials Say*, DEF. ONE (July 4, 2023), <https://www.defenseone.com/technology/2023/07/chinas-commercial-space-ventures-pose-variety-threats-dod-officials-say/388178/> [https://perma.cc/4587-B39N].

⁷⁴ See Bruce McClintock, *The Russian Space Sector: Adaptation, Retrenchment, and Stagnation*, 10 SPACE & DEF. 3, 6–7 (2017); cf. Andrew Stanniland & Denis Curtin, *An Examination of the Governmental Use of Military and Commercial Satellite Communications*, in HANDBOOK OF SATELLITE APPLICATIONS 271, 274 (Joseph N. Pelton et al. eds., 2d ed. 2017) (reporting that many countries have altered their space procurement patterns, integrating commercial entities more deeply into government and military activities). See generally ANATOLY ZAK, RUSSIAN MILITARY AND DUAL-PURPOSE SPACECRAFT: LATEST STATUS AND OPERATIONAL OVERVIEW (2019), <https://www.cna.org/reports/2019/06/IOP-2019-U-020191-Final.pdf> [https://perma.cc/CZJ8-V2ZU].

attacks only against military objectives, not against civilians and their property, and that “constant care” must be exhibited in the protection of civilians.⁷⁵ An important corollary, sometimes known as “passive precautions,”⁷⁶ which I have elsewhere labeled “reverse distinction,”⁷⁷ further requires combatants to physically separate themselves from civilians (or vice-versa). This conspicuous separation is mandatory in order to spare civilians some of the worst effects of combat and to enable the opposing military to vindicate its primary legal obligation to aim only at military targets.

Reverse distinction is hard law, incorporated into the 1977 Additional Protocol I of the 1949 Geneva Conventions⁷⁸ and embodied in customary

⁷⁵ Protocol Additional to the Geneva Conventions of 12 August 1949, and Relating to the Protection of Victims of International Armed Conflicts (Protocol I), art. 48, June 8, 1977, 1125 U.N.T.S. 3 [hereinafter AP I] (stating the “basic rule” that “[i]n order to ensure respect for and protection of the civilian population and civilian objects, the Parties to the conflict shall at all times distinguish between the civilian population and combatants and between civilian objects and military objectives and accordingly shall direct their operations only against military objectives.”); *id.* art. 57.1 (“In the conduct of military operations, constant care shall be taken to spare the civilian population, civilians and civilian objects.”); *see also* JEAN-MARIE HENCKAERTS & LOUISE DOSWALD-BECK, *CUSTOMARY INTERNATIONAL HUMANITARIAN LAW* 3 (2005) (identifying “the Principle of Distinction between Civilians and Combatants” as Rule 1 and the companion principle requiring distinction between civilian objects and military objectives as Rule 7 in their authoritative study for the International Committee of the Red Cross on the customary international law of armed conflict). Note that the United States has not ratified AP I, but accepts many portions of its content, notably including the principle of distinction, as binding customary international law. *See generally* Michael J. Matheson, Deputy Legal Advisor, U.S. Dep’t of State, Remarks on the United States Position on the Relation of Customary International Law to the 1977 Protocols Additional to the 1949 Geneva Conventions Address (Jan. 2, 1987), in *The Sixth Annual American Red Cross-Washington College of Law Conference on International Humanitarian Law: A Workshop on Customary International Law and the 1977 Protocols Additional to the 1949 Geneva Conventions*, 2 AM. U. J. INT’L L. & POL’Y 415, 419 (1987).

⁷⁶ *See, e.g.*, INT’L COMM. OF THE RED CROSS, COMMENTARY ON THE ADDITIONAL PROTOCOLS OF 8 JUNE 1977 TO THE GENEVA CONVENTIONS OF 12 AUGUST 1949 ¶ 2241 (Yves Sandoz et al. eds., 1987), <https://ihl-databases.icrc.org/applic/ihl/ihl.nsf/1a13044f3bbb5b8ec12563fb0066f226/d37f727128e875d4c12563cd0043518b> [<https://perma.cc/YZZ3-ZQC6>] (differentiating between “active” and “passive” precautions); Geoffrey Corn & James A. Schoettler, Jr., *Targeting and Civilian Risk Mitigation: The Essential Role of Precautionary Measures*, 223 MIL. L. REV. 785, 791, 827–28 (2015) (differentiating between “positive” precautionary measures while attacking vs. “passive” precautions while defending).

