Dangers From Regulatory Vacuums in Outer, Inner, and Near Space

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ABSTRACT

Space, "the final frontier," has become an alluring, but increasingly risky market for both public and private investments. A Gold Rush mentality anticipates broadband solutions to the Digital Divide provided by large constellations of small, low earth orbiting satellites, extraction of precious stones and rare earth minerals worth billions of dollars from asteroids, a vibrant space launch and tourism industry, and expanding earth observation opportunities. However, the absence of effective government oversight, necessary consumer safeguards, and shared "rules of the road" diminish the prospects for robust space commerce. The ambitious plans of Elon Musk and other space entrepreneurs could crash and burn, despite recent market success, such as Starlink's anticipated $6.6 billion revenue for 2024 and SpaceX's scheduling 148 rocket launches all occurring in 2024.

Without substantial refinement of global space treaties, enacted over 50 years ago, expanding and imprudent use of space resources could trigger "the tragedy of the commons," rendering the most valuable regions of space unusable. Satellites could collide or strike orbiting debris at extremely high speeds. Accidental collisions are more likely in a congested environment, such as the zone 200-1200 miles above earth where low earth orbiting satellites operate.

A much more costly calamity can occur when a valuable, fully operational satellite collides with space debris, or when it becomes a target in a test of anti-satellite ("ASAT")

technology. The likelihood of a space object collisions increases substantially when space faring nations and private ventures do not nudge worthless debris, such as satellites reaching end of life and jettisoned rocket stages, farther into deep space, or on a steep downward trajectory to achieve complete vaporization before reaching earth. The testing and future use of ASAT technology risks "weaponizing" space, despite treaty-level commitments by just about all nations to use it solely for peaceful purposes, benefitting everyone.

This paper explains how national governments have generated or tolerated private ventures generating space debris that collectively have reached a dangerous tipping point. The paper examines instances where space debris proliferated from collisions and tests of anti-satellite ("ASAT") technology without any the duty of the at fault party to compensate the harmed party, and to dispose of the newly created waste. It also explains how intergovernmental agreements, such as the five space treaties administered by the United Nations, and the space/spectrum management agreements of the International Telecommunication Union, lack an enforcement mechanism mandating space debris mitigation, and sanctions for noncompliance.

The failure to address and resolve proliferating debris from ASAT testing and abandoned waste will increase the risk that space will become less attractive for space commerce. The paper identifies how intergovernmental agreements can mandate space debris mitigation, impose sanctions for noncompliance, and create financial incentives for the recycling or disposal of already orbiting debris.

I. Introduction

"For the first time in human history, outer space is becoming accessible, useful, and habitable." [1] Innovations in rocket launching and satellite technology have made "The Final Frontier," [2] ripe for exploration, resource extraction, and even colonization. [3] Low earth orbiting ("LEO") satellite networks have the potential to narrow the Digital Divide by making broadband ubiquitous [4] and affordable. [5] Other market opportunities include:

extraction of valuable minerals from asteroids; [6]

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[1] Chase Hamilton, *Space and Existential Risk: The Need for Global Coordination and Caution in Space Development*, 21 Duke L. & Tech. Rev. 1 (Aug. 7, 2022); https://scholarship.law.duke.edu/cgi/viewcontent.cgi?article=1372&context=dltr.

[2] Bonny Birkeland, *Space: The ~~Final~~ Next Frontier*, 104 Minn. L. Rev. 2061 (2020); https://minnesotalawreview.org/wp-content/uploads/2020/04/Birkeland_Final.pdf.

[3] Tina Highfill &Chris Surfield, *New and Revised Statistics for the U.S. Space Economy, 2012–2021*, Survey of Current Business, U.S. Bur. of Econ. Analy., (Jun. 27, 2023); https://apps.bea.gov/scb/issues/2023/06-june/pdf/0623-space-economy.pdf; John-Paul Menez, *Exploring the Business of Space*, Yale Insights (Oct. 25, 2022); https://insights.som.yale.edu/insights/exploring-the-business-of-space; Sarah Kreps, Avishai Melamed & Ray Jayawardhana, *The Promise and Perils of the New Space Boom*, THE BROOKINGS INSTITUTE (Nov. 2, 2022); https://www.brookings.edu/articles/the-promise-and-peril-of-the-new-space-boom-us-china-competition-spacex-international-law/.

[4] Steven E. Grotch, *Mega-Constellations: Disrupting the Space Legal Order*, 37 Emory Int'l L. Rev. 101 (2022); 37 Emory Int'l L. Rev. 101 (2022); https://scholarlycommons.law.emory.edu/eilr/vol37/iss1/3/; Steven E. Grotch, Mega-Constellations: Disrupting the Space Legal Order, 37 Emory Int'l L. Rev. 101 (2022); https://scholarlycommons.law.emory.edu/eilr/vol37/iss1/3; Snezhana Stadnik Tapia, *The Global "Last Mile" Solution: High-Altitude Broadband Infrastructure*, 4 Geo. L. Tech. Rev. 47 (2019); https://georgetownlawtechreview.org/wp-content/uploads/2020/01/4.1-p47-123-Tapia.pdf.

[5] Colby Leigh Rachfal, *Low Earth Orbit Satellites: Potential to Address the Broadband Digital Divide*, Congressional Research Service, R46896 (Aug. 31, 2021); https://crsreports.congress.gov/product/pdf/R/R46896.

[6] Matthew Pascale, *Space, The Final Frontier: Navigating the Complexities of Commercial Spaceflight, Resource Extraction, and Colonization*, 2023 J. L. Tech. Pol'y. 151; https://illinoisjltp.com/file/146/Pascale2023_Issue%201.pdf; Monica Kamin,*The Allocation &*

development of a vibrant space launch and tourism industry; [7]

space exploration; [8]

colonization of the Moon and Mars; [9] and

an expanded array of services via commercial satellites, such as remote sensing [10] that monitors atmospheric and terrestrial conditions. [11]

Sadly, several countervailing interests and motivations jeopardize existing uses of space by public and private actors, as well as the full development of emerging commercial markets. A

Exploitation of Natural Resources in Space, 18 Animal & Nat. Resources L. 93 (2022); https://www.animallaw.info/sites/default/files/ANRLR%20Vol%2018.pdf; Laura C. Byrd, *Soft Law in Space: A Legal Framework for Extraterrestrial Mining*, 71 Emory L. J. 801 (2022); https://scholarlycommons.law.emory.edu/elj/vol71/iss4/3.

[7] Alex S. Li, *Touring Outer Space: The Past, Present, and Future of Space Tourism*, 71 Clev. St. L. Rev. 743 (2023); https://engagedscholarship.csuohio.edu/clevstlrev/vol71/iss3/8.

[8] John Thurston, *Make "Space" for Innovation*., B.C. Intell. Prop. & Tech. Forum (2023); https://lira.bc.edu/files/pdf?fileid=f9a19312-d008-4e1f-93fa-be18cf81443c; Matthew B. Hershkowitz, *Deep Space (Treaty) Exploration: Reviving Today's Obsolete Space Treaties*, 28 Mich. St. L. Rev. 1 (2019); https://hcommons.org/deposits/item/hc:35661/.

[9] Josselin Lavigne, *Political Sovereignty of a Colony in Outer Space*. 48 N.C. J. Int'l L. 147 (2022); https://heinonline-org.ezaccess.libraries.psu.edu/HOL/Page?handle=hein.journals/ncjint48&id=217&collection=journals&index=.

[10] *See* U.S. Department of the Interior, U.S. Geological Survey, *What is remote sensing and what is it used for?*; https://www.usgs.gov/faqs/what-remote-sensing-and-what-it-used; National Aeronautics and Space Administration, EARTHDATA, *What is Remote Sensing?*; https://www.earthdata.nasa.gov/learn/backgrounders/remote-sensing.

[11] *See also*, John S. Goehring, *U.S. Commercial Space Regulation: The Rule of Three*, 13 J. Nat'l Sec. L. & Pol'y 337 (2023); https://jnslp.com/wp-content/uploads/2023/05/US_Commercial_Space_Regulation.pdf; Phoebe T. Clewley, *Newspace: The Rise of the Private Space Industry is Threatening the Current Legal Framework Governing Outer Space*, 21 J. High Tech. L. (2021); https://bpb-us-e1.wpmucdn.com/sites.suffolk.edu/dist/5/1153/files/2021/05/Clewley_FINAL.pdf.

worst-case scenario anticipates severe decline in space commerce investment and insurance underwriting [12] caused by the growing risk of high-cost space collisions [13] between abandoned space objects, such as deactivated satellites and used rocket launch stages, and quite valuable operational satellites and space vehicles. [14]

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[12] Josh Raizner, *Covered? Insurance Viability in the New Space Age*, 35 Geo. J. Legal Ethics 1057 (2022).http://www.commonlii.org/in/journals/NLUDLRS/2011/11.pdf.

[13] "With the rising use of satellite constellations, the amount of satellites could increase by as much as 600 percent in the next three to five years. This surge in satellites will generate more space debris and increase the probability of collisions that may interrupt services, cause millions of dollars of damages, or even lead to a cascading series of collisions that prevents the use of LEO." Dylan Houle, *Preventing the Next Global Crisis: Addressing the Urgent Need for Space Debris Removal*, 111 Calif. L. Rev. 1955, 1956-57 (Dec. 2023); https://lawcat.berkeley.edu/record/1280971?v=pdf.

[14] Dylan Houle, *Preventing the Next Global Crisis: Addressing the Urgent Need for Space Debris Removal*, 111 Cal. L. Rev. 1955 (2023); https://www.californialawreview.org/print/preventing-the-next-global-crisis-addressing-the-urgent-need-for-space-debris-removal.

The ambitious plans of Elon Musk [15] Jeff Bezos, [16] and Richard Branson [17] could fail despite recent commercial achievements, such as SpaceX's scheduled 148 rocket launches in 2024 [18] and Starlink's anticipated $6.6 billion in revenues for the year. [19]

The indiscriminate use of antisatellite weaponry also accelerates the potential for catastrophic disruption in space activities, [20] by adding even more space debris. High ranking current and former U.S. government officials candidly state that space has become a volatile new

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[15] Pete Syme, Marianne Guenot, & Morgan McFall-Johnsen, *Elon Musk's SpaceX: How the world's richest person leads the space rocket pioneer*, Business Insider (March 29, 2024); https://www.businessinsider.com/spacex-elon-musk.

[16] Alan Boye, '*Let's go!' Jeff Bezos gets revved up when Blue Origin raises up its New Glenn rocket*, GeekWire (Feb. 21, 2024); https://www.geekwire.com/2024/jeff-bezos-blue-origin-new-glenn-rocket/.

[17] Chester Dawson, C. & Loren Grush, *Richard Branson's Space Empire Is a Waning Dream*. Bloomberg Newsletter Business of Space (April 17, 2024); https://www.bloomberg.com/news/newsletters/2024-04-17/virgin-galactic-richard-branson-s-space-tourism-venture-is-fading.

[18] Seth Kurkowski, *How many rockets has SpaceX launched in 2024?* Space Explored;https://spaceexplored.com/2024/05/28/spacex-launches-2024/.

[19] Rachel Jewett, *Starlink On Track to Hit $6.6B in Revenue This Year, Quilty Report Estimates*, ViaSatellite (May 9, 2024); https://www.satellitetoday.com/finance/2024/05/09/starlink-on-track-to-hit-6-6b-in-revenue-this-year-quilty-report-estimates/.

