SPACE AND EXISTENTIAL RISK: THE NEED FOR GLOBAL COORDINATION AND CAUTION IN SPACE DEVELOPMENT

CHASE HAMILTON†

ABSTRACT

This Article examines urgent risks resulting from outer space activities under the current space law regime. Emerging literature alarmingly predicts that the risk of a catastrophe that ends the human species this century is approximately 10–25%. Continued space development may increase, rather than decrease, overall existential risk due in part to crucial and identifiable market failures. Addressing these shortcomings should take priority over the competing commercial, scientific, and geopolitical interests that currently dominate in space policy. Sensible changes, including shifting space into a closed-access commons as envisioned by the 1979 Moon Treaty, may help in achieving existential security.

† Charles (Chase) Hamilton, J.D. 2021, Duke University School of Law. This Article is the product of years of work and immeasurable support from others. Thank you to Bass Connections for supporting the 2020–21 interdisciplinary project *Going to Mars: Science, Society, and Sustainability*, which helped in developing these ideas. This Article benefited from many helpful comments, including from Professor Jonathan Wiener, Timothy Foster, Spencer Kaplan, the *Going to Mars* team (listed at https://www.ourmartian.world/about), and the Duke Law & Technology Review staff. All errors are my own.

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INTRODUCTION

> Many of the dangers we face indeed arise from science and technology—but, more fundamentally, because we have become powerful without becoming commensurately wise. The world-altering powers that technology has delivered into our hands now require a degree of consideration and foresight that has never before been asked of us. —Carl Sagan.[1]

For the first time in human history, outer space is becoming accessible, useful, and habitable. Unfortunately, the rapid development of technology driving our access to space is outpacing the wisdom necessary to use it responsibly. This Article is an effort to address urgent ethical, political, and legal questions about humanity's future in light of developing space technologies. Without a dramatic change in course, humanity may suffer a species-ending catastrophe this century. Safeguarding humanity's future will likely require leveraging helpful space technologies and eventually becoming a multi-planetary species,[2] but the process of space development can create or escalate other existential risks. Whether space is more likely to help us or hurt us depends largely on our legal, regulatory, and policy regimes.[3]

There is considerable disagreement about the goals of space development, and these differing views give rise to various possible configurations of law and regulation.[4] One approach emphasizes the importance of space as a unique environment for conducting scientific research.[5] From this perspective, space should be primarily governed by a principle of non-exclusion, shared access, and environmental

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[1] CARL SAGAN, PALE BLUE DOT: A VISION OF THE HUMAN FUTURE IN SPACE 179 (Ballantine Books 1997).
[2] *See generally* ANNALEE NEWITZ, SCATTER, ADAPT, AND REMEMBER: HOW HUMANS WILL SURVIVE A MASS EXTINCTION (2013) (discussing the strategy of settling in space to mitigate existential risk); *see also supra* section IV(A)(4) (discussing the merits of such a strategy).
[3] *See* DUKE PROJECT ON GOING TO MARS, MARTIAN MIGRATION: POL'Y REP. ON SCI., SOC'Y, & SUSTAINABILITY viii (Charles (Chase) Hamilton et al. eds., 2021) (arguing in a similar spirit that the success of potential space settlements depends on further inquiry into social, legal, and political questions).
[4] *See* Alanna Krolikowski & Martin Elvis, *Marking Policy for New Asteroid Activities: In Pursuit of Science, Settlement, Security, or Sales?*, 47 SPACE POL'Y 7, 8 (2019) (arguing that the different possible uses of asteroid resources are best served by policy regimes with distinct features).
[5] *See* James S.J. Schwartz, *Space settlement: What's the Rush?* 110 FUTURES 56, 58 (2019) (arguing for the primacy of scientific interests).

preservation.[6] Another approach envisions extracting resources from planets, moons, and asteroids to spur economic growth.[7] This view emphasizes the role of competition and the need for exclusive property rights to space resources.[8] While each of these approaches offer upsides, they also expose humanity to a variety of unacceptable, catastrophic risks, including in the near term.[9] While other goals may be tempting, space policy should seek to avoid introducing or exacerbating existential risks and, where possible, provide avenues for achieving existential security.[10]

Legal controversies must be analyzed with this policy goal in mind. Motivated by the allure of commercial enterprise and geopolitical advantage, the United States' (US's) approach to space law emphasizes decentralization along three fronts: open access for commercial activity by private actors, broadly-permitted military activities by states, and a preference for national rather than international space governance.[11] By contrast, many non-Western states (Russia, China, and the Global South) typically support a more centralized, coordinated approach to space.[12] For example, under the 1979 Moon Treaty, space and its resources would be considered the "common heritage of [hu]mankind,"[13] prohibiting states and private actors from exploiting space resources until an international regime lays ground rules for orderly management and

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[6] *See* Krolikowski & Elvis, *supra* note 4 (stating these principles follow when scientific research is the fundamental goal).
[7] *See* Matthew Weinzierl, *Space, the Final Economic Frontier*, 32 J. ECON. PERSP. 173, 175 (2018) (providing a framework for market activities like resource extraction to expand through decentralization).
[8] *Id.* at 187; *see also* David Collins, *Efficient Allocation of Real Property Rights on the Planet Mars*, 14 B.U. J. SCI. & TECH. L. 201, 202 (2008) (arguing with a neoliberal approach).
[9] *See infra* Section IV.
[10] *See infra* Section III. For the only other relatively comprehensive examination of space and existential risk, see generally DANIEL DEUDNEY, DARK SKIES: SPACE EXPANSIONISM, PLANETARY GEOPOLITICS, & THE ENDS OF HUMANITY (2020) (arguing from a critical scholarship perspective that space development is more likely to cause than prevent extinction).
[11] *See infra* Section II.
[12] *Id.*
[13] Agreement Governing the Activities of States on the Moon and Other Celestial Bodies, art. XI, Dec. 18, 1979, 1363 U.N.T.S. 3 [hereinafter "Moon Treaty"]. No spacefaring nation has signed this treaty, rendering it largely ineffectual. I choose to use "[hu]mankind" rather than the original, gendered "mankind." *See generally* Pat K. Chew & Lauren K. Kelley- Chew, *Subtly Sexist Language*, 16 COLUM. J. GENDER & L. 643 (2007) (describing research that male-gendered language tends to trigger male-biased imagery in the minds of readers, which has harmful effects over time).

equitable sharing.[14] Military activities would be limited, and international law would play a central, coordinating role.[15] While these two different legal approaches have been subject to much scrutiny, little consideration has been given from the standpoint of existential risk.