⁷⁷ David A. Koplow, *Reverse Distinction: A U.S. Violation of the Law of Armed Conflict in Space*, 13 HARV. NAT’L SEC. J. 25 (2022).

⁷⁸ AP I, *supra* note 75, art. 58 (“Precautions Against the Effects of Attacks,” providing “The Parties to the conflict shall, to the maximum extent feasible: (a) without prejudice to Article 49 of the Fourth Convention, endeavour to remove the civilian population, individual civilians and civilian objects under their control from the vicinity of military objectives; (b) avoid locating military objectives within or near densely populated areas; (c) take the other necessary precautions to protect the civilian population, individual civilians and civilian objects under their control against the dangers resulting from military operations.”).

international law, but it is expressed in a notably soft form: the separation obligation applies only to the extent that it is “feasible” to do so.⁷⁹ The applicable legal authorities never adequately define “feasibility,” but some cases are clear. Surely, it would not be feasible to disentangle the major dual-use public infrastructure that is used interchangeably and simultaneously by military and civilian personnel alike, such as the networks of roadways, electricity grids, and water and sewerage systems. On the other hand, it would surely be impermissible by these standards to emplace a military headquarters in a hospital, to park military jets or tanks near civilian residences, or to use civilians as human shields in combat.⁸⁰

These rules are widely acknowledged; when they are disrespected, countries do not hesitate to call out violators and even charge them as war criminals.⁸¹ Yet when it comes to space, especially in LEO, deviation from reverse distinction seems to be the norm. Countries regularly employ civilian space assets for military and intelligence purposes: they launch military payloads on civilian booster rockets; they co-host military and civilian components inside the same satellite “bus.”⁸² This intermingling occurs despite the fact that LoAC has no exemption for space activities—in fact, the OST explicitly establishes that the full corpus of international law applies in space.⁸³ It would be “feasible” to segregate the military

⁷⁹ *Id.*; see also OFF. OF GEN. COUNS., U.S. DEP'T OF DEF., LAW OF WAR MANUAL § 2.5.3.2 (2023) <https://media.defense.gov/2023/Jul/31/2003271432/-1/-1/0/DOD-LAW-OF-WAR-MANUAL-JUNE-2015-UPDATED-JULY%202023.PDF> [<https://perma.cc/AV47-BNVG>] [hereinafter DOD LAW OF WAR MANUAL] (likewise providing that parties to an armed conflict are obligated “to take feasible measures to separate physically their own military objectives from the civilian population and other protected persons and objects.”).

⁸⁰ The law of armed conflict does not recognize a separate or intermediate category of “dual-use” or “dual-capable” items; by definition, everything is either a military objective (and presumptively subject to attack) or a civilian object (and generally immune from attack). See DOD LAW OF WAR MANUAL, *supra* note 79, § 5.6.1.2. Military objectives are defined as “those objects which by their nature, location, purpose or use make an effective contribution to military action and whose total or partial destruction, capture or neutralization, in the circumstances ruling at the time, offers a definite military advantage.” AP I, *supra* note 75, art. 52.2.

⁸¹ See, e.g., Koplow, *supra* note 77, at 47–52 (discussing widely condemned instances of conspicuous violations of the requirement for reverse distinction, involving deliberately locating military equipment proximate to civilian housing or cultural property and using civilians as human shields against attacks).

⁸² See, e.g., DOD’S USE OF COMMERCIAL SATELLITES, *supra* note 71, at 3–6 (defining commercially-hosted military payloads, explaining their potential benefits, and describing Department of Defense use of the concept); Stanniland & Curtin, *supra* note 74 (describing advantages of hosted payloads and increasing use of the strategy); Theresa Hitchens, *Space Force Plans Multiple Hosted Payloads for GEO Belt Monitoring*, BREAKING DEF. (Jan. 6, 2022), <https://breakingdefense.com/2022/01/space-force-plans-multiple-hosted-payloads-for-geo-belt-monitoring/> [<https://perma.cc/D5S7-GRZ5>]; Nathan Strout, *NGA Adds Small Satellite Imagery to Its Unclassified Collection*, C4ISRNET (Nov. 5, 2020), <https://www.c4isrnet.com/intel-geoint/2020/11/05/nga-adds-small-sat-imagery-to-its-unclassified-collection/> [<https://perma.cc/C3ZN-YPWP>] (reporting that the National Geospatial Intelligence Agency has purchased “thousands of new images and terabits of additional geospatial data” from several LEO commercial satellite operators).