[20] Eytan Tepper, *The Laws of Space Warfare: A Tale of Non-Binding International Agreements*. 83 Md. L. Rev. (2024); https://digitalcommons.law.umaryland.edu/mlr/vol83/iss2/4 David A. Koplow, *ASAT-isfaction: Customary International Law and the Regulation of Anti-Satellite Weapons*, 30 Mich. J. Int'l L. 1187 (2008-2009); https://repository.law.umich.edu/cgi/viewcontent.cgi?params=/context/mjil/article/1141/&path_info=.

theater of warfare: "a certain threshold has now been passed: Space has effectively become part of the military fighting domain." [21]

This article outlines the space and radio spectrum resource management process with an eye toward explaining how governments can establish essential regulatory safeguards without reducing incentives for innovation and investment. Absent timely international agreement on enforceable space debris mitigation requirements, the most valuable regions of space eventually will become inaccessible, or conditionally available at great cost and risk. The article explains how international consensus on amendments to the five space treaties administered by the United Nations ("UN"), and the space/spectrum management agreements of the International Telecommunication Union ("ITU") can support a robust commercial space marketplace.

II. Unimpeded Space Debris Proliferation Risks Catastrophe

The absence of comprehensive and effective government oversight, consumer safeguards, and essential operational guardrails, frustrates and possibly thwarts existing and prospective development of outer space by governments and private ventures. Some nations appear quite willing to exploit ambiguities in treaty commitments to pursue aggressive, unilateral goals in space. [22]

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[21] Eric Lipton, *New Star Wars Plan: Pentagon Rushes to Counter Threats in Orbit*, The New York Times (May 17, 2024); https://www.nytimes.com/2024/05/17/us/politics/pentagon-space-military-russia-china.html.

[22] For example, it appears that the Russia has launched satellites that have nuclear weaponry, despite having acceded to treaties limited outer space to peaceful pursuits. United States House of Representatives, Permanent Select Committee on Intelligence, Press Releases, *Turner Warns of Russia's Nuclear Anti-Satellite Weapons Program During Speech at CSIS* (June 20, 2024); https://intelligence.house.gov/news/documentsingle.aspx?DocumentID=1425. Guy Faulconbridge , Patricia Zengerle& Steve Holland, *Kremlin dismisses US warning about Russian nuclear capability in space*, Reuters (Feb. 15, 2024); https://www.reuters.com/world/kremlin-dismisses-us-warning-about-russian-nuclear-capability-space-2024-02-15/.

Even nations committed to full compliance lack a clear sense of whether and how existing treaties apply to issues and conflicts, particularly ones triggered by emerging space technologies and markets.

The failure to make timely and comprehensive updates to the international consensus on space law and policy, achieved over fifty years ago, increases the risk that the most valuable areas of space will become inaccessible [23] due to a spiraling increase in the probability of space object collisions. [24] Worse yet, when nations test weapons designed to disable or destroy satellites and other space traveling objects of enemies, the procedure typically generates a large debris field requiring ongoing tracking and collision avoidance techniques. Sizeable fragments of anti-satellite ("ASAT") weapons and targets remain in orbit after completion of a test. [25]

The ability of space ventures to offer faster, better, smarter, cheaper, and ubiquitous service, largely depends on the effectiveness of conflict anticipation, avoidance, and resolution by the UN [26] and the ITU. [27] These intergovernmental organizations have treaty-level

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[23] Jaime GrJeen, *Befouling the Final Frontier*, The New York Times (Nov. 5, 2023); https://www.nytimes.com/2023/11/05/magazine/commercial-satellites-space-junk.html.

[24] European Space Agency, *Space debris by the numbers* (Dec. 6, 2023); https://www.esa.int/Space_Safety/Space_Debris/Space_debris_by_the_numbers.

[25] Aaron Bateman, *Anti-satellite weapons are creating space hazards. Here's a way to limit the damage*, Bulletin of the Atomic Scientists (Jan. 21, 2022); https://thebulletin.org/2022/01/anti-satellite-weapons-are-creating-space-hazards-heres-a-way-to-limit-the-damage/; United Nations Institute for Disarmament Research, *Towards ASAT Test Guidelines*, File 2, The Space Dossier (2018); https://unidir.org/files/publication/pdfs/-en-703.pdf.

[26] United Nations, Office for Outer Space Affairs, *Roles and Responsibilities*; https://www.unoosa.org/oosa/en/aboutus/roles-responsibilities.html.

[27] International Telecommunication Union, *Regulation of satellite systems* (Feb. 2022);

responsibilities to administer, register, and manage space and radio spectrum resources. While the UN and ITU have achieved a reputation for competency, they must interpret broad and ambiguous mandates that do not establish a clear division of substantive responsibilities, specific authority to impose duties of care in space, the power to impose sanctions for noncompliance, and reasonable opportunities to extend oversight to address problems resulting from changing technological and market conditions. [28]

The UN and ITU have extensively identified and studied chronic and acute problems that threaten the viability of commercial space markets. [29] Unfortunately, they have yet to come up with an effective strategy to resolve conflicts using the powers already conferred, or to secure a clearer designation of responsibilities through space treaty amendments. Additionally, in having to share administrative, policy, and regulatory duties, the UN and ITU appear uncertain about how to operate with transparency and clarity in coordinating current responsibilities. Their failure to achieve progress in foreclosing or remedying imprudent and harmful uses of space

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https://www.itu.int/en/mediacentre/backgrounders/Pages/Regulation-of-Satellite-Systems.aspx; *ITU-R: Managing the radio-frequency spectrum* (Oct. 2021); https://www.itu.int/en/mediacentre/backgrounders/Pages/itu-r-managing-the-radio-frequency-spectrum-for-the-world.aspx.

[28] United Nations, Meetings Coverage and Press Releases, *For Second Time Since Late April Security Council Fails to Adopt First-Ever Resolution on Preventing Arms Race in Outer Space*, SC/15700 (Oct. 19, 2023); https://press.un.org/en/2024/sc15700.doc.htm; Bill Boothby, *Space Weapons and the Law*, 93 Int'l L. Stud. 179 (2017); https://digital-commons.usnwc.edu/ils/vol93/iss1/6/.

[29] United Nations, Report of the Committee on the Peaceful Uses of Outer Space, Official Records, Seventy-eighth Session, Supplement No. 20 (Sixty-sixth session, (31 May–9 June 2023); https://www.unoosa.org/res/oosadoc/data/documents/2023/a/a7820_0_html/A_78_020E.pdf; International Telecommunication Union, RESOLUTION ITU-R 74, *Activities related to the sustainable use of radio-frequency spectrum and associated satellite-orbit resources used by space services* (2023); https://www.itu.int/pub/R-RES-R.74-2023.

resources may trigger "the tragedy of the commons" [30] rendering choice portions of space unusable. Both unintended and intentional actions by just a few treaty signatories can defeat the global consensus that space should remain a shared resource available for peaceful purposes for the benefit of everyone.

Currently, the UN and ITU cannot halt the domino effect that expanded space debris has on the likelihood of satellite collisions. ASAT testing nations have done nothing to reduce the large debris fields that can remain in orbit for years before starting a descent to earth. Most national governments do not require public and private operators to dispose or reuse satellites reaching the end of mission, and parts of rocket launchers that have completed their role in a staged ascent. Governments and private ventures have no duty to recycle no longer useful space objects, nor do they have to remove them from choice orbital locations by ejecting them farther out into space, or nudging them in downward trajectories guaranteeing complete vaporization [31] before reaching earth. Without compulsory duties to conserve space by removing debris and

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[30] Garrett Hardin, *The Tragedy of the Commons*, 162 Science 1243 (Dec. 13 1968); https://math.uchicago.edu/~shmuel/Modeling/Hardin,%20Tragedy%20of%20the%20Commons.pdf. *See also*, Keiko Nomura, Simon Rella, Haily Merritt, Mathieu Baltussen. Darcy Bird, Annika Tjuka.& Dan Falk, *Tipping Points of Space Debris in Low Earth Orbit*. 18 Int'l J. of the Commons 17 (2024); https://thecommonsjournal.org/articles/10.5334/ijc.1275.

[31] Even the complete vaporization of space objects appears to have potentially hazardous impacts on the environment below. "In a series of high-altitude research flights over Alaska and the U.S. Midwest in March and April, researchers sampled stratospheric air using specialized mass spectrometers. They discovered surprising amounts of many metals commonly used in rockets and satellites, often in ratios mirroring those found in specific high-performance aerospace alloys. The investigation revealed that the metals are accumulating within sulfuric acid particles, which constitute most of the stratosphere's particulates and influence our world's ozone layer and climate." Leonard David & Lee Billings, *Space Junk Is Polluting Earth's Stratosphere with Vaporized Metal*, Scientific American (Oct. 26, 2023); https://www.scientificamerican.com/article/space-junk-is-polluting-earths-stratosphere-with-vaporized-metal/.

refrain from generating more, the space environment will become increasingly congested and polluted. [32]

Space debris qualifies for the derogatory term space junk, because abandoned and discarded material has the potential to collide with quite valuable resources, such as operational satellites, space stations, and launch vehicles carrying astronauts and valuable cargo:

> There are no international space laws to clean up debris . . .. [The part of space where low earth orbit satellites operate] . . . is now viewed as the World's largest garbage dump, and it's expensive to remove space debris from LEO because the problem of space junk is huge — there are close to 6,000 tons of materials in low Earth orbit. [33]

Worse yet, nations, keen on commercialization of space, [34] but also "weaponizing" it as a new theater of warfare, appear unwilling to assume responsibilities they supported when acceding to global treaties, including the commitment to pursue only peaceful uses benefiting everyone. [35] "[T]he deliberate destruction of the Chinese Fengyun-1C spacecraft in 2007 and the accidental collision of an American and a Russian spacecraft in 2009 alone have increased the

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[32] Jaime Green. *Befouling the Final Frontier*, The New York Times (Nov. 5, 2023); https://www.nytimes.com/2023/11/05/magazine/commercial-satellites-space-junk.html.

[33] National Aeronautics & Space Administration, Planetary Orbits, *Space Debris*; https://www.nasa.gov/headquarters/library/find/bibliographies/space-debris/[hereinafter cites as NASA Space Debris Overview].

[34] Marty Levers, *Star Trek, Star Wars, or Battlestar Galactica--The Occurring Privatization of Space Exploration, and the Need for "Global" Regulations*, 24 San Diego Int'l L.J. 383 (2023); https://digital.sandiego.edu/cgi/viewcontent.cgi?article=1343&context=ilj.

[35] United Nations, Meetings Coverage and Press Releases, *Outer Space Becoming Contested Domain for Supremacy with Space-Based Communications, Intelligence Assets, Anti-Satellite Weapons, First Committee Hears*, GA/DIS/3722 (Oct. 19, 2023); https://press.un.org/en/2023/gadis3722.doc.htm; David C. DeFrieze, *Defining and Regulating the Weaponization of Space*, 74 Jt. Force Q. 110 (2014); https://ndupress.ndu.edu/Portals/68/Documents/jfq/jfq-74/jfq-74_110-115_DeFrieze.pdf;

large orbital debris population in LEO by approximately 70%, posing greater collision risks for spacecraft operating in low Earth orbit." [36] The risk of costly calamities in space continues to rise at an alarming rate. [37]

III. The Three Regions of Space

Outer space starts at approximately 60 miles above earth [38] where its atmospheric envelope dissipates completely. A more granular segmentation identifies three regions, based on distance from earth, as well as what services can be offered, and whether national or international laws, treaties, and other agreements apply.

A. Outer Space

Several different orbital locations within outer space provide a favorable environment for launching different kinds of satellites and vehicles. In locations approximately 200-1200 miles above earth, small, low earth orbiting ("LEO") satellites provide telecommunications, Internet access, surveillance, and environmental monitoring. [39] Experimental space stations operate in this vicinity as well. In middle earth orbit, constellations of larger satellites provide navigation

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[36] NASA Space Debris Overview.

[37] John Yoo, *Rules for the Heavens: The Coming Revolution in Space and the Laws of War*, 2020 Ill. L. Rev. 123; Kirt, J. (2015); https://illinoislawreview.org/print/vol-2020-no-1/rules-for-the-heavens/; Joseph Kurt, *Triumph of the Space Commons: Addressing the Impending Space Debris Crisis Without an International Treaty*, 40 Wm. & Mary Envtl. L. & Pol'y Rev. (2015), https://scholarship.law.wm.edu/wmelpr/vol40/iss1/9.