This Article contends that a decentralized approach to space law increases the likelihood of an existential catastrophe. Existential risk reduction is an intergenerational global public good that is predictably undersupplied by individual actors.[16] International coordination is necessary to align individual interests with humanity's collective wellbeing, for example by imposing costs that exceed the benefits of activities that increase existential risk.[17] Space law does not impose such costs. Instead, it is rife with externalities, including factors that incentivize individual actors—private and governmental alike—to exploit the benefits of space development without paying due regard to the impact on humanity's collective security.[18] A change of course is needed.

Section II lays out the current space law regime, including contentious disagreements about the degree of centralization it imposes. Section III surveys existential risk literature to help articulate a governing principle for space development. Section IV identifies ten existential risk mechanisms impacted by the current space law regime. Section V offers a path forward.

II. An Incomplete Space Law Regime

The corpus of international space law is contained within just four treaties, the most important of which is the 1967 Outer Space Treaty (OST).[19] Ratified by 110 states, including every spacefaring nation, the

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[14] *See* Joanne I. Gabrynowicz, *The "Province" and "Heritage" of Mankind Reconsidered: A New Beginning*, THE 2D CONF. ON LUNAR BASES & SPACE ACTIVITIES . 21ST CENTURY 691, 691–92 (1992) (interpreting the common heritage of humanity principle).
[15] *Id.*
[16] *See infra* Section III(B).
[17] *Id*.
[18] *See infra* Section IV.
[19] Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies, Jan. 27, 1967, 18 U.S.T. 2410, 610 U.N.T.S. 205 [hereinafter "Outer Space Treaty"]. The other three treaties are the 1968 Rescue Agreement (Agreement on the Rescue of Astronauts, the Return of Astronauts and the Return of Objects Launched into Outer Space, Apr. 22, 1968, 19 U.S.T. 7570, 672 U.N.T.S. 119), the 1972 Liability Convention (Convention on International Liability for Damage Caused by Space Objects, Mar. 29, 1972, 24 U.S.T. 2389, 961 U.N.T.S.

OST was negotiated quickly during the height of the Cold War after the launch of the Earth's first artificial satellite.[20] The Soviet Union (USSR) and the US wanted to avoid making space a costly theater of conflict and drafted three particularly distinctive provisions to that end.[21] The meaning of these provisions is subject to considerable disagreement.

A. *Article II, Non-Appropriation, and Commercial Activities*

Under the 1967 Outer Space Treaty (OST), outer space is the "province of all [hu]mankind[;]" its exploration and use is mainly for "scientific investigation" and must "be carried out for the benefit and in the interests of all countries, irrespective of their degree of economic or scientific development . . . ."[22] Moreover, Article II provides that space and celestial bodies (planets, moons, asteroids, and so forth) are "not subject to national appropriation by claim of sovereignty, by means of use or occupation, or by any other means."[23] Thus, space is widely considered by international legal scholars to be a type of global commons—a shared domain where access to non-rivalrous goods (like scientific exploration) cannot legally be prevented by others and whose rivalrous goods (like mineral resources) should not be snatched up by individual countries for personal gain.[24] This structure was meant to strike a balance between freedom of scientific investigation and avoidance of a first-come, first-served land grab reminiscent of European empires in previous centuries.[25]

It has long been clear from the non-appropriation principle that no state has the right to claim any celestial body as sovereign territory. In recent years, however, controversy has arisen as to whether Article II applies to the activities of private actors as well as nations, and whether the non-appropriation of celestial bodies prohibits the extraction of space resources for commercial purposes. The US now appears to believe that the non-appropriation principle does prohibit the activities of private

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187), and the 1975 Registration Convention (Convention on Registration of Objects Launched into Outer Space, Jan. 14, 1975, 28 U.S.T. 695, 1023 U.N.T.S. 15).

[20] *See* Peter Jankowitsch, *The Background and History of Space Law*, *in* HANDBOOK OF SPACE LAW 4 –5 (Frans von der Dunk & Fabio Tronchetti eds., 2015).

[21] *See id*. at 3.

[22] Outer Space Treaty, *supra* note 19, at art. I.

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

[24] *See* Frans von der Dunk, *International Space Law*, *in* HANDBOOK OF SPACE LAW, *supra* note 20, at 55–56.

[25] Fabio Tronchetti, *The Non-Appropriation Principle Under Attack: Using Article II of the Outer Space Treaty in Its Defence*, 50 PROC. L. OUTER SPACE 526, 530 (2007).

actors who extract space resources for commercial purposes. In 2015 Congress passed the U.S. Commercial Space Launch Competitiveness Act (CSLCA), recognizing under domestic law private property rights to space resources acquired by American citizens:[26]

> A United States citizen engaged in commercial recovery of an asteroid resource or a space resource under this chapter shall be entitled to any asteroid resource or space resource obtained, including to possess, own, transport, use, and sell the asteroid resource or space resource obtained in accordance with applicable law, including the international obligations of the United States.[27]

The statute is followed by a disclaimer of extraterritorial sovereignty: "It is the sense of Congress that by the enactment of this Act, the United States does not thereby assert sovereignty or sovereign or exclusive rights or jurisdiction over, or the ownership of, any celestial body."[28] In April 2020, President Donald Trump signed an executive order furthering the sentiment that "Americans should have the right to engage in commercial exploration, recovery, and use of resources in outer space" and, puzzlingly, declaring that "the United States does not view [outer space] as a global commons."[29]

These bold claims came as a shock to the international community. Scholars have denounced the CSLCA as a "detraction" from international space law, partly because the records of negotiation of the OST includes widespread recognition that Article II was meant broadly to prohibit appropriation of all kinds.[30] For example, during negotiation of the Treaty, Belgium expressed that it "had taken note of the interpretation of the term 'non-appropriation' advanced by several delegations—without contradiction—as covering both the establishment of sovereignty and the creation of titles to property in private law."[31]

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[26] U.S. Commercial Space Launch Competitiveness Act of 2015, Pub. L. No. 114-90, 129 Stat. 704 (2015) (codified in scattered sections of 51 U.S.C.).
[27] *Id*. § 51303.
[28] *Id*. § 403.
[29] *Executive Order on Encouraging International Support for the Recovery and Use of Space Resources*, Sec. 2, WHITE HOUSE (Apr. 6, 2020), https://trumpwhitehouse.archives.gov/presidential-actions/executive-order-encouraging-international-support-recovery-use-space-resources/.
[30] Stephan Hobe & Kuan-Wei Chen, *Legal Status of Outer Space and Celestial Bodies*, *in* ROUTLEDGE HANDBOOK OF SPACE LAW 30 (Ram Jakhu & Paul Dempsey, eds., 2017).
[31] Virgiliu Pop, *Appropriation in Outer Space: The Relationship Between Land and Ownership and Sovereignty on the Celestial Bodie*s, 16 SPACE POL'Y 275, 276 (2000) (internal citation omitted).