⁸³ See OST, *supra* note 16, art. III.

and civilian space assets and activities (even if doing so might cost somewhat more), just as the separation obligation is honored in other domains. The Navy relies upon its own assets, not routinely exploiting private ships for military operations (even if there could sometimes be a tactical advantage in doing so); the Army purchases and operates its own vehicles, not renting private trucks (even if that alternative might occasionally be cheaper). The United States does, in fact, operate many of its own governmental satellites for military and intelligence functions, and will continue to do so into the future—exploitation of private sector assets is not irresistible.

These conspicuous, deliberate, sustained violations of key LoAC principles unravel the fundamental legal concept of attempting to protect civilians and their property. Instead, they add artificially to the natural dangers facing commercial space enterprise. They make more civilian satellites into targets for hostility, impermissibly transferring some of the risks associated with armed conflict from legitimate military targets onto civilian objects, thereby undermining a key purpose of LoAC.⁸⁴

Not just coincidentally, we also observe an ominous uptick in the militarization of space. The leading spacefaring countries, especially the United States, China, and Russia, have increased their vigorous pursuit of space weapons capabilities; undertaken testing of threatening equipment and maneuvers; established new bureaucratic elements devoted to pursuit of military superiority in space; and escalated the hostility of their rhetoric pointing to space as a warfighting theater. Each accuses the other of weaponizing the exoatmospheric domain as a military operational theater, and all seem poised for an accelerating “space race,” featuring additional armaments and a sharply increased danger of armed conflict in space.⁸⁵

⁸⁴ See Koplow, *supra* note 77, at 102–105. *But see* DANIEL P. BEAULIEU, STATE PRACTICE AND MILITARY OBJECTIVES: INTERNATIONAL HUMANITARIAN LAW REGARDING MILITARY APPLICATIONS OF OTHERWISE COMMERCIAL SATELLITES (Ctr. on L., Ethics, & Nat’l Sec. Essay Series No. 16, 2023), <https://sites.duke.edu/lawfire/files/2023/01/Maj-Danny-Beaulieu-Civil-Commercial-Satellites-Paper.pdf> [<https://perma.cc/R7HN-355X>] (arguing that a satellite that is used for both military and civilian purposes becomes a military objective and that state practice has accepted this pattern of use as lawful); John Goehring, *The Legality of Intermingling Military and Civilian Capabilities in Space*, ARTICLES OF WAR (Oct. 17, 2022), <https://lieber.westpoint.edu/legality-intermingling-military-civilian-capabilities-space/> [<https://perma.cc/6YF4-BVX9>]; Saltzman, *supra* note 70 (“There is no easy way to physically separate civil, commercial, military satellites from one another because the laws that govern orbits are immutable.”).

⁸⁵ See generally SECURE WORLD FOUND., GLOBAL COUNTERSPACE CAPABILITIES: AN OPEN SOURCE ASSESSMENT (Brian Weeden & Victoria Samson eds., 2023), https://swfound.org/media/207541/swf_global_counterspace_capabilities_2023_es_en.pdf [<https://perma.cc/TR3G-4M6N>] (describing countries’ growing capabilities for anti-satellite operations); KARI A. BINGEN ET AL., CTR. FOR STRATEGIC & INT’L STUD., SPACE THREAT ASSESSMENT 2023 (2023), <https://aerospace.csis.org/wp->

V. RECOMMENDATIONS

The commonality among all three of these problematic developments, and the central recommendation of this Article, is a call for more space law—further articulation of the legal infrastructure applicable to space, including appropriate governance of the new LEO megaconstellations—to help resolve some of the critical definitional and regulatory lacunae that have helped generate the current ambiguities and abuses.

The historical evolution of space law has been staccato. The earliest years of the space age were remarkably productive for international law: within only a decade of the 1957 orbit of the first *Sputnik*, the world had negotiated and brought into force the OST, which still stands as the “constitution” (or the “Magna Carta”) for space. Moreover, within only another decade or so, the world had generated the three other foundational space treaties, which have likewise been joined by most of the relevant countries, bringing a modicum of order to the space regime.⁸⁶ By the normally torpid standards of international law, which usually develops at only the most glacial pace, this was a breakneck success.