[38] Phil Plait, *Where Does Outer Space Begin?* Scientific American (Feb. 2, 2024); https://www.scientificamerican.com/article/where-does-outer-space-begin/.

[39] David A. Koplow, *Large Constellations of Small Satellites: The Good, the Bad, the Ugly, and the Illegal*, 15 Harv Nat'l Sec. J. 257 (May 19, 2024); https://harvardnsj.org/2024/05/19/large-constellations-of-small-satellites-the-good-the-bad-the-ugly-and-the-illegal/.

services, including the U.S. Global Positioning System ("GPS") whose satellites encircle the earth at an altitude of 12,550 miles. [40]

Communications and other types of "geosynchronous" satellites, in orbits 22,300 miles above, match the earth's orbital speed. [41] A satellite at this location appears to hover in a stable "geostationary" orbit, easily targeted to receive and relay content to millions of consumers equipped with small, inexpensive receiving antennas. Satellites located far above have a transmission "footprint" covering as much as one third of the earth's surface. Geosynchronous communications satellites can provide a competitive alternative to terrestrial options, by transmitting content, such as audio and video programming, using one-to-many, point-to-multipoint technology.

Outer space extends farther out toward the Moon, asteroids, and planets. Scientific satellites have explored this region for several decades. Recently, test and demonstration satellites have extracted soil samples from asteroids [42] and the Moon. [43] Innovations in launch

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[40] Catherine G. Manning, National Aeronautics and Space Administration, *GPS* (Sep. 25, 2023); https://www.nasa.gov/directorates/somd/space-communications-navigation-program/gps/.

[41] National Aeronautics and Space Administration, *Planetary Orbits*; https://science.nasa.gov/learn/basics-of-space-flight/chapter5-1/; European Space Agency, *Types of orbits*; https://www.esa.int/Enabling_Support/Space_Transportation/Types_of_orbits.

[42] National Aeronautics and Space Administration, OSIRIS-Rex; https://science.nasa.gov/mission/osiris-rex/; Robert Heins, *Shoot for the Moon, If You Miss You'll Land Among Valuable Asteroids: An Analysis of the Legal Ramifications of Asteroid Mining*, 61 Jurimetrics J. 219 (Winter, 2021); https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3743074.

[43] Ken Moritsugu, *Moon rock samples brought to Earth for first time in 44 years*, The Christian Science Monitor (Dec. 17, 2020); https://www.csmonitor.com/Science/Spacebound/2020/1217/Moon-rock-samples-brought-to-Earth-for-first-time-in-44-years (retrieval of material from asteroid Bennu returned to Earth on Sept. 24, 2023). *See also*, National Aeronautics & Space Administration, *Asteroids: Exploration*; https://science.nasa.gov/solar-system/asteroids/exploration/.

vehicles and capsules offer the prospect of commercial space tourism, extraction of rare minerals, and even permanent manned outposts on the Moon and Mars. [44]

An increasing number of spacefaring nations have launched communications, scientific, environmental monitoring, military, weather, navigation, and surveillance satellites in outer space: "At the end of 2022, countries had a total of 6,718 active satellites orbiting the planet, an increase of nearly 2,000 satellites in just one year." [45] Estimates for 2024 exceed 10,000 satellites. [46] Such expanded use increases the potential for congestion in the geosynchronous orbital arc, because satellites, operating in the same frequency band, must be separated by approximately two degrees to prevent signal interference. [47] In response to robust growth in LEO satellite launches, the ITU and national regulatory authorities have established specific procedures and registration requirements to prevent radio signal interference and collisions.

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[44] *See, e.g.*, Kirsten Grind, *Elon Musk's Plan to Put a Million Earthlings on Mars in 20 Years*, The New York Times (July 11, 2024); https://www.nytimes.com/2024/07/11/technology/elon-musk-spacex-mars.html; National Aeronautics and Space Administration, *Space Exploration*; https://www.nasa.gov/headquarters/library/find/bibliographies/space-colonization/.

[45] Stephen Young, *How Many Satellites Are in Space? The Spike in Numbers Continues. the Equation*, Union of Concerned Scientists (July 11, 2023); https://blog.ucsusa.org/syoung/how-many-satellites-are-in-space-the-spike-in-numbers-continues/.

[46] Erica Marchand, *Ten Thousand active satellites now orbiting Earth*, Spacedaily (June, 27, 2024); https://www.spacedaily.com/reports/Ten_Thousand_active_satellites_now_orbiting_Earth_999.html.

[47] ITU Backgrounders, *Sharing the Sky – ITU's Role in Managing Satellite and Orbit Spectrum Resources* (2014); https://www.itu.int/en/plenipotentiary/2014/newsroom/Documents/backgrounders/pp14-backgrounder-sharing-the-sky.pdf.

Outer space also has become a potential new theater of warfare. Because national defense and surveillance satellites operate in this region, warring nations may target them for disruption, or destruction. Heretofore, China, India, Russia, and the U.S. have tested ASAT weapons, [48] without regard to readily anticipated harmful impact on space access. If ASAT testers fail to execute space debris mitigation procedures, they will substantially increase congestion and the potential for future collisions. The worst-case scenario in space debris proliferation renders all or part of space unusable: "A trio of satellite breakups — two caused by anti-satellite (ASAT) missile tests — are responsible for a large percentage of dangerous debris in the ever-more popular real estate of low Earth orbit, creating an especially 'bad neighborhood' there, according to space traffic observers at LeoLabs." [49]

B. Inner Space

Inner space refers to the portion of outer space where LEO satellites operate, far below the geosynchronous satellite orbital arc. [50] Because of the much closer proximity to earth, LEO satellite operators must launch a large constellation of small satellites, numbering in the thousands, to achieve complete global coverage. To avoid radio interference and collisions, carriers register the orbital trajectory of each satellite with domestic regulatory agencies and the

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[48] Connor Mallon, *Anti-Satellite Weapons & The Law of Armed Conflict*, 30 Syracuse J. Int'l L & Com. 317 (2023); https://jilc.syr.edu/wp-content/uploads/2024/02/502.pdf.

[49] Theresa Hitchens, *Debris from ASAT tests creating 'bad neighborhood' in low Earth orbit: Analyst*. Breaking Defense (June 16, 2023); https://breakingdefense.com/2023/06/debris-from-asat-tests-creating-bad-neighborhood-in-low-earth-orbit-analyst/. *See also*, LeoLabs, *What's up in LEO? Insights and analysis from 2022* (Jan. 18, 2023); https://leolabs.space/article/leo-annual-review-2022/.

[50] Jonathan McDowell, *Where does outer space begin?*. 73 Physics Today 70 (2020); https://pubs.aip.org/physicstoday/article/73/10/70/853191/Where-does-outer-space-begin-As-suborbital-space.

ITU. [51] The registration process helps prevent collisions by identifying occupied orbital locations and radio frequencies that other satellite operators should avoid.

C. Near Space

While technically not part of what is considered space, so-called near space refers to part of the earth's atmosphere where orbiting vehicles, including extremely large balloons, can offer new surveillance and environmental sensing capabilities. [52] Near space lies well above the area, closer to earth, where aircraft and weather observation balloons operate. In 2023, the government of China released what it claimed to be a high-altitude weather observation balloon, the size of three school buses, that traveled across North America. [53] U.S. government officials characterized the vehicle as designed for surveillance and considered its overhead passage from

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[51] Alexandre Vallet, *ITU and space: Ensuring interference-free satellite orbits in LEO and beyond*, ITU News (Feb. 9, 2022); https://www.itu.int/hub/2022/02/itu-space-interference-free-satellite-orbits-leo/; Vladislav Beregovskiy, Submission of NGSO satellite systems and networks subject to coordination (2020); https://www.itu.int/en/ITU-R/space/WRS20space/29%20Submission%20of%20NGSO%20satellite%20systems%20and%20networks%20subject%20to%20coordination.pdf.

[52] Thomas Boudreau, *The Earth's Atmosphere as a Global Trust: Establishing Proportionate State Responsibility to Maintain, Restore and Sustain the Global Atmosphere*, 7 Envtl. & Earth L.J. Law Journal 39 (2017); https://lawpublications.barry.edu/ejejj/vol7/iss1/2/.

[53] Edward Wong, Helene Cooper & Chris Buckley, *Furor Over Chinese Spy Balloon Leads to a Diplomatic Crisis*, The New York Times (Feb. 4, 2023); https://www.nytimes.com/2023/02/03/world/asia/china-spy-balloon.html; Issac Chotiner, *What's Behind the Chinese Spy Balloon*, The New Yorker (Feb. 18, 2023); https://www.newyorker.com/news/q-and-a/whats-behind-the-chinese-spy-balloon; Christopher A. Ford, *Xi Jinping, Michel Foucault, and Spy Balloons? Communist China's Theory of Control and Visions of a Post-Westphalian World Order*; 11 Nat'l Sec. L.J. 1 (2023); https://www.nslj.org/wp-content/uploads/Ford-Xi-Jinping-Michel-Foucault-and-Spy-Balloons-Communist-Chinas-Theory-of-Control-and-Visions-of-a-Post-Westphalian-World-Order.pdf.

Alaska to South Carolina a violation of national sovereignty and international law, as well as a potential hazard to commercial aviation. [54]

IV. Chronic and Emerging Challenges to Space Commerce

The UN and the ITU, as well as national governments, face the daunting task of calibrating their oversight so that effective rules of road apply without creating disincentives for investment and innovation in space markets. Set out below, are ongoing and new quandaries requiring timely resolution.

A) Chronic Challenges

1) Balancing Equity and Efficiency

Despite its vastness, only a small part of space currently presents an attractive value proposition to potential investors. The narrow geosynchronous orbital arc, in outer space, offers an environment where communications satellites appear geostationary, making it possible to install earth station antennas that can maintain the necessary "line of sight" link without having to track a moving target. Direct-to-home satellite television ventures, such as Dish and DirecTV, in the U.S., and SES Astra, Eutelsat, and SkyTelevision in Europe, can profitably operate by combining the large geographical footprint of geosynchronous satellites and the ability to provide access via small, inexpensive, and easily installed receiving antennas locked in on one geostationary transmitter.

Within inner space, a relatively small sliver provides the best balance in proximity to earth and the number of satellites needed to provide service. Starlink, Viasat, One Web, Project

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[54] United States Dept. of State, Office of the Spokesperson, *Senior State Department Officials on the People's Republic of China* (Feb. 3, 2023); https://www.state.gov/senior-state-department-officials-on-the-peoples-republic-of-china/.

Kuiper, Iridium, Globalstar, and Orbcomm, offer, or plan to provide voice and broadband data services, via large constellations of LEO satellites.[55] To prevent radio signal interference and collisions, LEO operators agree to disclose and coordinate the orbital planes of their small satellites with other LEO networks and with operators of higher geosynchronous orbiting satellites that might experience interference from signals aimed at satellites in lower orbits.

The UN and ITU maintain registries of space vehicle launches, orbits, and radio spectrum uses with an eye toward reducing the likelihood of radio signal interference and collisions. Satellites and other vehicles, such as space stations, must operate in orbits that are sufficiently separated from other fast-moving objects. Satellites currently have limited, if any, capability to identify and avoid potential collisions. Earth-based monitoring, tracking, and predicting the future trajectory of space debris lacks accuracy. [56]

Developed countries have accrued a first mover advantage, with early access to the best orbital locations, unimpaired by concerns about congestion, the consequences of discarding objects in space, and the growing risk of collisions. Inter-governmental organizations have a mandate to safeguard space as a shared resource ("res communes") [57] for the benefit of all,

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[55] 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; Kristin Cooke, *What Are the New Satellite Internet Providers?*. SatelliteInternet.com. (Aug. 4, 2023); https://www.satelliteinternet.com/resources/history-and-future-of-satellite-internet/.