Similarly, France believed Article II reflected "the prohibition of any claim of sovereignty or property rights in space . . . ."[32] The emphasis in Article II on state-related forms of appropriation like sovereignty reflects the assumption by everyone at the time that states would be the only actors in space.[33] It was not until decades later that private space activities became viable.[34]

Under the traditional interpretation of Article II, individual countries and their citizens have no right to exploit finite space resources for commercial purposes.[35] The CLSCA lifts the condition of excludability for its private actors, creating a common goods dilemma.[36] Acting individually, each state faces a choice: sit by and watch as other states allow their citizens to profit from appropriating finite space resources, or join in the race. Already, Luxembourg has followed the United States' reinterpretation, stating in a 2017 law that "[s]pace resources can be appropriated" by private companies for commercial purposes.[37] With the floodgates opening, more states are sure to follow. The severity of this problem depends on the degree to which market incentives pull in favor of practices with negative externalities. This Article discusses this topic in Sections III(B) and IV.

B. *Article IV, Weapons of Mass Destruction, and Peaceful Purposes*

Article IV prohibits the placement of "weapons of mass destruction" (WMDs) in orbit around the Earth or on celestial bodies, and further provides that celestial bodies are to be used "exclusively for peaceful purposes."[38] It additionally provides that celestial bodies shall

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[32] *Id*.
[33] *See* Abigail Pershing, *Interpreting the Outer Space Treaty's Non-Appropriation Principle: Customary International Law from 1967 to Today*, 44 YALE J. INT'L L. 149, 154–157 (noting supporting sources).
[34] *Id*.
[35] Tronchetti, *supra* note 25.
[36] The well-known tragedy of the commons arises for rivalrous, non-excludable goods. Economically rational actors fail to invest in future gains from common goods, which may end up being taken by another. All are incentivized to snatch up everything they can because they cannot exclude others from doing the same. Overuse over time causes depletion of the resource to everybody's disadvantage, and yet competition among individuals incentivizes such mutually destructive behavior. Garrett Hardin, *The Tragedy of the Commons*, 162 SCI. 1243, 1243 (1968).
[37] *Luxembourg Law on the Exploration and Use of Space Resources*, Article I, LEGILUX (2017), https://legilux.public.lu/eli/etat/leg/loi/2017/07/20/a674/jo (translated from French).
[38] Outer Space Treaty, *supra* note 19, at art. IV.

not be used for "[t]he establishment of military bases, installations and fortifications, the testing of any type of weapons[,] and the conduct of military maneuvers . . . ."[39] These provisions played an important role in preventing an arms race from spreading to celestial bodies and avoiding the placement of nuclear weapons in orbit around the Earth.[40] Still, the ambition of peaceful purposes stands in tension with the prolific military space activities that occur today.[41]

There is disagreement about the ambit of "exclusively peaceful purposes" on celestial bodies.[42] In the early years, the USSR interpreted "peaceful" to mean "non-military," which would have broadly prohibited the use of celestial bodies for any military goals.[43] In contrast, the US interpreted "peaceful" as "non-aggressive," which permitted any military activities otherwise allowed by international law[44]—essentially, anything except the other limitations listed in Article IV, as well as provisions from the UN Charter prohibiting the use or threat of force.[45] By the time the OST was ratified, the US's interpretation had won out, and the USSR withdrew its objections.[46]

In a similar resistance to anti-military space doctrine, the US has repeatedly objected to efforts to develop new space arms control measures. Most states believe at least one of two changes are necessary: a comprehensive treaty aimed at the deweaponization of space, or at minimum, an anti-satellite (ASAT) weapon ban treaty. The issue of deweaponization is helpfully elucidated by pointing to a difference between militarization and weaponization in space contexts. "Militarization" refers to the use of space systems for terrestrial military activities, such as through reconnaissance, the Global Positioning System, and weather monitoring satellites. "Weaponization," on the other hand, refers to the deployment of offensive weapons in space or on the ground with their intended target located in space. Deweaponization efforts therefore seek to prohibit the testing, deployment, or use of such weapons.

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[39] *Id*.
[40] Setsuko Aoki, *Law and Military Uses of Outer Space*, *in* ROUTLEDGE HANDBOOK OF SPACE LAW, *supra* note 30, at 197.
[41] *Id*.
[42] Fabio Tronchetti, *Legal aspects of the military uses of outer space, in* HANDBOOK OF SPACE LAW, *supra* note 20, at 331.
[43] Aoki, *supra* note 40, at 200.
[44] *Id*. at 199.
[45] Tronchetti, *supra* note 42, at 339–40.
[46] Aoki, *supra* note 40, at 200.

Most of the world has long supported the deweaponization of space.[47] In particular, Russia and China have offered six proposals between them since 1982,[48] the latest of which from 2014 revolves around prohibitions on the placement of weapons in outer space and on the use or threat of force against outer space objects.[49] Despite these efforts, each proposal has been unequivocally shot down by the US.[50] The US asserts two concerns: first, that the scope of the prohibitions is underinclusive; second, that each proposed treaty lacks adequate verification measures.[51] The US nominally would prefer a treaty to go beyond prohibiting the threat or use of force against outer space objects so that it also explicitly includes the research, development, testing, production, storage, and deployment of terrestrially-based ASATs.[52] Their concern is that a party could build and have in its inventory a readily deployable ASAT.[53] The US points to continued ASAT development efforts by Russia and China as evidence that the latest draft treaty is designed to uniquely advantage countries who have already invested in terrestrial ASAT technology.[54]

The American position is undermined by the fact that Russian and Chinese ASAT development may be motivated partly by the US's repeated efforts to stonewall arms control agreements. The US also rejects the good in favor of the perfect, refusing to sign onto two arms control measures that would be at least marginal improvements just because they might not apply to some aspects of terrestrial-based weapon development. Russia and China have emphasized that deweaponization is a gradual process, and that these two measures would be among the most effective and feasible ways of preventing armed conflict in outer

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[47] Tronchetti, *supra* note 42, at 334.
[48] *See* Aoki, *supra* note 40, at 210 (listing proposals made in the Conference on Disarmament).
[49] *Draft Treaty on the Prevention of the Placement of Weapons in Outer Space, the Threat or Use of Force against Outer Space Objects*, Feb. 12, 2008; *see* NTI, *PAROS Treaty*, https://www.nti.org/education-center/treaties-and-regimes/proposed-prevention-arms-race-space-paros-treaty/ (last visited May 31, 2022) (describing developments in the treaties).
[50] *See* Aoki, *supra* note 40, at 210–12 (noting the US's objections to each).
[51] DELEGATION OF THE UNITED STATES OF AMERICA TO THE CONFERENCE ON DISARMAMENT, ANALYSIS OF THE 2014 RUSSIAN-CHINESE DRAFT "TREATY ON THE PREVENTION OF THE PLACEMENT OF WEAPONS IN OUTER SPACE, THE THREAT OR USE OF FORCE AGAINST OUTER SPACE OBJECTS" (PPWT) (CD/1985) 1, 2 (2014) [hereinafter US Comments], https://undocs.org/pdf?symbol=en/CD/1998.
[52] *Id*.
[53] *Id.*
[54] *Id*.