But the lawmaking process for space became constipated after that point: since 1979, there have been no new generally accepted space treaties and precious few attempts to negotiate any binding companions to the original four

content/uploads/2023/04/230414_Bingen_SpaceThreatAssessment_2023_UPDATED-min.pdf [https://perma.cc/5HQQ-QV7K]; U.S. SPACE FORCE, SPACEPOWER: DOCTRINE FOR SPACE FORCES (2020), https://www.spaceforce.mil/Portals/1/Space%20Capstone%20Publication_10%20Aug%202020.pdf [https://perma.cc/YY9X-CBM3]; U.S. DEF. INTEL. AGENCY, CHALLENGES TO SECURITY IN SPACE (2022), https://www.dia.mil/Portals/110/Documents/News/Military_Power_Publications/Challenges_Security_Space_2022.pdf [https://perma.cc/F772-T88H]; U.S. DEP'T OF DEF., DOD DIRECTIVE 3100.10: SPACE POLICY (2022), <https://www.esd.whs.mil/Portals/54/Documents/DD/issuances/dodd/310010p.PDF> [https://perma.cc/NQG4-PDPG]; Chelsea Gohd, *Everyone Wants a Space Force – But Why?*, SPACE.COM (Sept. 11, 2020), <https://www.space.com/every-country-wants-space-force.html> [https://perma.cc/3AXC-EUEA] (noting space force military units in France, Canada, Japan, Russia, and China); Audrey Decker, *How the “Stormbringers” Are Preparing for War in Space*, DEF. ONE (June 27, 2023), <https://www.defenseone.com/threats/2023/06/how-stormbringers-are-preparing-war-space/387998/> [https://perma.cc/ABR7-YEMG]; Saltzman, *supra* note 70; Erwin, *U.S. Sharpens Plan*, *supra* note 70.

⁸⁶ In addition to the OST, *supra* note 16, and the Liability Convention, *supra* note 26, the Agreement on the Rescue of Astronauts and the Return of Objects Launched in Outer Space, Apr. 22, 1968, 19 U.S.T. 7570, 672 U.N.T.S. 119, and the Convention on Registration of Objects Launched into Outer Space, Jan. 14, 1975, 28 U.S.T. 695, 1023 U.N.T.S. 15, have been joined by most spacefaring states. The Agreement Governing the Activities of States on the Moon and Other Celestial Bodies, Dec. 18, 1979, 1363 U.N.T.S. 3, has attracted far less adherence. See U.N. Comm. on the Peaceful Uses of Outer Space, Legal Subcmte., *Status of International Agreements Relating to Activities in Outer Space as at 1 January 2022*, at 5–10, U.N. Doc. A/AC.105/C.2/2022/CRP.10 (Mar. 28, 2022).

instruments.⁸⁷ The few sparse forays at standard-setting have been mostly confined to non-legally-binding norms; even many of these have failed to gain traction.⁸⁸

The current posture, therefore, provides a bare legal skeleton, without the necessary musculature. That is not at all the outcome intended by the negotiators and drafters of the OST; they certainly did not expect that their short 1967 document would provide the world with all the space law it would ever need. Instead, they anticipated a continuing stream of lawmaking (as occurred, transitorily, in the 1970s). After all, the full name of the OST is the “Treaty on *Principles* Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies” (emphasis added); the expectation was that those original “principles” would soon be supplemented in order to create a more comprehensive, detailed, workable legal code for space.

The contemporary experience with the emerging large constellations of small LEO satellites vividly demonstrates the problem: the existing corpus of international space law is not wrong or obsolete, but it is incomplete and patchy. As illustrated above, in numerous critical areas, the OST and its progeny do not sufficiently clarify space actors’ respective legal rights and responsibilities; crucial terms of art (such as “due regard” and “interference”) are left undefined and unelaborated. As the space activities of key countries and companies barrel ahead, the shortage of black letter law provides openings for rapacious self-serving behavior, with the first, richest, and most technologically advanced players asserting themselves as they see fit, leaving everyone else to contemplate the leftovers.⁸⁹

⁸⁷ See, e.g., U.N. Conf. of Disarmament, *Draft Treaty on the Prevention on the Prevention of the Placement of Weapons in Outer Space, the Threat or Use of Force against Outer Space Objects*, U.N. Doc. CD/1985 (June 12, 2014). *Rio Declaration on Environment and Development*, Principles 2, 3, U.N. Doc. A/CONF.151/26/Rev.1 (Vol. 1), annex I (Aug. 12, 1992) (proposed space treaty by Russia and China which has not attracted support in the United States or elsewhere).