[56] Starburst, *Is Space Situational Awareness the New Gold Rush of the New Space Economy?* (Jan. 5, 2024); https://starburst.aero/news/is-space-situational-awareness-the-new-gold-rush-of-new-space/.

[57] Devin E. Miller, *The New Space Race: Exploration and Exploitation in the Commons of the Twenty-First Century*, 50 Syracuse J. Int'l L. & Com., 153 (2023); https://jilc.syr.edu/wp-content/uploads/2024/02/502.pdf; John S. Goehring, *Why Isn't Outer Space a Global Commons?*. 11 J. Nat'l Sec. L. & Pol'y 573 (2005); https://jnslp.com/2021/06/03/why-isnt-outer-space-a-global-commons/.

including nations that might never become spacefaring. [58] Accordingly, the UN and ITU seek to balance the ability of market forces to maximize efficiency and deployment of satellites with equity concerns that could reserve orbital slots for developing nations to use in the future.

2) Non-Enforceability, Ambiguities, Staleness, and Obsolescence in the Five U.N. Space Treaties

Soon after the onset of space exploration, but without ongoing revisions reflecting technological and market changes, [59] the nations of the world reached consensus on access to, and use of, space resources. United Nations General Assembly Resolution 1348 (XIII)(1958) and Resolution 1472 (XIV) (1959) established the Committee on the Peaceful Uses of Outer Space ("COPUOS"). [60] COPUOS has a broad mission to determine how the UN, and its specialized agencies and other international bodies, can foster international cooperation to anticipate, avoid, and resolve conflicts likely to occur in outer space activities. [61]

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[58] John S. Goehring, *U.S. Commercial Space Regulation: The Rule of Three*, 13 J. Nat'l Sec. L & Pol'y (2023); https://jnslp.com/2023/05/06/us-commercial-space-regulation-the-rule-of-three/.

[59] H. Austin Simpson, *Regulating Science Fiction: The Regulatory Deficiencies in a Rapidly Growing Commercial Space Industry*, 87 J. Air L. & Com. 759 (2022); https://scholar.smu.edu/jalc/vol87/iss4/4/.

[60] United Nations, Office for Outer Space Affairs, History; https://www.unoosa.org/oosa/en/aboutus/history/index.html; *See also*, UN-Space; https://www.unoosa.org/oosa/en/ourwork/un-space/index.html.

[61] Paul B. Larsen, *Outer Space: How Shall the World's Governments Establish Order Among Competing Interests?*, 29 Wash. Int'l L.J. 1 (2019); https://digitalcommons.law.uw.edu/wilj/vol29/iss1/3.

COPUOS has two subcommittees: one for addressing scientific and technical issues, and the other for addressing legal matters. [62] The scope of scientific and technical issues includes the impact of solar radiation on space activities, the use of space technology for socioeconomic development and disaster relief, global navigation satellite systems, and the long-term sustainability of outer space activities. Legal issues include monitoring the status and application of the five UN treaties on outer space, the definition and delimitation of outer space, national space legislation, legal mechanisms relating to space debris mitigation,[63] and international mechanisms for cooperation in the peaceful exploration and use of outer space.

The UN Office for Outer Space Affairs ("UNOOSA") provides Secretariat services to COPUOS and its two subcommittees, including the maintenance of a central registry of objects launched into outer space as well as dissemination of information relating to the recovery of space objects, launch and re-entry of nuclear-powered satellites, and other events relating to the use and exploration of outer space. [64]

Under the auspices of COPUOS, U.N. Member States established five space-related treaties and agreements: 1) Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies; [65]

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[62] United Nations, Office of Outer Space Affairs, *Committee on the Peaceful Uses of Outer Space and its Subcommittees*; https://www.unoosa.org/oosa/en/ourwork/copuos/comm-subcomms.html.

[63] *See, e.g.*, Annie Handmer & Steven Freeland, *The Use of Law to Address Space Debris Mitigation and Remediation: Looking Through a Science and Technology Lens*, 87 J. Air L. & Com. 375 (2022); https://scholar.smu.edu/jalc/vol87/iss3/2/.

[64] United Nations, Office for Outer Space Affairs *Roles and Responsibilities*; https://www.unoosa.org/oosa/en/aboutus/roles-responsibilities.html.

[65] 18 U.S.T. 2410 (1967), 610 U.N.T.S. 205 (1967); https://www.unoosa.org/oosa/en/ourwork/spacelaw/treaties/introouterspacetreaty.html.

2) Agreement on the Rescue of Astronauts, the Return of Astronauts and the Return of Objects Launched into Outer Space; [66] 3) Convention on International Liability for Damage Caused by Space Objects; [67] 4) Convention on Registration of Objects Launched into Outer Space; [68] and 5) Agreement Governing the Activities of States on the Moon and Other Celestial Bodies. [69]

Collectively, these inter-governmental agreement create a non-enforceable framework establishing shared principles including the non-appropriation of outer space by any one country, a commitment to refrain from using weapons in space, the right to explore space, liability for damage caused by space objects, the safety and rescue of spacecraft and astronauts, prevention of harmful interference with space activities and the environment, notification and registration of space activities, and the possible harvesting of natural resources.

On the matter of spacecraft collisions, Article VIII of the Outer Space Treaty requires signatory nations to retain jurisdiction and control over any space object launched from its territory, and over any personnel while in outer space, or on a celestial body. [70]

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[66] 19 U.S.T. 7570 (1968), 672 U.N.T.S. 119 (1968); https://www.unoosa.org/oosa/en/ourwork/spacelaw/treaties/rescueagreement.html.

[67] 24 U.S.T. 2389 (1972), 961 U.N.T.S. 187 (1972); https://www.unoosa.org/oosa/en/ourwork/spacelaw/treaties/liability-convention.html

[68] 28 U.S.T. 695 (1975), 1023 U.N.T.S. 15 (1975); https://www.unoosa.org/oosa/en/ourwork/spacelaw/treaties/registration-convention.html

[69] 1363 U.N.T.S. 3 (1979); https://www.unoosa.org/oosa/en/ourwork/spacelaw/treaties/moon-agreement.html.

[70] "A State Party to the Treaty on whose registry an object launched into outer space is carried shall retain jurisdiction and control over such object, and over any personnel thereof, while in outer space or on a celestial body. Ownership of objects launched into outer space, including objects landed or constructed on a celestial body, and of their component parts, is not affected by their presence in outer space or on a celestial body or by their return to the Earth. Such objects or component parts found beyond the limits of the State Party to the Treaty on

The Liability Convention specifies that a signatory nation shall provide compensation for damage caused by a space object it has launched. Nations also may incur liability for damages incurred in space for which it is at fault. Because the Convention does not define fault, it remains uncertain under what specific circumstances a launching country would incur liability. [71] The Convention also provides procedures for the settlement of claims for damages.

In 2010, COPUOS created non-binding Space Debris Mitigation Guidelines with an eye toward encouraging voluntary efforts by spacefaring nations to reduce the risk of collisions. [72] Because the space treaties lack any enforcement mechanism, the ongoing accessibility of space depends on the good will of signatories to cooperate and resolve differences. [73]

With no compulsory obligation to refrain from generating more space debris and to recover already generated waste, only a few Member States, including the U.S. [74] and the

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whose registry they are carried shall be returned to that State Party, which shall, upon request, furnish identifying data prior to their return." https://www.unoosa.org/oosa/en/ourwork/spacelaw/treaties/outerspacetreaty.html.

[71] Sraavya Poonuganti, *It's Raining Rockets: Heightening State Liability for Space Pollution*, 23 Chi. J. Int'l L. 490 (2023); https://chicagounbound.uchicago.edu/cjil/vol23/iss2/5/; Trevor Kehrer, *Closing the Liability Loophole: The Liability Convention and the Future of Conflict in Space*, 20 Chi. J. Int'l L. 178 (2019); https://chicagounbound.uchicago.edu/cjil/vol20/iss1/5; Joel A Dennerley, *State Liability for Space Object Collisions: The Proper Interpretation of 'Fault' for the Purposes of International Space Law*, 29 Euro. J. Int'l L. 281 (2018); https://doi.org/10.1093/ejil/chy003.

[72] United Nations, Office for Outer Space Affairs, *Space Debris Mitigations Guidelines of the Committee on the Peaceful Uses of Outer Space*, ST/SPACE/49 (2010);https://www.unoosa.org/res/oosadoc/data/documents/2010/stspace/stspace49_0_html/st_space_49E.pdf. *See also*, United Nations, Office for Outer Space Affairs, *Space Debris*; https://www.unoosa.org/oosa/en/ourwork/topics/space-debris/index.html.

[73] Kaitlyn Johnson, *Space Sustainability and Debris Mitigation*, Center for Strategic and International Studies (2020); https://www.jstor.org/stable/pdf/resrep26047.6.pdf.

[74] United States Federal Communications Commission, Space Innovation Mitigation of Orbital Debris in the New Space Age. Second Report and Order, IB Docket Nos. 22-271, 18-

European Union [75] have established mitigation requirements and regulations with an eye toward providing more granularity, specificity, and enforcement than the general language contained in the space treaties. For example, in 2023, the FCC imposed a financial penalty on a regulated satellite operator that unintentionally may have increased the possibility of costly collisions. The Commission fined Dish Network $150,000 for failing to relocate a deactivated communications satellite that continued to occupy a scarce and valuable geostationary slot. [76] Deactivated geostationary satellites eventually start a descent back to earth during which collisions can occur. Fast descending satellites and other space objects typically lack the ability to anticipate and avoid a collision, nor can earth-based managers issue maneuvering commands.

Rather than seek amendments to the space treaties, under the aegis of the UN, the U.S. has promoted a package of forward-looking reforms, including a more specific commitment to mitigate space debris: The Artemis Accords Principles for Cooperation In The Civil Exploration And Use Of The Moon, Mars, Comets, And Asteroids For Peaceful Purposes. [77] Few nations

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313, FCC 22-74 (2022); https://docs.fcc.gov/public/attachments/FCC-22-74A1.pdf; National Science and Technology Council, *National Orbital Debris Implementation Plan* (2022); https://www.whitehouse.gov/wp-content/uploads/2022/07/07-2022-NATIONAL-ORBITAL-DEBRIS-IMPLEMENTATION-PLAN.pdf.

[75] European Space Agency, *ESA Space Debris Mitigation Requirements*, ESA Space Debris Mitigation Working Group, Reference ESSB-ST-U-007 Issue 1(Oct. 30, 2023); https://technology.esa.int/upload/media/ESA-Space-Debris-Mitigation-Requirements-ESSB-ST-U-007-Issue1.pdf; *See also*, European Space Agency, *ESA's Annual Space Environment Report* (2023); https://www.sdo.esoc.esa.int/environment_report/Space_Environment_Report_latest.pdf; European Space Agency, *Space debris by the numbers* (2023); https://www.esa.int/Space_Safety/Space_Debris/Space_debris_by_the_numbers.

[76] United States Federal Communications Commission, DISH Operating L.L.C., Order, DA 23-888 (Oct. 2, 2023); https://docs.fcc.gov/public/attachments/DA-23-888A1.docx.