space.[55] In any case, the US has not yet formally offered any solutions of its own.[56]

The US criticizes the draft treaty for lacking verification measures and objects to signing a treaty whose verification measures would only be determined through subsequent negotiation.[57] Russia and China contend in reply that it is precisely following the implementation of the treaty that verification mechanisms will become worth discussing in light of experience.[58] They also point out that the US frequently signs arm control treaties without formal verification mechanisms, including the OST.[59] The deadlock is driven no doubt in part by the long history of competition and distrust between these nations.[60]

Another major issue in the arms control context is the presence of dual-use technology that can be used for either military or civil purposes.[61] For example, devices that can be used to help remove space debris can also be used to tamper with or destroy active satellites.[62] A similar issue concerns the definition of Weapons of Mass Destruction (WMDs), which the OST prohibits from being placed in orbit around the Earth and on celestial bodies.[63] At the time of drafting, WMDs were

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[55] Permanent Rep. of China to the Conference on Disarmament & the Charge d'affaires a.i. of the Russian Federation, Letter dated 11 September 2015 from the Permanent Rep. of China to the Conference on Disarmament and the Charge d'affairs a.i. of the Russian Federation addressed to the Secretary-General of the Conference Transmitting Comments by China and the Russian Federation Regarding the United States of America Analysis of the 2014 Updated Russian and Chinese Texts of the Draft Treaty on Prevention of the Placement of Weapons in Outer Space and of the Threat or Use of Force Against Outer Space Objects (PPWT), ¶ 3, U.N. DOC. CD/2042 (Sep. 13, 2015) [hereinafter China & Russia Comments], https://undocs.org/pdf?symbol=en/CD/2042 (2015).
[56] *See* Aoki, *supra* note 40, at 210 (listing Conference on Disarmament proposals).
[57] US Comments, *supra* note 51, ¶ 1(a).
[58] China & Russia Comments, *supra* note 55, ¶ 24.
[59] *Id*. at ¶¶ 20–21.
[60] *See, e.g.*, Christine Huang et al., *China's Partnership With Russia Seen as Serious Problem for the U.S., Pew Research* (Apr. 22, 2022), https://www.pewresearch.org/global/2022/04/28/chinas-partnership-with-russia-seen-as-serious-problem-for-the-us/ (describing research on American views of relations between Russia, China, and the US).
[61] Tronchetti, *supra* note 42, at 332.
[62] James Alver et al., An Analysis of the Potential Misuse of Active Debris Removal, On-Orbit Servicing, and Rendezvous & Proximity Operations Technologies (May 6, 2019) (Master's Thesis, The George Washington University), https://swfound.org/media/206800/misuse_commercial_adr_oos_jul2019.pdf.
[63] Outer Space Treaty, *supra* note 19, at art. IV.

defined "to include atomic explosive weapons, radio-active material weapons, lethal chemical and biological weapons, and any weapons developed in the future which have characteristics comparable in destructive effect to those of the atomic bomb or other weapons mentioned above."[64] Today, there is concern that any large object could be a WMD if crashed into the Earth from orbit—a type of warfare called kinetic bombardment.[65]

Finally, Article IV of the OST deals only with activities on celestial bodies and in orbit around the Earth.[66] Crucially, these provisions do not seem to apply to activities in the empty space between celestial bodies—the void of outer space—which constitutes the vast majority of the universe.[67]

These ambiguities, combined with the rising importance of space to commercial and military actors alike, point to the need for further legal development. A comprehensive regime change to govern all aspects of the military uses of outer space, rather than the OST's piecemeal approach, may be necessary.[68] Unfortunately, the history of space policy shows that a lack of trust and transparency between countries hinders negotiations.

C. Article VI, State Supervision, and Flags of Convenience

International space law relies heavily on nations to decide upon and enforce their own national space laws. Article VI of the OST provides that states must "authoriz[e] and continu[ously] supervis[e]" all "national activities in outer space[,]" including those by non-governmental actors.[69] States therefore "bear international responsibility" for ensuring that private actors respect international law when conducting space activities.[70] As a further incentive for adopting effective national space laws, Article VII makes states internationally

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[64] Commission for Conventional Armaments, Resolutions Adopted by the Commission at its 13th Meeting, 12 August 1948, and a 2nd Progress Report of the Commission, U.N. DOC. S/C.3/32/Rev.1, at 2 (Aug. 18, 1948), https://digitallibrary.un.org/record/755665?ln=fr.
[65] *US Project Thor Would Fire Tungsten Poles at Targets From Outer Space*, SPACE DAILY (Nov. 12, 2018), spacedaily.com/reports/US_Project_Thor_would_fire_tungsten_poles_at_targets_from_outer_space_999.html.
[66] Tronchetti, *supra* note 42, at 338.
[67] *Id*.
[68] *See* Tronchetti, *supra* note 42, at 332 ("[A] coherent and comprehensive legal framework governing military activities in outer space is currently missing.").
[69] Outer Space Treaty, *supra* note 19, at art. VI.
[70] *Id*.

liable for damages caused by any actors who have launched space objects from within their borders.[71] The OST therefore relies on states to adopt national laws that regulate the behaviors of its space activities.

The hope may have been that, by allowing states to set and enforce their own standards, countries would work out the best practices over time amongst themselves.[72] The drafters of the OST, however, presumed that all space activity would be conducted directly by states, just as it had been during the Cold War.[73] They did not foresee the importance and influence private markets would come to have on space practices.[74] As the cost of space access diminishes and the value of space activities rises, humanity will likely witness a dangerous race to the bottom in national approaches to space law.[75]

Consider license shopping in the maritime context. For centuries, ships simply flew the flag of the ship owner's home country.[76] The flag state has jurisdiction over the ship and is responsible for inspecting for safety and the crew's working conditions.[77] Starting in the 1920s during the Prohibition, many American ship owners began to register their ships not with the US but with Panama in order to legally serve alcohol to their passengers.[78] Even after the Prohibition, ship owners realized that, compared to the US, Panama provided a tax refuge, weaker labor laws, and lax oversight.[79] Thus emerged so-called "flags of convenience," licenses from states that ship owners may have no connection to but that offer favorable regulatory practices.[80] Unfortunately, with less oversight came lower operating standards.[81] Ships flying flags of convenience became known for having unsafe and unethical working conditions and, tragically, have been responsible for some of the highest-profile oil spills in history.[82] Further, even where a flag state has sufficient regulations on the books, it is often unable or unwilling to enforce them, making it a