⁸⁸ See, e.g., Eur. External Action Serv., *Draft International Code of Conduct for Outer Space Activities* (Mar. 31, 2014), https://www.eeas.europa.eu/sites/default/files/space_code_conduct_draft_vers_31-march-2014_en.pdf [<https://perma.cc/K8V3-SLXA>] (European Union proposal for a non-legally-binding code of conduct for space; did not attract sustained diplomatic support); U.N. OFF. FOR OUTER SPACE AFFAIRS, *supra* note 29 (successful development of non-legally-binding code of conduct for space topics not related to weapons); Senjuti Mallick, *Why Laws and Norms Matter in Space*, *Space Rev.* (June 12, 2023), <https://www.thespacereview.com/article/4602/1> [<https://perma.cc/AE7H-L8ZY>]; Robin Dickey, *Why Norms Matter More than Ever for Space Deterrence and Defense, War on the Rocks* (June 13, 2023), <https://warontherocks.com/2023/06/why-norms-matter-more-than-ever-for-space-deterrence-and-defense/> [<https://perma.cc/NG7W-L2EB>].

⁸⁹ See, e.g., Austin Albin, *The International Community Is Not Prepared for a Future in Space*, *SPACE REV.* (Sept. 5, 2023), <https://www.thespacereview.com/article/4642/1> [<https://perma.cc/B6YB-JFFR>] (calling for greater development of the political and legal norms for governing space).

There is thus an immediate need to assert the proscriptive power of international law in a more comprehensive way, to construct a space regime that would be fair, stable, effective, safe, and profitable. Structures which are not legally binding—perhaps stylized as corporate codes of conduct or industry best practices—can play a useful supporting role, but it may be illusory to suppose that voluntary self-restraint by profit-seeking entities or by national militaries can suffice.⁹⁰

Regarding the first problem identified in this Article, the congestion of space, the world needs to develop a system better than “first come, first served” for governance of the most popular and remunerative orbital swaths.⁹¹ Initial aggressive exploiters should not be allowed to preemptively crowd out everyone else; even if they are not explicitly staking a claim to exclusivity of use, their usurpation of the orbital regimes may amount to illegitimate “appropriation.” More broadly, there is an urgent need for effective space traffic management, akin to the generally well-functioning global regime of air traffic control.⁹²

⁹⁰ See generally WORLD ECON. F., SPACE INDUSTRY DEBRIS MITIGATION RECOMMENDATIONS (2023), https://www3.weforum.org/docs/WEF_Space_Industry_Debris_Mitigation_Recommendations_2023.pdf [<https://perma.cc/P4FL-2DUW>] (proposals by consortium of space corporations for collision avoidance, post-mission disposal, and data sharing); SPACE SAFETY COAL., BEST PRACTICES FOR THE SUSTAINABILITY OF SPACE OPERATIONS (2023), https://spacesafety.org/wp-content/uploads/2023/04/SSC_Best_Practices_for_Space_Operations_Sustainability_v29.pdf [<https://perma.cc/C4VC-NXX7>] (recommendations for actions to preserve optimal use of space); T. Maclay et al., *Responsible Satellite Design and Operational Practices: A Critical Component of Effective Space Environment Management (SEM)*, 8 J. OF SPACE SAFETY ENG'G 150 (2021) (representatives of leading space companies OneWeb, Iridium, and Maxar outlining a series of proposals to strengthen the protection of the space environment); IISL, *supra* note 36, at 94–103 (analyzing possibilities for constructive self-regulation by space industry).

⁹¹ E.g., INT'L TELECOMM. UNION, ITU RADIO REGULATORY FRAMEWORK FOR SPACE SERVICES, https://www.itu.int/en/ITU-R/space/snl/Documents/ITU-Space_reg.pdf [<https://perma.cc/23L9-UXCT>] (observing that ITU space-related regulations regarding orbital slots and frequencies have long been based on a “first come, first served” procedure); GREEN, ET AL., *supra* note 33, at 125 (calling for international action to depart from “first-come, first-served” approaches).