[77] National Aeronautics & Space Administration, The Artemis Accords Principles For Cooperation In The Civil Exploration and Use of the Moon, Mars, Comets, and Asteroids

have agreed to this non-binding agreement, and even long-standing allies have not yet acceded to what constitutes a "bottom up" approach, preceding and possibility subverting a single, global agreement achieved through consensus building under the auspices of the UN. [78]

On one hand, the Artemis Accords offer greater clarity than existing UN-administered treaties on the obligation of nations, and the commercial ventures they authorize, to exploit space resources, including affirmative duties to avoid generating more space debris. On the other hand, some nations question the document's compatibility with international law. Critics view the document as favoring the few nations capable of undertaking costly initiatives, such as colonization of the Moon and Mars, and mining scarce and valuable natural resources on asteroids and planets. [79]

The Artemis Accords represent an attempt by the U.S. government to remedy deficiencies in the conventional multilateral process under the auspices of the UN and ITU. [80]

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for Peaceful Purposes (2020); https://www.nasa.gov/wp-content/uploads/2022/11/Artemis-Accords-signed-13Oct2020.pdf?emrc=653a00.

[78] *See* Bradley, C. Goldsmith, J. &. Hathaway, O., *The Rise of Nonbinding International Agreements: An Empirical, Comparative, and Normative Analysis*. 90 Chi. L. Rev. 1281 (2023); https://live-chicago-law-review.pantheonsite.io/sites/default/files/2023-09/01_Bradley_ART_Final.pdf; Yutaka Osada, *Governance of Space Resources Activities: In the Wake of the Artemis Accords*, 53 Geo. J. Int'l L. 399 (2022); https://live-chicago-law-review.pantheonsite.io/sites/default/files/2023-09/01_Bradley_ART_Final.pdf.

[79] *See, e.g.*, Isabelle M. Thibault, *Space Mining: Restricted by Non-Appropriation; Set Free by Principles of Property Mining*, 89 J. Air L. & Com. 161 (2024); https://scholar.smu.edu/jalc/vol89/iss1/6/; Paul B. Larsen. *Is There a Legal Path to Commercial Mining on the Moon?*. 83 Pitt. Rev. 1 (2021); https://lawreview.law.pitt.edu/ojs/lawreview/article/view/821.

[80] Joshua Lee, Elsbeth J. Magilton & Amelia Ruffolo, *Diplomatic Impact in the Stars? A Review of the Impact of the Artemis Accords on Global Relationships*, 30 Cath. U. J. L. & Tech 1 (2022); https://scholarship.law.edu/jlt/vol30/iss2/3/; Walker A. Smith, *Using the Artemis Accords to Build Customary International Law: A Vision tor a U.S.-Centric Good Governance Regime in Outer Space*, 86 J. Air L. & Com. 661 (Fall, 2021);

This initiative can achieve progress on matters that have languished, with no apparent rush to find remedies. Numerous critics have identified problems with the space treaties, including the pace and efficacy of multilateral consensus building on legal and regulatory matters affecting space law and policy. [81]

The space treaties were negotiated and finalized when few nations had become space-faring and no private venture had begun to develop commercial market segments. Accordingly, the UN documents rely on Nation States, not private ventures, to negotiate and resolve any dispute. [82] Commercial ventures now dominate many major markets segments, including launch and satellite services. Typically, a variety of participants, of various nationalities, are involved in such activities as finance, launch, ownership, management, regulatory compliance, and liaison with the UN and ITU. For example, a private U.S. venture, incorporated in Bermuda, might contract with the European Space Agency and its French member, CNES, to launch a satellite from a facility in French Guyana for services licensed by national regulatory agencies and financed by ventures located throughout the world.

The space treaties increasingly fail to reflect the impact of existing and emerging technologies that did not exist when the treaties were enacted decades ago. Similarly, the space

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https://scholar.smu.edu/jalc/vol86/iss4/5/; *See generally*, Peter Y. Kim, *In, From, and to Space: Safeguarding the United States of America and Her Interests,* 42 U. Pa. J. Int'l L. 1157 (Summer, 2021); https://scholarship.law.upenn.edu/jil/vol42/iss4/4/.

[81] Diane M. Janosek, *Innovative Thinking: Modernizing Outer Space Governance*, 29 Cath. U. J. L. & Tech 63 (2021); Marcus Schladebach, *Fifty Years of Space Law: Basic Decisions and Future Challenges*, 41 Hastings Int'l & Comp .L. Rev. 245 (2018); https://repository.uchastings.edu/hastings_international_comparative_law_review/vol41/iss3/2.

[82] *See* Christina Isnardi, *Problems with Enforcing International Space Law on Private Actors,* 58 Colum. J. of Transnat'l L. 489, 491 (2020); https://www.jtl.columbia.edu/journal-articles/problems-with-enforcing-international-space-law-on-private-actors.

treaties do not recognize private actors, instead of Nation States, as major stakeholders in space commerce. In addition to an established presence in such major market segments as rocket launches, telecommunications, and remote sensing, one can anticipate the near-term development of a commercial market for space tourism,[83] asteroid mining,[84] and other types of extraction of space resources for private gain.

The authors of the space treaties could not possibly "future proof" the documents by anticipating all ensuing developments in technology and markets. Currently, national governments and private ventures lack certainty on the scope and applicability of the space treaties. For example, it will become increasingly difficult to balance a clear commitment toward peaceful and shared access to space resources, with state actors considering space a likely new theater of warfare, locus for colonization and assertion of sovereign control, and potential source of ample tax revenues.

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[83] *See* Alec Fante, *Who Is Manning the Ship? The Environmental and Legal Questions Facing the Emerging Commercial Space Tourism Market*, 34 Vill. Envtl. L.J. 33 (2023); https://digitalcommons.law.villanova.edu/cgi/viewcontent.cgi?article=1463&context=elj.

[84] *See* W. Spencer Haywood, *Commercial Space Mining Within the Framework of the Outer Space Treaty: Vexing Issue Or Simple Solution?*, 62 U. Louisville L. Rev. 813 (Summer, 2024); https://uofllawreview.org/forthcoming; James McSweeney, *Live Long and Prosper: The Need for a New Multilateral Agreement Governing Asteroid Mining*, 58 U. Louisville L. Rev. 559, 572-73 (2020); https://heinonline.org/HOL/LandingPage?handle=hein.journals/branlaj58&div=31&id=&page=; Samuel Roth, *Developing a Law of Asteroids: Constants, Variables, and Alternatives*, 54 Colum. J. Transnat'l L. 827, 831-33 (2016); https://heinonline.org/HOL/LandingPage?handle=hein.journals/cjtl54&div=23&id=&page=.

3. Slow and Contentious ITU Consensus Building on Spectrum Allocations and Satellite Orbital Locations

Founded in 1865, the ITU holds the longevity record among intergovernmental organizations now affiliated with the UN. [85] It has a broad mandate to manage the global use of radio spectrum by allocating frequency bands, ensuring that operators avoid causing signal interference, and registering a nation's satellite orbital slot and spectrum uses. [86] The ITU has earned a favorable reputation for lending its "good offices" to reach global consensus on spectrum and satellite issues, albeit one that can take years to complete. [87]

As radio technology has evolved, the ITU has made new and revised spectrum allocations to accommodate technologies supporting aviation, astronomy, broadcasting, fixed and mobile services to users in the air, seas, and land, navigation, remote sensing, satellite tracking, space exploration, and weather observation. It also identifies different orbital locations [88] that satellites

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[85] International Telecommunication Union, *Discover ITU's History*; https://www.itu.int/en/history/Pages/DiscoverITUsHistory.aspx.

[86] International Telecommunication Union Radio *Regulatory Framework for Space Services*; https://www.itu.int/en/ITU-R/space/snl/Documents/ITU-Space_reg.pdf; *Spectrum management*; https://www.itu.int/pub/R-REP-SM.

[87] Kristen Cordell, *The International Telecommunication Union: The Most Important UN Agency You Have Never Heard Of*, Center for Strategic and International Studies (Dec. 14, 2020); from: https://www.csis.org/analysis/international-telecommunication-union-most-important-un-agency-you-have-never-heard; Gabriele Balbi & Andreas Fickers, eds., *History of the International Telecommunication Union (ITU)* (2020); https://www.degruyter.com/document/doi/10.1515/9783110669701/html; George A. Codding Jr., *Evolution of the ITU*, 15 Telecomm. Pol'y 271 (Aug.1991); https://www.sciencedirect.com/science/article/pii/030859619190050L.

[88] International Telecommunication Union, *Regulation of satellite systems*; https://www.itu.int/en/mediacentre/backgrounders/Pages/Regulation-of-Satellite-Systems.aspx; Yvon Henri, International Telecommunication Union, *Orbit Spectrum Allocation Procedures ITU Registration Mechanism* (2008); https://www.itu.int/en/ITU-R/space/symposiumWroclaw2008/Wroclaw_YH.pdf.

can use. Additionally, operational rules establish regulatory protection for priority services even if activated after the launch of satellite offering a lower priority service. Carriers providing secondary services might have to transmit with lower power, or use different frequencies to ensure that they do not interfere with operators providing a priority service. [89] The ITU also requires coordination between existing and prospective satellite operators to ensure that satellites in different orbits do not increase the potential for interference, or collision. [90]

The customary course of spectrum planning and management at the ITU involves a sequence of activities: 1) development of an agenda of new allocations and reallocations, first subject to study and analysis; 2) opportunities for national delegations to articulate their position; 3) consensus building and development of national commitments, to reduce the number of non-conforming footnotes to specific spectrum allocations by individual nations; 4) formal designation of frequency allocations for one or more specific services by the ITU and individual nations; and 5) the eventual registration of radio spectrum uses and satellite orbital locations by the ITU.

Currently, the ITU convenes month long spectrum and space resource planning conferences every fourth year. [91] Typically, final decisions on major issues occur only after two or more World Radiocommunication Conferences ("WRCs") have convened, because the ITU

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[89] International Telecommunication Union, Frequently Asked Questions, International Frequency Management; https://www.itu.int/net/ITU-R/terrestrial/faq/index.html#i001.

[90] Timur Kadyrov, International Telecommunication Union, *Non-geostationary satellite systems and networks* (2020); https://www.itu.int/en/ITU-R/space/WRS20space/27%20Non-geostationary%20satellite%20systems%20and%20networks.pdf.

[91] International Telecommunication Union, *World Radiocommunication Conferences (WRC)*; https://www.itu.int/en/ITU-R/conferences/wrc/Pages/default.aspx.

seeks consensus among all stakeholders. The potential for delay in reaching closure increases when conference delegates raise concerns newly addressed by the ITU, but not directly related to its management of spectrum and satellites. [92] New and controversial topics include national security vulnerability of domestic telecommunications networks to espionage and disruption by foreign governments and their commercial agents, [93] Internet governance, [94] and more aggressive assertion of national sovereignty. [95]

B. Emerging Challenges

1) The Tragedy of the Commons and Kessler Syndrome from Congestion and Proliferating Space Debris

Spacefaring nations and private ventures conceptually understand the societal benefits accruing from coordinated, shared use of such scarce resources, such as geostationary satellite

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[92] International Telecommunication Union, *ITU Cybersecurity Activities*; https://www.itu.int/en/action/cybersecurity/Pages/default.aspx; *Key Areas of Action*; https://www.itu.int/en/action/Pages/default.aspx.

[93] *See, e.g.*, United States Cybersecurity and Infrastructure Security Agency, *Cyber Threats and Advisories*; https://www.cisa.gov/topics/cyber-threats-and-advisories; Federal Communications Commission, *National Security and Emergency Preparedness Content*,; https://www.fcc.gov/tags/national-security-and-emergency-preparedness; United States Senate, Committee on Homeland Security and Governmental Affairs, *Threats to U.S. Networks: Oversight of Chinese Government-Owned Carriers* (2020); https://www.govinfo.gov/content/pkg/GOVPUB-Y4_G74_9-PURL-gpo142492/pdf/GOVPUB-Y4_G74_9-PURL-gpo142492.pdf.

[94] International Telecommunication Union, *Internet Policy and Governance*; https://www.itu.int/en/action/internet/Pages/default.aspx; *Internet Governance*; https://academy.itu.int/itu-d/projects-activities/capacity-development-topics/internet-governance.