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[71] *Id*. at art. VII.
[72] Hobe & Chen, *supra* note 30, at 38.
[73] Pershing, *supra* note 33.
[74] *Id*.
[75] Frans G. von der Dunk, *Towards 'Flags of Convenience' in Space?*, SPACE, CYBER, & TELECOMM. L. PROGRAM FAC. PUBLICATIONS 76, at 1 (2012).
[76] *Id*.
[77] *Id*.
[78] ELIZABETH R. DESOMBRE, FLAGGING STANDARDS: GLOBALIZATION AND ENVIRONMENTAL, SAFETY, AND LABOR REGULATIONS AT SEA 76 (2006).
[79] *Id*.
[80] *See id*. at 3 (noting that States compete for ship registrations by keeping regulations minimal or lightly enforced and shipowners register in those States).
[81] *Id*.
[82] *See id*. at 1 (giving an example of one large oil spill).

haven for arms smuggling and human trafficking.[83] In an effort to combat these lapses, the law of the high seas evolved to require a "genuine link" between the ship and the flag country.[84] The "genuine link" requirement is, however, notoriously weak.[85] Today more than 40% of the world's cargo is carried by ships registered with Panama, Liberia, and the Marshall Islands—collectively making up only 0.1% of the world's population[86]—despite the fact that most ships have never visited those places.[87]

Flags of convenience may be the future of private space activity given the current legal regime.[88] Like in the maritime context, space businesses are free to license shop between countries based on regulatory schemes and practices, and—unlike in maritime law—there is not even a weak "genuine link" requirement.[89] Instead, liability and responsibility for private actors falls to the "launching State[,]" defined simply as "(i) [a] State which launches or procures the launching of a space object[, and] (ii) [a] State from whose territory or facility a space object is launched[.]"[90] Because international space law does not directly impose safety standards, best practices, or compliance and verification mechanisms, these are left entirely up to the flag state.[91] As more private space operators emerge and the value of their businesses skyrocket, countries will likely realize that they can make their flags more attractive by imposing lower regulatory standards or enforcing them less stringently. Launchers may look for states that allow them to launch without rigorous safety inspections; operators could even more simply move the terrestrial headquarters of their existing space-based activities to states that will not seriously supervise them. As competition drives

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[83] Human Rights Watch, *Statement to the United Nations Open-Ended Informal Consultative Process on Oceans and the Law of the Sea* (June 2, 2003), *https://www.un.org/Depts/los/general_assembly/contributions2004/HRW2004.pdf*.
[84] von der Dunk, *supra* note 75, at 2.
[85] *Id*. at 2–3.
[86] These three states combined have only 9 million of the world's 7.8 billion people.
[87] *Why So Many Shipowners Find Panama's Flag Convenient*, BBC (Aug. 5, 2014), https://www.bbc.com/news/world-latin-america-28558480 (noting that "almost three quarters of the world's fleet was registered under a flag of a country other than its own").
[88] von der Dunk, *supra* note 75, at 2.
[89] *Id*.
[90] 1975 Registration Convention, art. I; 1972 Liability Convention, art. I; which both use language drawing from the Outer Space Treaty, *supra* note 19, art. VII.
[91] von der Dunk, *supra* note 75, at 4.

standards and supervision lower, the risks rise.[92] Even if most countries exercise stringent and effective oversight, it takes only one defector willing to accept higher risks before we witness a harbor under which dangerous space practices could proliferate.[93]

The US has long opposed the development of any new international legal instruments that would limit its access to or use of outer space.[94] In its refusal to make any concessions, the US may be opening a Pandora's box.

III. UNDERSTANDING AND PRIORITIZING EXISTENTIAL RISK

The question of space development is unlike most other questions of policy—it is extraordinarily *big*, concerning the future of our entire species. As a matter of procedure, it makes sense to break from traditional approaches to risk analysis that start by focusing on marginal and local considerations and only at the end look towards the broader stakes, if considering them at all. For example, when considering local pollutant regulations, the likelihood that our competing policy options will bear significantly on the survival of humanity is so small and hard to predict that it is generally not worth the time or resources to try. Decisions made about space, on the other hand, stand to change the course of humanity's development and could be felt for centuries. In this Section, I survey the body of existential risk literature to better understand existential risk and why its mitigation should be the governing principle of space development.

A. The Expected Value of Existential Risk Mitigation

Existential risks are those risks to humans that are species-wide in scope and terminal in magnitude.[95] In other words, a quintessential existential risk is one that threatens the permanent end of the human species—a disaster from which humanity's recovery is impossible and survival is unendurable.[96] Also, there are some risks that scholars consider to be existential that would not entail the "bang" of a sudden life-ending disaster—there are also "crunches" (permanent stagnation in

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92 *Id*. at 13–16.
93 *Id*. *See also supra* note 139 and accompanying discussion of the Unilateralist's Curse.
94 *See, e.g.*, GEORGE W. BUSH, U.S. NATIONAL SPACE POLICY 2 (2006) ("The United States will oppose the development of new legal regimes or other restrictions that seek to prohibit or limit U.S. access to or use of space.").
95 *See* Nick Bostrom, *Existential Risks: Analyzing Human Extinction Scenarios and Related Hazards*, 9 J. EVOLUTION & TECH. 1, 2 (2002) (defining existential risks).
96 *Id*.

human development, such as through a disaster that leaves humanity alive but unable to ever technologically recover), "shrieks" (development into an undesirable and irrevocable condition, such as permanent takeover by a repressive totalitarian global regime), and "whimpers" (gradual and irrevocable disappearance of value, such as through a squandering of finite resources).[97] What all of these scenarios have in common is the permanent and drastic curtailment of humanity's long-term potential.[98] However, for demonstrative purposes, I will largely focus for now on catastrophes that could bring about human extinction (the "bangs").