⁹² See, e.g., NAT'L AERONAUTICS & SPACE ADMIN., TOP2-294, SPACE TRAFFIC MANAGEMENT (STM) ARCHITECTURE, <https://ntts-prod.s3.amazonaws.com/t2p/prod/t2media/tops/pdf/TOP2-294.pdf> [<https://perma.cc/2FLS-LCBL>]; Memorandum on Space Policy Directive-3, National Space Traffic Management Policy, 83 Fed. Reg. 28969, 28969 (June 18, 2018) (“To maintain U.S. leadership in space, we must develop a new approach to space traffic management.”); *id.* at 28970 (setting a goal of “[m]itigat[ing] the effect[s] of orbital debris”); *id.* at 28975 (directing officials to “Prevent Unintentional Radio Frequency Interference”); *id.* at 28973 (emphasizing that the United States should “explore strategies that will lead to the establishment of common global best practices,” including regarding the use of large constellations of satellites). See generally MIR SADAT & JULIA SIEGEL, ATLANTIC COUNCIL, SPACE TRAFFIC MANAGEMENT: TIME FOR ACTION (2022), https://www.atlanticcouncil.org/wp-content/uploads/2022/08/Space-traffic-management_time-for-action.pdf [<https://perma.cc/2NHZ-DWEX>]; BRUCE MCCLINTOCK, ET. AL., RAND CORP., RB-A1949-1, THE TIME FOR INTERNATIONAL SPACE TRAFFIC MANAGEMENT IS NOW (2023), https://www.rand.org/pubs/research_briefs/RBA1949-1.html [<https://perma.cc/H4ZX-57VT>].

Beyond those basics, the terribly destructive and largely unconstrained production of long-lived space debris must also be addressed urgently and vigorously. One useful step would be to augment the Liability Convention, by operationalizing the scheme of tort damages for collisions in space and providing steep financial incentives to avoid crashes; this reform will require, *inter alia*, better articulation of the concept of “fault.”⁹³ The nascent international environmental law also needs more teeth to regulate and minimize the polluting effects of space launches, operations, and returns. A new legal requirement for conscientious, comprehensive public environmental impact assessments of all space activities would be a good start.⁹⁴

Turning to the second issue—the LEO constellations’ interference with astronomy—the OST principles of “due regard” and “cooperation” need to be amplified, to make clear the respective rights of competing users of the scarce resource. Neither astronomers nor satellite companies can claim an absolute right to unrestrained freedom in space, so boundary lines need to be clarified. The OST’s mechanism for “consultations” about interference should likewise be delineated and energized, compelling rivalrous parties to negotiate constructively.⁹⁵

Voluntary accommodations would be welcomed to engineer better solutions to mitigate the creation of disruptive streaks of light afflicting observatories’ images. But if these prove insufficient (as they are likely to be), then mandatory treaty, legislative, regulatory, or litigation alternatives should be pursued. In either case, the U.N. Committee on the Peaceful Uses of Outer Space should be more vigorously engaged in an effort to create an acceptable accommodation. In short, the untrammelled expression of *laissez faire*, allowing a passive approach to national and international regulation so the most powerful players can proceed essentially as they like, is no longer tenable in a world with so many competing space applications.⁹⁶

Finally, the disconnect must be resolved between the LoAC requirement of reverse distinction and the apparent penchant for space operators to persistently

⁹³ See, e.g., BOLEY, ET. AL., *supra* note 33, at 6 (recommending new national laws to lower the barriers for private entities seeking damages for space-related liability).

⁹⁴ Cf. United Nations Convention on the Law of the Sea, arts. 192–237, Dec. 10, 1982, 1833 U.N.T.S. 397 (establishing a detailed program for protection of the maritime environment, including an obligation to conduct environmental assessments and a mechanism for enforcement).

⁹⁵ In other contexts, the International Court of Justice has repeatedly determined that an obligation to negotiate in good faith includes more than merely a willingness to talk; it implies a duty to engage in give-and-take, to try to accommodate the legitimate interests of other participants, and to reach a mutually-acceptable solution. See, e.g., North Sea Continental Shelf Cases (Fed. Rep. Ger./Den.; Fed. Rep. Ger./Neth.), Judgment, 1969 I.C.J. Reports 3, ¶ 85–86 (Feb. 20); Legality of the Threat or Use of Nuclear Weapons, Advisory Opinion, 1996 I.C.J. 226, ¶ 98–103 (July 8).