[95] See Monika U. Ehrman, *Property, Sovereignty, and Customary Governance in Outer Space Resource Extraction*, 57 Ga. L. Rev. 1769 (2023); https://georgialawreview.org/article/84236-property-sovereignty-and-customary-governance-in-outer-space-resource-extraction/stats/all/pageviews; Josselin Lavigne, *The Political Sovereignty of a Colony in Outer Space*, 48 N.C. J. Int'l L. 147 (2022); https://heinonline.org/HOL/LandingPage?handle=hein.journals/ncjint48&div=7&id=&page=.

orbital slots and the angles (planes) at which LEO satellites travel. However, each operator has an incentive to maximize individual benefits, leaving others to conserve and refrain from overconsumption. If too many satellite operators opt to serve individual interests, everyone will suffer when the risk of signal interference and collision reaches an unmanageable tipping point.

The term tragedy of the commons [96] describes how self-serving, individual use of a shared resource generates overconsumption eventually leading to depletion and possibly complete ruin. For example, if a government offers public land for cattle grazing at little or no expense, each rancher has an incentive to increase the number of animals consuming vegetation, an exhaustible, shared resource. At some point, overgrazing depletes the soil and the entire flock of cattle risks starvation.

Users of space resources risk a similar calamity from overconsumption and wasteful generation of space debris. The Kessler Syndrome refers to the worst-case scenario when the launching of too many satellites and other space objects, results in radio signal interference, an unmanageable risk of space vehicle collisions, and the proliferation of debris generated by the failure of space operators to engage in necessary disposal of no longer useful satellites and other space objects. [97] By abandoning space objects instead of recycling, or relocating then farther out

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[96] "Space is considered a global common, so the [Outer Space Treaty] prescribes international rights and obligations in accordance to a shared interest in peace, security, and cooperation. These mutual obligations are intended to mitigate the tragedy of commons--an accelerated depletion of shared resources--without minimizing any individual's ability to exploit the resources." John Thurston, *Make "Space" For Innovation*, 2023 B.C. Intell. Prop. & Tech. F. 1,3; https://sites.bc.edu/iptf/2022/02/22/make-space-for-innovation/.

[97] Mike Wall, *Kessler Syndrome and the space debris problem*. Space.com. (July 14, 2022); https://www.space.com/kessler-syndrome-space-debris; Richard L. Hermer-Fried, "*Kessler Syndrome: A United States' Statutory Solution for Satellite Debris*, 18 J. Int'l Bus. & L. 259 (2019); https://scholarlycommons.law.hofstra.edu/jibl/vol18/iss2/9/.

in space, or vaporized on its way back to earth, users of space resources create a potential catastrophic environmental hazard. [98] Space debris proliferation raises the operating costs of every spacefaring nation and business by increasing the risk that an operational and valuable object, like a multi-million-dollar satellite, may collide with an equally valuable asset, or more likely, become inoperable and a total financial loss due to its collision with an abandoned and worthless object still orbiting in space.

Even tiny pieces of space debris have tremendous destructive power, that can render vast portions of outer space unusable. The region where LEO satellites operate has the greatest potential for further commercial development, but also the largest deployment of satellites, as well as the most abandoned space objects, such as used, but not retrieved, rocket launch stages. With so many space objects located in a relatively small portion of space, the possibility of collisions grows as does the potential for even more space debris. [99]

While there have been few collisions heretofore, the vast increase in the number of orbiting satellites and trackable space debris already has triggered many close calls, [100] including the execution of emergency collision avoidance procedures at both currently orbiting space

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[98] Michael B. Runnels, *On Launching Environmental Law into Orbit in the Age of Satellite Constellations*. 88 J. Air L. & Com. 181 (2023); https://scholar.smu.edu/jalc/vol88/iss1/5.

[99] Makena Young & Akhil Thadani, *Low Orbit, High Stakes*, Center for Strategic and International Studies (Dec. 2022); https://aerospace.csis.org/wp-content/uploads/2023/02/221214_Young_LowOrbit_HighStakes-min.pdf.

[100] Sara Webb, Brett Carter, B., & Christopher Fluke, *Space is getting crowded with satellites and space junk. How do we avoid collisions?*. The Conversation (Oct. 19, 2023); https://theconversation.com/space-is-getting-crowded-with-satellites-and-space-junk-how-do-we-avoid-collisions-215545; Raffi Khatchadourian, *The Elusive Peril of Space Junk*, The New Yorker (Sep. 21, 2020); https://www.newyorker.com/magazine/2020/09/28/the-elusive-peril-of-space-junk.

stations. [101] Anticipating the possibility that two SpaceX satellites might collide with its space station, the Chinese government submitted an informal complaint to the United Nations, [102], even though this nation has generated extensive space debris in tests of its ASAT weaponry. In 2023, a 23-ton Chinese launch vehicle reentered the earth's atmosphere without an accurate forecast of where intact portions would arrive on earth. [103]

2) Space as a New Theater of War—Anti-Satellite Weaponry

Arguably, ASAT testing in space [104] currently constitutes the most egregious and avoidable human threat to space commerce, because of the vastly more space debris occurring

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[101] Elizabeth Howell, *How often does the International Space Station have to dodge space debris?*. Space.com (March 13, 2023); https://www.space.com/international-space-station-space-dodge-debris-how-often; Kiona Smith, *Space is increasingly hazardous — here's how NASA dodges deadly debris*, Inverse.com (Nov. 1, 2022); https://www.inverse.com/science/evasive-action-how-the-iss-deals-with-space-debris; National Aeronautics & Space Administration, *NASA Administrator Statement on Russian ASAT Test* (Nov. 15, 2021); https://www.nasa.gov/news-release/nasa-administrator-statement-on-russian-asat-test/#:~:text=%E2%80%9CAll%20nations%20have%20a%20responsibility,of%20our%20crew%20in%20orbit.%E2%80%9D.

[102] Permanent Mission of China to the United Nations (Vienna) (2021). *Note verbale dated 3 December 2021*; https://www.unoosa.org/res/oosadoc/data/documents/2021/aac_105/aac_1051262_0_html/AAC105_1262E.pdf.

[103] Kenneth Chang, *China Lucks Out Again as Out-of-Control Rocket Booster Falls in the Pacific*, The New York Times (Nov. 5 2022); https://www.nytimes.com/2022/11/04/science/china-rocket-debris.html; Brett Tingley, *Whew! 23-ton Chinese rocket debris falls to Earth over Pacific Ocean* (Nov. 4, 2022); https://www.space.com/china-long-march-5b-rocket-falls-into-pacific-ocean.

[104] Secure World Foundation, *Anti-Satellite Weapons Threatening the Sustainability of Space Activities* (May 2022); https://swfound.org/media/207392/swf-asat-testing-infographic-may2022.pdf, *See also*, Secure World Foundation, *Space Sustainability: A Practical Guide* (2018);https://swfound.org/media/206407/swf_space_sustainability_booklet_2018_web.pdf.

when testers fail to use techniques that can reduce or eliminate residue. [105] China, [106] India, [107] Russia, [108]and the U.S. [109] have contributed to space debris proliferation when testing anti-satellite technology. A single test, lacking space debris prevention or mitigation, can result in thousands more objects requiring constant monitoring. For example, using an earth-based ASAT weapon in 2021, Russia generated 1500 pieces of trackable debris, 10 centimeters in diameter or larger, when it only partially destroyed one of its no longer operational satellites. [110] The test

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[105] Kari A. Bingen, Kaitlyn Johnson, Makena Young, & John Raymond, *Space Threat Assessment 2023*, Center for Strategic and International Studies (April 14, 2023); https://www.csis.org/analysis/space-threat-assessment-2023; Secure World Foundation, *SWF Releases 2023 Fact Sheets on Anti-Satellite Testing, Military and Intelligence RPOs, and the X-37B* (July 11, 2023); https://swfound.org/news/all-news/2023/07/counterspace-fact-sheets-2023.

[106] Brian Weeden, *Chinese Direct Ascent Anti-Satellite Testing*, Secure World Foundation (July, 2023); https://swfound.org/media/207604/fs23-01_chinese-da-asat-testing_0723.pdf. "In 2007, China performed a successful anti-satellite (ASAT) test and destroyed an aging weather satellite at an altitude of some five hundred miles. This event contributed more than 35,000 pieces of space debris, increasing at a stroke the amount of total orbital space debris by approximately twenty-five percent." Scott J. Shackelford, *Governing the Final Frontier: A Polycentric Approach to Managing Space Weaponization and Debris*, 51 Am. Bus. L.J. 429 (Summer, 2014)(citations omitted); https://doi.org/10.1111/ablj.12031.

[107] Brian Weeden, *Indian Direct Ascent Anti-Satellite Testing*, Secure World Foundation (July, 2023); https://swfound.org/media/207606/fs23-03_indian-da-asat-testing_0723.pdf.

[108] Brian Weeden, *Russian Direct Ascent Anti-Satellite Testing*, Secure World Foundation (July, 2023); https://swfound.org/media/207607/fs23-04_russian-da-asat-testing_0723.pdf; *Russian Co-Orbital Anti-Satellite Testing*, Secure World Foundation (July, 2023); https://swfound.org/media/207608/fs23-05_russian-co-orbital-asat-testing_0723.pdf.

[109] Brian Weeden, *U.S. Direct Ascent Anti-Satellite Testing*, Secure World Foundation (July, 2023); https://swfound.org/media/207610/fs23-07_us-da-asat-testing_0723.pdf; *U.S. Co-Orbital Anti-Satellite Testing*, Secure World Foundation (July, 2023); https://swfound.org/media/207611/fs23-08_us-co-orbital-asat-testing_0723.pdf.

[110] Wendy Whitman Cobb, *Russian anti-satellite weapon test: What happened and what are the risks?*, The Conversation (Nov. 16, 2021); https://theconversation.com/russian-anti-satellite-weapon-test-what-happened-and-what-are-the-risks-172016; United States Space Command, *Russian direct-ascent anti-satellite missile test creates significant, long-lasting space debris*

occurred just 48 miles above the International Space Station, which had two Russian cosmonauts onboard, triggering the execution of emergency avoidance maneuvers. [111]

The European Space Agency ("ESA") estimates that as of September 2023, 35,030 debris objects require ongoing tracking to assess the potential for future collisions. [112] 640 objects were created during break-ups, explosions, collisions, or anomalous events resulting in fragmentation, and over 11,000 tons of abandoned space objects remain in orbit. Even a tiny particle has the potential to cause harm when striking a satellite or other valuable orbiting object. Space debris travels at speeds ten times faster than gunshot bullets. [113]

ASAT-generated space debris significantly increases the likelihood that two space objects will collide. The domino effect of increasing space debris can render parts of space not worth the risk of investment considering the potential for total financial loss. Bear in mind that when a collision occurs, a cascade of even more debris surely follows, particularly when the responsible party incurs no duty to compensate the harmed party. For example, in February 2009, the defunct Russian Kosmos 2251 satellite slammed into an operational communications small

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(Nov. 15, 2021); https://www.spacecom.mil/Newsroom/News/Article-Display/Article/2842957/russian-direct-ascent-anti-satellite-missile-test-creates-significant-long-last/; Antony J. Blinken, Secretary of State, *Russia Conducts Destructive Anti-Satellite Missile Test* (Nov. 15, 2021); https://www.state.gov/russia-conducts-destructive-anti-satellite-missile-test/.

[111] Shannon Bugos, *Russian ASAT Test Creates Massive Debris*, Arms Control. Assn. (Dec. 2021); https://www.armscontrol.org/act/2021-12/news/russian-asat-test-creates-massive-debris.

[112] European Space Agency, *Space debris by the numbers* (Dec. 6, 2023); https://www.esa.int/Space_Safety/Space_Debris/Space_debris_by_the_numbers.