Almost everybody agrees extinction would be bad,[99] but it is difficult to comprehend just how bad. Still, in order to incorporate existential risks into policymaking considerations, it is important to speak in terms of expected value, which requires us to estimate the badness of extinction.[100]

For one, a sudden existential catastrophe would entail the death of all living people. In quantitative terms, this would be worse than any tragedy humanity has ever experienced, surpassing the number of deaths accrued from the Holocaust seven hundred times over.[101] Nevertheless, attempting to imagine catastrophe on such a mass scale does not typically motivate us to the same degree as a tragic accident involving the death of even a single child.[102] This is a classic case of scope

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[97] *Id*. at 5.
[98] *Id*.
[99] *See* Nick Bostrom, *Existential Risk Prevention as Global Priority*, 4 GLOBAL POL. 15, 23–24 (2013) (noting the convergence of ethical theories on the badness of extinction).
[100] A decision's expected value—the standard metric for determining an agent's optimal choice—is the probability-weighted sum of its possible outcomes' values. JORDAN SOBEL, TAKING CHANCES: ESSAYS ON RATIONAL CHOICE ix (1995). Estimating the badness of extinction is therefore crucial for comparing the expected value of existential risk reduction against other, lower-magnitude–higher-probability options.
[101] The Holocaust is estimated to have killed eleven million people. If the world contains 7.8 billion people at the time of extinction, as it does now, that would entail deaths amounting to 709.09 Holocausts. *See also* Bostrom, *supra* note 99, at 18 (noting that on a graph representing total world population over time, "[c]alamities such as the Spanish flu pandemic, the two world wars, and the Holocaust scarcely register").
[102] *See* Eliezer Yudkowski, *Cognitive Biases Potentially Affecting Judgment of Global Risks* , *in* GLOBAL CATASTROPHIC RISKS 114 (Nick Bostrom & Milan M. Ćirković eds., 2008) ("People who would never dream of hurting a child hear of an existential risk, and say, 'Well, maybe the human species doesn't really deserve to survive'.").

insensitivity, our psychological inability to "feel" the badness of outcomes as scaling up with the number of deaths involved.[103] In fact, psychological research demonstrates "mass numbing"—a person's willingness to pay to save other people from some risk actually tends to *decrease* as the number of people at risk grows beyond ten or so.[104] Rationally, however, each person's death would represent a great loss and ought to be avoided. This is one way existential risks involve stakes much higher than most other traditional policy concerns.

The badness of extinction would not end at losses felt in the present, but would be severely exacerbated by the loss of a future for humanity. This additional loss would be even worse than an utterly devastating catastrophe, such as the mass death of billions.[105] This is because the ultimate potential of life on Earth is incomprehensibly high. The most conservative estimates predict that, absent extinction in the next one billion years, the Earth can support 10^{16} human lives of present-day length.[106] The scale of that number leads to a shocking result: assuming, as almost all ethicists do, that future lives are about as morally valuable as today's lives,[107] "the expected value of reducing existential

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[103] *Id*. (applying cognitive research to existential risks); *see also* Chase Hamilton, *Modernizing Conservationism: Renewable Energy's Species-Preserving Effect and the Endangered Species Act*, 41 DUKE ENVIRON. L. & POL. F. 379, 410–11 (2021) (summarizing mental heuristics involving tradeoffs between individuals and groups in both human and nonhuman contexts).

[104] *See* Paul Slovic, *"If I Look at the Mass I Will Never Act": Psychic Numbing and Genocide*, 2 JUDGMENT & DECISION MAKING 79 (2007); Paul Slovic et al., *Psychic Numbing and Mass Atrocity*, *in* BEHAV. FOUNDS. POL'Y 126 (Eldar Shafir ed., 2013) (finding that people are most willing to pay to save groups of around ten people, but that they become less willing to pay to save larger groups of people than they are willing to pay to save one or two individuals). For a discussion of mass numbing as applied to existential risks, *see* Jonathan Wiener, *The Tragedy of the Uncommons: On the Politics of the Apocalypse*, 7 GLOBAL POL'Y 67, 72–73 (2016).

[105] *See* DEREK PARFIT, REASONS AND PERSONS 453–54 (1984) (arguing that the moral difference between peace and a war that kills 99% of the world's population is actually much smaller than the difference between a war that kills 99% and a war that kills 100% of the world's population).

[106] Bostrom, *supra* note 99, 18–19. To be conservative, Bostrom assumes these lives will last 100 years on average. These lives will probably end up being much longer and much better than today's lives with the advancement of technologies. *See generally* OLLE HÄGGSTRÖM, HERE BE DRAGONS: SCIENCE, TECHNOLOGY, AND THE FUTURE OF HUMANITY (2016) (exploring humanity's long-term potential).

[107] Moral philosophers widely agree that future lives are about as valuable as present ones. After all, for most of human history, *we* were future lives, and we generally take our lives to be worth living. *See, e.g.*, PARFIT, *supra* note 105, at 425

risk by a mere *one millionth of one percentage point* [0.00000001%] is at least a hundred times the value of a million human lives."[108] In other words, even marginal reductions in existential risk tend to swamp other policy interests. These numbers become even more gargantuan if one assumes that humanity will develop advanced technologies and eventually expand into space.[109]

There are other, nonquantitative reasons that the loss of humanity's future would be uniquely bad.[110] One is an argument from normative uncertainty: there is no consensus regarding what outcomes would count as a big win for humanity.[111] Humanity should therefore preserve its ability to recognize value and steer the future accordingly, which will not be possible if humankind no longer exists.[112] Another argument looks not to the future, but the past: each generation has a

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("[In general,] we ought to be equally concerned about the predictable effects of our acts whether these will occur in one, or a hundred, or a thousand years."); John Nolt, *Nonanthropocentric climate ethics*, 2 WIREs CLIMATE CHANGE 701, 703 ("[M]any intergenerational ethicists view the discounting of harms and benefits to future people as unjustifiable discrimination."); ORD, *infra* note 114, at 413 (noting that the overwhelming majority of philosophers reject a pure time preference on valuing human lives).

[108] Bostrom, *supra* note 99, 18–19 (emphasis in original).

[109] *Id*. at 19 ("The more technologically comprehensive estimate [incorporating space settlements and mind digitization] of 10^{54} human-brain-emulation subjective life-years (or 10^{52} lives of ordinary length) makes the same point even more starkly. Even if we give this allegedly lower bound on the cumulative output potential of a technologically mature civilisation a mere 1 per cent chance of being correct, we find that the expected value of reducing existential risk by a mere *one billionth of one billionth of one percentage point* is worth a hundred billion times as much as a billion human lives.").

[110] Non-quantitative considerations may still have a place in weighing the expected value of risk mitigation, either in affecting one's consideration of the magnitude of an outcome's value or in altering the way one approaches the risk non-consequentially. *See generally* Carl Cranor, *Toward a Non-Consequentialist Approach to Acceptable Risks*, *in* RISK: PHILOSOPHICAL PERSPECTIVES 36 (Tim Lewens ed., 2007).