⁹⁶ See BOLEY, ET. AL., *supra* note 33, at 3–4 (recommending actions to prevent satellite megaconstellations from imposing externality costs on astronomers and other stakeholders); IISL, *supra* note 36, at 110 (concluding that voluntary measures, dependent on the good will of corporations, will not suffice to ensure adequate protection of all space interests).

blur the line between military and civilian space activities. The law could be changed or the practices could be changed, but the current persistent and widespread violation dishonors our collective commitment to the rule of law in this most essential field.

More generally, diplomacy needs to find a way to lower the temperature and the operational tempo of military activities in space. Arms control in space is never going to be easy, and the current global political climate is inhospitable towards it, but determined negotiators can create a path forward. Sometimes, it is during the periods of the worst crisis and tension that cooler heads can prevail in recognizing the shared imperative for mutual accommodation.⁹⁷ A treaty to rein in ASAT development, testing, production, and use should be high on the international agenda.⁹⁸

⁹⁷ During the Cold War, some of the biggest breakthroughs for arms control followed only shortly after some of the most dangerous international confrontations. For example, the 1963 Limited Test Ban Treaty, which inaugurated the restraints on the testing of nuclear weapons, was negotiated quickly on the heels of the 1962 Cuban Missile Crisis and the 1961 erection of the Berlin Wall. *See generally* Andreas Wenger & Marcel Gerber, *John F. Kennedy and the Limited Test Ban Treaty: A Case Study of Presidential Leadership*, 29 *PRESIDENTIAL STUD. Q.* 460 (1999); JAMES E. GOODBY, *THE U.S. ARMS CONTROL AND DISARMAMENT AGENCY IN 1961–63* (2017), https://www.hoover.org/sites/default/files/research/docs/goodby_the_us_arms_control.pdf [<https://perma.cc/YU2S-3CGF>].

⁹⁸ Among the numerous recent proposals for arms control in space, *see generally* Daniel Porras, *Anti-Satellite Warfare and the Case for an Alternative Draft Treaty for Space Security*, 75 *BULL. ATOMIC SCIENTISTS* 142 (2019); Brian G. Chow, *Space Arms Control: A Hybrid Approach*, 12 *STRATEGIC STUD. Q.*, Summer 2018, at 107; Victoria Samson & Brian Weeden, *It's Time for a Global Ban on Destructive Antisatellite Testing*, *SCI. AM.* (Jan. 14, 2022), <https://www.scientificamerican.com/article/its-time-for-a-global-ban-on-destructive-antisatellite-testing/> [<https://perma.cc/KKU7-T626>]; Patricia Lewis, *Create a Global Code of Conduct for Outer Space*, in *CHATHAM HOUSE EXPERT PERSPECTIVES* 13 (Jake Statham ed., 2019), <https://www.chathamhouse.org/sites/default/files/publications/research/2019-06-10-Expert-Perspectives.pdf> [<https://perma.cc/T8ZA-FWWD>]; Alexey Arbatov, *Arms Control in Outer Space: The Russian Angle, and a Possible Way Forward*, 75 *BULL. ATOMIC SCIENTISTS* 151 (2019); Icho Kealotswe-Matlou, *The Rule of Law in Outer Space: A Call for International Outer Space Authority*, in *WAR AND PEACE IN OUTER SPACE: LAW, POLICY, AND ETHICS* 91 (Cassandra Steer & Matthew Hersch eds., 2021); Arne Sönnichsen et. al., *The Militarization of Space – Unique Opportunities for Arms Control*, 95 *DIE FRIEDENS-WARTE* 247 (2022); John Fairlamb, *The US Should Negotiate a Ban on Basing Weapons in Space*, *THE HILL*, (Feb. 2, 2021, 1:00 PM), <https://thehill.com/opinion/national-security/536774-the-us-should-negotiate-a-ban-on-basing-weapons-in-space/> [<https://perma.cc/ZWR2-Y3SS>]; Press Release, White House, *Fact Sheet: Vice President Harris Advances National Security Norms in Space* (Apr. 18, 2022) (announcing a U.S. initiative to halt the testing of destructive direct-ascent anti-satellite weapons), <https://www.whitehouse.gov/briefing-room/statements-releases/2022/04/18/fact-sheet-vice-president-harris-advances-national-security-norms-in-space/> [<https://perma.cc/QKQ4-8ECZ>]; Bruce Turner, Ambassador, U.S. Mission to Int'l Orgs. in Geneva, Remarks to the Conference on Disarmament on Prevention of an Arms Race in Outer Space (PAROS) (Mar. 30, 2023), <https://geneva.usmission.gov/2023/03/30/remarks-arms-race-in-outer-space-paros/> [<https://perma.cc/3U7K-B5XK>]; Paul Meyer, *Can Outer Space Be Kept Free of Armed Conflict?*, 168 *RUSI J.*, July 20, 2023, at 40 (highlighting the work of the United Nations Open-Ended Working Group on Reducing Space Threats Through Norms, Rules and Principles of Responsible