[113] National Aeronautics & Space Administration, NASA Orbital Debris Program Office *Frequently Asked Questions, How fast is orbital debris traveling?*; https://orbitaldebris.jsc.nasa.gov/faq/#.

satellite operated by Iridium, a commercial venture providing voice and data service via LEO satellites. [114] The Russian government offered no compensation for ruining a working commercial asset, and the collision created an estimated 2000 additional debris objects, the size of a softball or larger. [115]

There is only one reported instance where a party agreed to pay financial compensation for harmful consequences of space activity. Without acknowledging any treaty-imposed responsibility, Russia paid 3 million Canadian dollars to the government of Canada after portions of the Cosmos 954 reconnaissance satellite failed to vaporize upon re-entry into the earth's atmosphere in 1978. [116] The Russian space debris scattered highly radioactive material along a 370-mile-expanse of northern Canada.

Knowledgeable analysts assert that space debris mitigation must begin now to foreclose costly future collisions of valuable spacecraft, particularly in light of the tens of thousands additional LEO satellites needed for global broadband networks, like Starlink: "Most likely the time scale for the collisional cascade is measured in years to decades, not hours or days—but the

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[114] Brian Weeden, *2009 Iridium-Cosmos Collision Fact Sheet*, Secure World Foundation (Nov. 10, 2010); https://swfound.org/media/6575/swf_iridium_cosmos_collision_fact_sheet_updated_2012.pdf. *See also*, David Wright, *Colliding Satellites: Consequences and Implications*, Union of Concerned Scientists (Feb. 26, 2009); https://www.ucsusa.org/sites/default/files/2019-10/SatelliteCollision-2-12-09.pdf.

[115] Frans G. von der Dunk, Too-Close Encounters of the Third Party Kind: Will the Liability Convention Stand the Test of the Cosmos 2251-Iridium 33 Collision?, University of Nebraska College of Law, Space, Cyber, and Telecommunications Law Program Faculty Publications, 28. (2010); https://digitalcommons.unl.edu/spacelaw/28.

[116] Tereza Pultarova, *Can SpaceX's Starlink sue Russia for anti-satellite missile test space debris fallout?*, Space.com (Nov. 30, 2021); https://www.space.com/spacex-starlink-russia-anti-satellite-test-legal.

addition of all of those new satellites and constellations make studying that possibility extremely important." [117]

Without effective end of life disposal of spacecraft, the following scenario appears likely:

> In the most probable scenario, fragments will initially collide with large, intact objects. Then, the resulting collision fragments will start to collide with other large, intact objects, and so on, and ultimately collision fragments will collide with collision fragments until all remaining objects are reduced to subcritical sizes.
>
> This run-away, self-sustained, cascading collision process is most likely to commence at altitudes having high debris population densities and insufficient cleansing by air drag, which would be around 900 km and 1400 km. [118]

3) Space Resource Exploitation for National and Private Gain, e.g., Colonization of the Moon/Mars and Asteroid Mining

Consistent with its characterization as a frontier, a gold rush urgency has encouraged entrepreneurs [119] to pursue a variety of commercial business plans that might previously have been dismissed as science fiction fantasy. Three of the world's richest and newsworthy individuals already have invested millions of dollars in LEO satellite networks and new launch vehicles. Along with others, they contemplate the future development of new commercial

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[117] Norton A. Schwartz, Joel E. Williamsen, James F. Heagy, & Rhett A. Moeller, *Orbital Debris and Kinetic Anti-satellite Concerns: How a "Kessler Syndrome" Threatens U.S. Use of Space Assets*, Institute for Defense Analyses, 7 (2021); https://www.jstor.org/stable/resrep30922.

[118] European Space Agency, *Frequently Asked Questions, What is the Kessler Syndrome, and how can it be avoided?* (April, 2021); https://www.esa.int/Space_Safety/Space_Debris/FAQ_Frequently_asked_questions.

[119] Kelsey Eyanson, *Billionaires Eclipse NASA: The Next Space Race Over National Regulation*, 60 Hous. L. Rev. 1181 (2023); https://houstonlawreview.org/article/77720-billionaires-eclipse-nasa-the-next-space-race-over-national-regulation.

markets for space tourism, extraction of valuable minerals, and colonization of the Moon and Mars.

Commercialization of space can coexist with the spirit and constraints established in the space treaties. However, the potential for conflict and overreach constitutes a legitimate concern. On one hand, there are examples on earth where private appropriation of a shared natural resource complies with international law. Private ventures, operating in international waters, can acquire fish, abandoned treasure, and oil, gas, and minerals in full compliance with applicable treaties. On the other hand, we cannot ignore the incentive of first movers to foreclose others from sharing access. One nation's peaceful creation of an outpost on the Moon for exploration and discovery in practice could transition into the assertion of sovereign control and ownership.

Currently, one can only speculate how national governments and private ventures will behave. It does appear that the space treaties and applicable international law do not fully establish the rights, responsibilities, options, and limitations applicable when governments and private ventures seek to extract value from shared space resources. The UN cannot expect all nations to comply with a voluntary moratorium on space ASAT testing, exploration, and resource extraction [120] pending enactment of new, or significantly modified treaties. Already, the U.S. championed Artemis Accords seeks to establish a baseline for what governments and

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[120] *See* United Nations, Resolution adopted by the General Assembly on 7 December 2022, *Destructive direct-ascent anti-satellite missile testing*, A/RES/77/41; https://www.undocs.org/Home/Mobile?FinalSymbol=A%2FRES%2F77%2F41&Language=E&DeviceType=Desktop&LangRequested=False (non-binding moratorium proposal passed on a vote of 155 nations in favor, 9 opposed, and 9 abstaining); Ching Wei Sooi, *Direct-Ascent AntiSatellite Missile Tests: State Positions on the Moratorium, UNGA Resolution, and Lessons for the Future*, Secure World Foundation (Oct. 2023); https://swfound.org/media/207711/direct-ascent-antisatellite-missile-tests_state-positions-on-the-moratorium-unga-resolution-and-lessons-for-the-future.pdf; Secure World Foundation, *Multilateral Space Security Initiatives*; https://swfound.org/multilateral-space-security-initiatives/.

private actors can do in a commercialized space marketplace. Uncertainty about whether and how international law applies to new circumstances can create a disincentive for investment and risk-taking, [121] but also motivate some entrepreneurs to jumpstart commercial operation before the onset of regulatory rules and limitations.

V. The Way Forward

Despite much uncertainty about how space markets will evolve, several issues already require resolution to provide clarity about best practices pertaining to existing and emerging conflicts. Set out below are recommendations on how the UN, ITU, and individual governments can promote robust and globally beneficial space commerce.

A. Timely Revisions to the Space Treaties

The space treaties came into force during the period from the middle 1960s to the late 1970s. They require substantial updating to reflect substantially changed circumstances, [122] highlighted by the commercialization and development of new space market segments by private ventures, an increase in the number of spacefaring nations and enterprises, and proliferating space debris with no mandate for compulsory disposal and mitigation. These challenges require affirmative and enforceable duties of care by signatory nations and commercial ventures, not a general appeal to their better nature. [123]

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[121] Matthew T. Smith, *One Small Plot for a Man, or One Giant Easement for Mankind?: A New Approach to the Outer Space Treaty's Property for Mankind Principle*, Ill. L. Rev. 1361 (2020); https://illinoislawrev.web.illinois.edu/wp-content/uploads/2020/08/Smith.pdf.

[122] Diane M. Janosek, *Innovative Thinking: Modernizing Outer Space Governance*, 29 Cath. U. J. L. & Tech 63 (2021); https://scholarship.law.edu/jlt/vol29/iss2/5/.

[123] Gershon Hasin, *From "Space Law" to "Space Governance": A Policy-Oriented Perspective on International Law and Outer Space Activities*, 64 Harv. Int'l L.J. 385 (Spring, 2023); https://journals.law.harvard.edu/ilj/wp-content/uploads/sites/84/HLI205_crop-4.pdf.

1) Recognition of Private, Non-State Actors

Private space market entrants deserve recognition in the space treaties with conferral of specific rights and responsibilities. [124] Transactions often involve multiple participants, including one or more national governments, private ventures, and/or public-private partnerships. For example, an operating satellite might have different parties involved in the financing, launch, ownership, operational management, license acquisition, and regulatory compliance. Currently, the space treaties confer rights and responsibilities on "State Parties," which have acceded to the agreement, with emphasis on the who launched or procuring the launch of a space object:

> Each State Party to the Treaty that launches or procures the launching of an object into outer space, including the moon and other celestial bodies, and each State Party from whose territory or facility an object is launched, is internationally liable for damage to another State Party to the Treaty or to its natural or juridical persons by such object or its component parts on the Earth, in air or in outer space, including the moon and other celestial bodies. [125]

The space treaties should explicitly recognize private ventures operating in space by conferring rights and responsibilities previously applied only to national governments. If a private venture's owned and operated space object collides with and damages another space

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[124] *See* Akshaya Kamalnath & Hitoishi Sarkara, *Regulation of Corporate Activity in the Space Sector*, 62 Santa Clara L. Rev. 375 (2022); https://digitalcommons.law.scu.edu/cgi/viewcontent.cgi?article=2935&context=lawreview;

Christina Isnardi, *Problems With Enforcing International Space Law on Private Actors*, 58 Colum. J. Transnat'l L. 489 (2020); https://heinonline.org/HOL/LandingPage?handle=hein.journals/cjtl58&div=14&id=&page=.

[125] United Nations, Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies, Article VII; https://www.unoosa.org/oosa/en/ourwork/spacelaw/treaties/introouterspacetreaty.html.

object, the private venture specifically should bear financial responsibility to compensate the harmed public or private entity for damages.

2) Treaty Enforceability

The space treaties create affirmative responsibilities on signatory nations, but impose no sanctions for noncompliance. Because the consequences will substantially rise when nations fail to comply with treaty responsibilities, the space treaties should be amended to sanction noncompliance. For example, a nation, or private party, deemed responsible for damages caused by a collision of space objects should lose the rights conferred by the applicable treaty until such time as it accepts responsibility and satisfactorily compensates the harmed party. The space treaties also should establish a mechanism for dispute resolution through an adjudication or binding arbitration process.

3) Monetary Commitments to, and Bounties for Debris Prevention, Mitigation, Collection, and Disposal

Ideally, public and private ventures owning and operating space objects, such as satellites, should incur the responsibility to deposit funds into an account that could be tapped to compensate a party harmed by a collision or impact from space debris abandoned by a known party. [126] Such an escrow account also could provide a bounty for ventures that collect and recycle or properly dispose of space debris. It already has become clear that a public or private partty clearly responsible for causing a collision may not voluntarily compensate the harmed party, despite uncontestable evidence of culpability. Currently, the space treaties lack an

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[126] Arpit Gupta, *Regulating Space Debris as Separate from Space Objects Authors*, 41 U. Pa. J. Int'l L. 223 (2019); https://scholarship.law.upenn.edu/jil/vol41/iss1/6; Chelsea Muñoz-Patchen, *Regulating the Space Commons: Treating Space Debris as Abandoned Property in Violation of the Outer Space Treaty*, 19 Chi. J, Int'l L. 233 (Summer, 2018); https://chicagounbound.uchicago.edu/cjil/vol19/iss1/7.

enforcement mechanism when a private or public entity refuses to accept responsibility and compensate the harmed party.

For commercial space markets to operate smoothly and efficiently, participants need uniform rules of the road, including binding laws and treaties. Private insurance options [127] probably would become prohibitively expensive if collisions increase and market participants cannot rely on the space treaties to establish compulsory procedures for resolving disputes with guaranteed financial compensation flowing to harmed parties.