[111] *See generally* DEREK PARFIT, ON WHAT MATTERS (2011) (arguing that ethics is a young field in which great progress can still be made); *see also* Ross Anderson, *We're Underestimating the Risk of Human Extinction*, ATLANTIC (Mar. 6, 2012), https://www.theatlantic.com/technology/archive/2012/03/were-underestimating-the-risk-of-human-extinction/253821/ (interviewing Nick Bostrom) ("[O]ur human experience might be just a small little crumb of what's possible. . . . [I]t might be that human nature constrains us to a very narrow little corner of the space of possible modes of being. . . . [H]umanity in its current stage might be like a little cowering infant sitting in the corner of [a grand] cathedral having only the most limited sense of what is possible.").

[112] Bostrom, *supra* note 99, 24–26.

custodial responsibility to continue the human project left to us by our ancestors.[113] These arguments help demonstrate that the stakes involved in existential contexts are unique and significant.

For the majority of people who do not take existential threats seriously, it is not because they seriously doubt the stakes, but because they do not believe that such events have a realistic chance of actually occurring.[114] Given that the potential losses from existential risks are so high, one would hope that their probabilities are low enough—far, far below 1%—to bring their expected values into a range that is reasonably comparable to other risks. That unfortunately does not seem to be the case. Startlingly, surveyed experts predict the likelihood of extinction by 2100 to be **between about 10% and 25%**.[115] These figures are about one million times higher than what people normally think[116] and may still be conservative.[117] If these estimations are even close to being correct, existential risk mitigation should be of the utmost priority wherever even minor gains in existential security can be confidently made.

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[113] *Id*. at 23 (noting the possibility of "custodial duties to preserve the inheritance of humanity passed on to us by our ancestors and convey it safely to our descendants").

[114] TOBY ORD, THE PRECIPICE 40–41 (2020).

[115] *See* ANDERS SANDBERG & NICK BOSTROM, FUTURE HUMAN. INST., GLOBAL CATASTROPHIC RISKS SURVEY, TECHNICAL REPORT 2008/1 (2008) (finding that surveyed experts offered a median anthropogenic risk of extinction by 2100 of 19%). Another report predicts a 9.5% chance of catastrophic chance this century. GLOBAL CHALLENGES FOUND., GLOBAL CATASTROPHIC RISKS ANNUAL REPORT 24 (2016). Nick Bostrom, the leading expert in this field, has said "[m]y subjective opinion is that setting this probability lower than 25% would be misguided, and the best estimate may be considerably higher." Bostrom, *supra* note 95, at 19. Toby Ord, another highly-qualified expert, gives existential catastrophe a one in six chance (16.6%) of occurring this century. ORD, *supra note* 114*,* at 169.

[116] Benjamin Todd, *The Case for Reducing Existential Risks*, 80,000 HOURS, https://80000hours.org/articles/existential-risks/ (published Oct., 2017).

[117] Sir Martin Rees, Britain's Astronomer Royal, gives humanity no more than 50-50 odds on surviving this century. MARTIN REES, OUR FINAL HOUR: A SCIENTIST'S WARNING 8 (2003). John von Neumann, as Chairman of the U.S. Air Force Strategic Missiles Evaluation Committee, stated after World War II that it was "absolutely certain (1) that there would be a nuclear war; and (2) that everyone would die in it." JOHN LESLIE, THE END OF THE WORLD: THE SCIENCE AND ETHICS OF HUMAN EXTINCTION 26 (1996). According to some plausible arguments, the odds of extinction may in fact be nearly 100%. *See infra,* notes 120–122 (describing the Fermi Paradox, Doomsday Argument, and Simulation Argument).

There are indirect and direct approaches for estimating the probability of existential risks. Indirect methods analyze general features of the world in which we live to identify the risk of extinction occurring. Some indirect risk estimation methods should cause one to reconsider their confidence that the odds of extinction are low, such as the influence of psychological biases[118] and the inherent error-proneness of low-probability risk assessments.[119] Even more worrying are the indirect methods that predict a very high probability of extinction, including the Fermi Paradox,[120] the Doomsday Argument,[121] and the Simulation

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[118] *See* Yudkowski, *supra* note 102, at 92 (discussing psychological factors that cause us to underestimate the probability of existential risks).

[119] The uncertainty and error-proneness of our first-order assessments of risk often dominates in low-probability, high-consequence contexts. Bostrom, *supra* note 99, at 16 ("Suppose that some scientific analysis *A* indicates that some catastrophe *X* has an *extremely* small probability *P*(*X*) of occurring. Then the probability that *A* has some hidden crucial flaw may easily be much greater than *P*(*X*). Furthermore, the *conditional* probability of *X* given that *A* is crucially flawed, $P(X|\neg A)$, may be fairly high. We may then find that most of the risk of *X* resides in the uncertainty of our scientific assessment that *P*(*X*) was small[.]").

[120] There are many trillions of Earth-like planets in the observable universe, each of which has some non-zero chance of developing life. Given the size and age of the universe, if even one species survived and evolved to be intelligent and spacefaring, the universe should be teeming with signs of their existence. But there are no signs of life—no spaceships, no signals, no superstructures built around stars. Thus, there must be (at least) one Great Filter—an evolutionary step that is extremely improbable—whose occurrence is necessary for an Earth-like planet to produce detectable life. The key question for us is whether a Great Filter is in our past (perhaps the development of eukaryotic life) or in our future (perhaps the safe development of nanotechnology, artificial intelligence, or norms against conflict), or both. If a Great Filter is in our future, the odds are extraordinarily high that we will end up like every other civilization before us—extinct before we spread throughout space enough to leave a footprint detectable to civilizations like ours. Nick Bostrom, *Where Are They? Why I Hope the Search for Extraterrestrial Life Finds Nothing*, MIT TECH. REV., May–June 2008, at 72.

[121] This controversial argument relies on the observer selection effect, otherwise known as anthropic reasoning. Imagine two urns containing sequentially numbered balls. You know that one has ten balls and the other has one million balls, but you do not know which is which. Imagine that you reach into one urn and pull out a ball labeled "#7." This would be a very strong indication that you had reached into the urn containing just ten balls. Similarly, imagine two possibilities, one where there will be 10^{11} humans, another with 10^{18} humans. You do not know which you are in, but you do, in fact, know you are #60 billion (just under 10^{11}). This may be a strong indication (with a probability of around 99.9999%) the world you are in is the first one and will soon go extinct. LESLIE, *supra* note 117, at 187.

Argument.[122] If one or more of these arguments are sound, we will almost certainly go extinct relatively soon. Unfortunately, we cannot presently confirm that even one of these arguments fails.[123]

While indirect methods of estimating existential risk give us reasons to prioritize making existential risk a focal point in our policy considerations, they have limited usefulness in helping identify and address the direct causes of a potential extinction-level event. Direct methods of risk assessment, on the other hand, look to specific potential existential risks as well as their range of causes and in doing so help reveal potential paths toward their prevention. The next subsection considers existential risk from the direct perspective.