CONCLUSION

The first, foundational step is to re-think the concept of a “race to space.” The tired rhetoric of racing implies a zero-sum game and a conspicuous “finish line”—neither of which properly characterizes humanity’s activities in orbit. There are doubtless competitive aspects to space, and there may even turn out to be combative aspects, but those are not the only, or the most important, framings. There is an immense shared global interest in establishing an orderly, stable regime, and ultimately the foundation for such a structure must include fairness to all stakeholders.⁹⁹

Space law will never be perfect or perfectly comprehensive—any more than the law of any other domain is—but space is not the lawless Wild West, and a cosmic “land rush” in LEO should be prevented.¹⁰⁰ This is a classic “collective action problem,” where the stakeholders (essentially everyone) need to develop a more collaborative approach to resolve shared opportunities and dangers in a more enlightened fashion, attentive to true long-run interests.

This is not a call for us to change our priorities, nationally or internationally, but to recognize where our true priorities have always been, and to act upon them with vigor, good faith, and a lawyer’s eye for implementing detail. We should not allow ourselves to be distracted by the newest shiny (and radio noisy) objects in space.

It should be no surprise that the proliferation of small, private sector LEO satellites has, to date, largely escaped effective regulation; technology always races ahead of the law, especially when there are billions of dollars at stake. Sometimes, international law can catch up before the gravest dangers are realized and permanent harm is inflicted. Large constellations of small satellites have now gained visibility, as well as market share, and they have forced our hand—it is time for national and international law to respond comprehensively, to vindicate humanity’s shared interests in avoiding the tragedy of the space commons, in

Behaviours); Roza, *supra* note 72 (recommending that an arms control regime for space should focus on specified behaviors to be endorsed or stigmatized, instead of focusing on particular types of hardware to regulate).

⁹⁹ Cf. Matthew Costlow et al., *A Misleading Metaphor: The Nuclear “Arms Race,”* WAR ON THE ROCKS (Nov. 20, 2023), <https://warontherocks.com/2023/11/a-misleading-metaphor-the-nuclear-arms-race/> [<https://perma.cc/VT4D-5L6G>] (criticizing the metaphor of a nuclear “arms race” as meaningless and doing more harm than good).

¹⁰⁰ Venkatesan, *supra* note 12 (rejecting the “rush” to space). See also Pace, *supra* note 44 (quoting Vice President Pence’s call for U.S. leadership in space in his role as Chair of the National Space Council: “But above all else, we choose to lead in space because we know that the rules and values of space, like every great frontier, will be written by those who get there first—and we owe it to mankind to bring American values to the boundless expanse of the heavens.”).

sustaining opportunities for astronomy, and in respecting LoAC rules (and avoiding needing to actively exercise them in space).¹⁰¹

In closing, we can echo and expand the iconic cinematic title of Sergio Leone's epic 1966 spaghetti Western movie, in which the protagonists enthusiastically compete to pursue a cache of hidden treasure, indifferent to the chaos, damage, and trauma they inflict along the way. In space, we should be able to do better than achieving an outcome that is simultaneously good, bad, ugly, and illegal.¹⁰²

¹⁰¹ VENKATESAN, ET. AL., *supra* note 67, at 77 (maintaining that "'Science vs. Internet' Is a False Choice").

¹⁰² *Cf.* THE GOOD, THE BAD, AND THE UGLY (Produzioni Europee Assc. 1966).