The space treaties should clarify that spacefaring nations and private ventures have a duty to dispose of objects, rather than abandon them wherever they happen to be. National regulatory authorities, such as the FCC, now require licensees to eject geosynchronous satellites, reaching end of life, into locations at or beyond a specified distance from their original orbital location. The FCC also requires operators of LEO satellites to eject them from orbit within five years of their completed missions so that they vaporize rather than become more space debris. [128]

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[127] Swiss Re, *Space Debris: On a Collision Course with Insurers?*(2011); https://www.swissre.com/dam/jcr:b359fb24-857a-412a-ae5c-72cdff0eaa94/Publ11_Space+debris.pdf; Benjamin L. S. Ritz, *Splash and Crash: Satellite Liability and Insurance*, 59 Hous. Law. 24 (Nov./Dec. 2021); https://issuu.com/leosur/docs/thl_novdec21.

[128] Federal Communications Commission, Space Innovation, IB Docket No. 22-271, Mitigation of Orbital Debris in the New Space Age, IB Docket No. 18-313, Second Report and Order, 37 FCC Rcd. 11818 (Sep. 30, 2022); https://docs.fcc.gov/public/attachments/FCC-22-74A1_Rcd.pdf; *See also*, Mitigation of Orbital Debris in the New Space Age, IB Docket No. 18-313, Order On Reconsideration, FCC 24-6 (Jan. 26, 2024); https://docs.fcc.gov/public/attachments/FCC-24-6A1.pdf; Orbital Debris; https://www.fcc.gov/space/orbital-debris.

Additionally, spacecraft launching parties should bear an obligation to ensure that booster stages and other parts are removed from orbit, or recycled. SpaceX already uses maneuvers to return launch boosters back to earth for refurbishment and reuse.

4) Curbing Weaponization of Space Conflicts with Reaffirmation of Treaty-level Commitments to Peaceful and Shared Uses

Ever growing deployment of satellites into space creates rising incentives to devise ways to disable and destroy them during times of war. Weaponization of space has started with the testing of ASAT technologies from both earth-based and in-orbit tactics. These weapons can target military, surveillance, commercial, and other networks that provide essential infrastructure supporting both national security and private welfare. Some national governments appear unwilling to abandon testing and use of space weaponry, despite having previously committed to the peaceful use and shared access to space resources. For example, in 2023 and 2024, Russia launched two satellites that appear to have nuclear ASAT weaponry and the ability to maneuver and attack multiple targets. [129]

Notwithstanding the weaponization of space, national governments should reemphasize that space activities must serve peaceful purposes. Most nations may never become spacefaring.

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[129] Joshua Keating, *How worried should we be about Russia putting a nuke in space?* Vox (May 22, 2024); https://www.vox.com/world-politics/350663/russia-space-nuke-satellite-weapon-putin; Madison Minges, *US National Security and a Rumored Russian Space Weapon*, American University School of International Service (March 6, 2024); https://www.american.edu/sis/news/20230306-us-national-security-and-a-rumored-russian-space-weapon.cfm; Aaron Bateman, *Why Russia Might Put a Nuclear Weapon in Space*, Foreign Affairs (March 7, 2024); https://www.foreignaffairs.com/russian-federation/why-russia-might-put-nuclear-weapon-space; Atlantic Council, *Experts react: What to know about Russia's apparent plans for a space-based nuclear weapon* (Feb. 15, 2024); https://www.atlanticcouncil.org/blogs/new-atlanticist/experts-react-what-to-know-about-russias-apparent-plans-for-a-space-based-nuclear-weapon/.

Even though these countries do not directly tap space resources, their residents benefit when public and private operators provide services that enhance public and individual welfare.

Arguably, everyone benefits when space continues to provide a safe location for mission critical and commercial services. Satellite networks can provide services cheaper and more widely available services compared to terrestrial options for widely dispersed users located in remote areas. For residents in these localities, commercial operators cannot make a business case for installing a terrestrial digital telecommunications network, using fiber optics lines and wireless cellular radio towers. Instead, carriers provide global access to video programming, broadband access to the Internet, and mission critical disaster recovery using satellites that can simultaneously serve a larger subscriber base anywhere within a wide signal coverage area.

Spiraling toward the Kessler Syndrome threatens a substantial decline in the global economy and individual wellbeing. Accordingly, the nations of the world should reaffirm that space is too precious to be ruined by the proliferation of debris and other unilateral and harmful activities of individual nations. Fundamental fairness requires nations, first able to tap new market opportunities, do not render access impossible, limited, or more expensive for other nations.

5) Clarity in Mission and Better Coordination of Responsibilities Between the U.N. and ITU

Considering the growing importance of space markets, a remedy for current problems could entail the creation of a new expert international regulatory authority serving as a “one stop shop” with a broad wingspan of responsibilities and enforcement powers. Considering the many types of services offered by satellites, practical and political limitations do not support the creation of a new intergovernmental agency, even one having the necessary broad range of expertise. For several reasons, outlined below, a far better course lies in clarifying and updating

the space treaties, coupled with better specification of UN and ITU responsibilities, and improved coordination.

Space commerce does not lend itself to oversight by a single intergovernmental agency and national regulatory authority. While digital service provided via satellite carriers constitutes one of the most promising and problem laden areas, many market segments involve tangible assets such as launch vehicles and space objects offering services not traditionally regulated by telecommunications authorities, such as the FCC. In the U.S., the following federal, Executive Branch agencies have sector-specific regulatory authority: the Bureau of Industry and Security, within the Department of Commerce, manages the Commercial Control List, specifying categories and product groups requiring an export license; the Office of Commercial Space Transportation, Federal Aviation Agency, Department of Transportation, regulates commercial spaceflight; the Directorate of Defense Trade Controls, Bureau of Political-Military Affairs, State Department, issues licenses for export of space equipment deemed compliant with the International Traffic in Arms Regulations; and the Office of the Deputy Assistant Secretary of Defense for Space Policy, Department of Defense, implements strategic guidance and national security space strategy. [130]

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[130] Space Foundation, *Space Oversight and Regulatory Bodies*; https://www.spacefoundation.org/space_brief/space-oversight-regulatory-bodies/; Georgetown Law Library, *Other U.S. Government Agencies Involved in Space Policy & Regulation* (2020); https://guides.ll.georgetown.edu/c.php?g=1037047&p=7762102. *See also*, Clementine G. Starling, Mark J. Massa, Lt Col Christopher P. Mulder, & Julia T. Siegel, *The future of security in space: A thirty-year US strategy*, Atlantic Council (April 11, 2021); https://www.atlanticcouncil.org/content-series/atlantic-council-strategy-paper-series/the-future-of-security-in-space/.

Additionally, the Defense Department has several other agencies involved in national security space activities, [131] and NASA has responsibility for U.S. space exploration, space technology, Earth and space science, and aeronautics research. [132] Several other agencies participate in assessing the risks to national security triggered by telecommunications services and commercial activities provided by ventures with significant foreign ownership. [133]

On the global, inter-governmental level, the UN and ITU share jurisdiction with the former responsible for administering the space treaties and registering all launched space objects and the later handling spectrum allocation and registration of radio licenses and orbital slot assignments made by national regulatory authorities. This division of labor becomes murky on emerging problems, such as the proliferation of space debris, because more proactive and comprehensive oversight is needed to augment the perfunctory and passive registration process. Both organizations have undertaken serious examination of the space debris problem and have

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131 Space Foundation, *National Security Space Agencies*; https://www.spacefoundation.org/space_brief/national-security-space-agencies/.

132 National Aeronautics & Space Administration, *NASA Missions*; https://www.nasa.gov/nasa-missions/.

133 *See* United States, Dept. of Justice. Team Telecom; https://www.justice.gov/nsd/team-telecom.

identified best practices for prevention, mitigation, and disposal [134] Additionally, a few national space agencies have created a forum for multi-lateral consultation and policy coordination. [135]

Stakeholder engagement on such matters as space debris mitigation and ASAT testing requires much more than further study. Both agencies should more aggressively seek amendments to space resource management treaties. Notwithstanding their comprehensive and conscientious efforts, the UN, ITU, and national space agencies, individually and collectively, have failed to achieve progress in finding ways to foreclose a cascade toward the Kessler's Syndrome tragedy of the commons.

Without "skin in the game," financial responsibilities, parties launching and operating space objects will not have sufficient incentives to mitigate space debris. [136] Having money at

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[134] *See, e.g.*, United Nations, Office For Outer Space Affairs, Space Debris Mitigation Guidelines of the Committee on the Peaceful Uses of Outer Space (2010); https://www.unoosa.org/pdf/publications/st_space_49E.pdf; Committee on the Peaceful Uses of Outer Space (COPUOS): Space Debris Mitigation Guidelines (Dec. 2007); https://www.unoosa.org/documents/pdf/spacelaw/sd/COPUOS.pdf; Space Debris; https://www.unoosa.org/oosa/en/ourwork/topics/space-debris/index.html; International Telecommunications Union (ITU): Recommendation Itu-R S.1003.2, *Environmental protection of the geostationary-satellite orbit* (2013); https://www.itu.int/rec/R-REC-S.1003-2-201012-I/en; Véronique Glaude & Cessy Karina, *Synergies for outer space sustainability: Lessons from ITU experiences*, International Telecommunication Union (Oct. 22, 2022); https://www.itu.int/hub/2022/10/space-sustainability-synergies/.

[135] *See, e.g.*, Inter-Agency Space Debris Coordination Committee https://iadc-home.org/what_iadc.

[136] United Nations, Office of Outer Space Affairs, *Catalyzing Space Debris Removal, Salvage, & Use via Maritime Lessons & a Space Salave Entity* (2021); https://www.unoosa.org/documents/pdf/copuos/lsc/2021/tech-03E.pdf; Lyndsey Gray, *Taking Out The Space Trash: Creating An Advanced Market Commitment For Recycling And Removing Large-Scale Space Debris*, Federation of Concerned Scientists (April 26, 2022); https://fas.org/publication/taking-out-the-space-trash-creating-an-advanced-market-commitment-for-recycling-and-removing-large-scale-space-debris/; Marit Undseth, Claire Jolly, & Mattia Olivari, *The Economics of Space Debris in Perspective*, Proc. 8th European Conference on Space Debris (virtual), Darmstadt, Germany (April, 2021); https://conference.sdo.esoc.esa.int/proceedings/sdc8/paper/12/SDC8-paper12.pdf; Carson

risk, in compulsory escrow account payments, and by having a clear and enforceable duty to compensate parties harmed by space object collisions, should motivate stakeholders to change their attitude and conduct vis a vis space debris. When parties can qualify for a bounty for removing space debris and for meeting compliance requirements, they have compelling financial incentives to use best practices [137] The availability of monetary inducements can stimulate the development of a market for collection and disposal of existing space debris.

VI. Conclusion

The ASAT and space debris challenges have become acute problems requiring immediate attention instead of further study and appeals to good space citizenship. The space treaties should establish clear and enforceable duties of care that spacefaring governments and private ventures must exercise.

Bullock, & Robert T. Johanson, R. T. *Policies for incentivizing orbital debris assessment and remediation*, 2 MIT Sci. Pol'y Rev. 8 (2021); https://sciencepolicyreview.org/2021/08/policies-incentivizing-orbital-debris-remediation/.

[137] Hannah Thurston, *Space Trash: Legal and Economic Questions About the Collection of Orbital Debris*, 18 J. L. Econ, & Pol'y 229 (2023); https://static1.squarespace.com/static/6233d0b9d24b954d519e5d62/t/64470eecced50f12e9474a57/1682378478470/V.18_1.pdf; Adam G. Mudge, *Incentivizing 'Active Debris Removal' Following the Failure of Mitigation Measures to Solve the Space Debris Problem: Current Challenges and Future Strategies*. 82 Air Force L. Rev. 88 (2022); https://www.afjag.af.mil/Library/AFJAGS-Library/; Alexander William Salter, *Space Debris: A Law and Economics Analysis of the Orbital Commons*, 19 Stan. Tech. L. Rev. 221 (2016); https://heinonline.org/HOL/LandingPage?handle=hein.journals/stantlr19&div=13&id=&page=.