B. Sources of Existential Risk

Existential risks can be divided into two broad categories: natural and anthropogenic. Potential extinction mechanisms with natural origins include asteroid impacts or supervolcanic eruptions. While these may be the existential risks discussed most frequently in news and fiction, natural existential catastrophes are known to occur infrequently because humanity and its precursors have survived for millions of years in the face of such threats.[124] The baseline likelihood of one occurring in the next hundred years is therefore very small—probably no more than 1

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[122] A technologically mature posthuman civilization would have enormous computing power capable of running simulations whose subjects are conscious. Therefore at least one of the following is true: (1) the fraction of civilizations like ours that reach a posthuman stage is very close to zero (that is, we will go extinct); (2) the fraction of posthuman civilizations that are interested in running conscious simulations (e.g. of their ancestors—people like us) is very close to zero; (3) very nearly all people with our kind of experiences are living in a simulation. If you, like many people, believe that we are not living in a computer simulation, then you are not entitled to believe that we will have descendants who will run lots of such simulations. Because we cannot know whether our descendants will want to run such simulations, you ought to considerably increase your credence in the belief that we will go extinct before producing such descendants. Nick Bostrom, *Are You Living in A Computer Simulation?* 53 PHIL. Q. 211, 243 (2003).

[123] The literature on these topics is still evolving. Part of the problem is that this scholarship is young and somewhat neglected. This suggests that there also may be (potentially many) crucial arguments we have not yet considered.

[124] The exact length of time depends on one's definition of "humanity." Early *Homo* species emerged about 2.5 million years ago, with *Homo erectus*, the first species to develop control of fire, emerging about 1.9 million years ago. Today's *Homo sapiens* emerged about 300,000 years ago. By contrast, humanity has survived fewer than eighty years with nuclear weapon capabilities.

in 10,000.[125] By contrast, with the advent of new technologies, our species is now creating entirely new kinds of risks—threats that we have no track record of surviving. For these anthropogenic risks, we cannot rely on our long history of survival as grounds for optimism. The odds of a human-caused existential catastrophe are probably at least 1,000 times higher than a natural existential event.[126] In fact, much of that risk may come from technologies intended to protect against natural risks but which introduce more danger than they prevent.[127]

Some risks are from mechanisms that could themselves directly cause extinction. These include present threats—nuclear war, reaching a point of no return for runaway climate change, and environmental depletion—as well as future threats, like manufactured biological agents, unaligned artificial intelligence, self-replicating nanotechnology, unexpected disaster from large-scale physics experiments, and geoengineering-caused adverse climate change.[128]

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[125] ORD, *supra* note 114, at 167.
[126] *Id*.
[127] *See, e.g.*, *infra*, Section IV(A)(1) (discussing asteroid deflection technology).
[128] *See generally* Bostrom, *supra* note 95 (listing potential extinction mechanisms).

Risk	Estimated probability of human extinction within 100 years
Asteroid or comet impact	~ 1 in 1,000,000
Supervolcanic eruption	~ 1 in 10,000
Stellar explosion	~ 1 in 1,000,000,000
Total natural risk	**~ 1 in 10,000** (.01%)
Nuclear war	~ 1 in 1,000
Climate change	~ 1 in 1,000
Other environmental damage	~ 1 in 1,000
"Naturally" arising pandemics	~ 1 in 10,000
Engineered pandemics	~ 1 in 30
Unaligned artificial intelligence	~ 1 in 10
Unforeseen anthropogenic risks	~ 1 in 30
Other anthropogenic risks	~ 1 in 50
Total anthropogenic risks	**~ 1 in 6** (16.67%)
Total existential risk	**~ 1 in 6** (16.67%)

Table 1. Source: ORD, supra *note 114, at 167. While these numbers are not meant to be precise, they capture an expert's sense of the orders of magnitude involved for each risk. Note that very nearly all of the total risk is anthropogenic.*

Existential risk is not determined just directly by technological threats, but also indirectly by social and legal regimes that help or hinder cooperation, altruism, and research. Of particular note is the fact that existential risk suffers from a massive collective action problem.[129] Reductions in existential risks are global public goods and are predictably undersupplied by private and public actors alike.[130] Each producer of existential safety—even a large nation—can capture only a

[129] Bostrom, *supra* note 99, at 26.
[130] *Id*.

small portion of the benefits; therefore, they are unlikely to respond to existential threats with vigor that reflects the social value of risk reduction.[131] Worse still, most of the beneficiaries of risk prevention are people who do not currently exist, multiplying the severity of the market failure.[132] Future people would be willing to pay the present generation enormous amounts of money or resources in return for even slight reductions of existential risk, but the mutually beneficial trade is hindered by the obvious fact that future people do not have a voice with which to negotiate.[133]

The collective action problem is particularly problematic because most existential risks demand international solutions.[134] Many risks cannot be substantially reduced by actions that are internal to one country.[135] For example, the scope of climate change is too large for one country to solve on its own.[136] In fact, some risks are only absolved with total global conformity.[137] For example, even if most countries closely regulate the creation of a dangerous nanotechnology, it takes only one country—or one actor within a country—that dissents or underestimates the risks to threaten the world.[138] This is called the Unilateralist's Curse[139] and it is especially problematic in the space context given the issue of flags of convenience.[140] Robust international coordination, and, in some cases, ceding decision-making authority to the larger group, is necessary to address these types of problems.[141]

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[131] *Id*. For example, a country may choose to mitigate existential risk only in proportion to their population, leaving other countries to make the same choice. But not all countries may do the same—some may freeride on the investments of others, knowing that it is in the other countries' interests to pick up their slack. The result is that countries tend to produce far less than their fair share of existential security.

[132] *Id*. at 27.

[133] *Id*. Accordingly, one of the clearest ways to reduce existential risk is to give future people greater representation in governance and decision-making. *See infra* Section V.

[134] *Id*.

[135] *Id*.

[136] *Id*.

[137] Nick Bostrom et al., *The Unilateralist's Curse and the Case for the Principle of Conformity*, 30 SOC. EPISTEMOLOGY 350, 351 (2016); Nick Bostrom, *The Vulnerable World Hypothesis*, 10 GLOBAL POL. 455, 462–70 (2019).

[138] Bostrom, *supra* note 137.

[139] Bostrom et al., *supra* note 137.

[140] *See supra* Section II(C).

[141] Bostrom et al., *supra* note 137, at 360.

Consider that human history is full of luck.[142] For example, scientists in the early 1940s worried that the first nuclear test, which would momentarily produce temperatures rivaling the sun and never before experienced on Earth, might cause a chain nuclear reaction and ignite the Earth's atmosphere and oceans.[143] They proceeded with the test anyways, and we are lucky in the sense that their worries did not pan out due to principles of physics we now better understand.[144] Luck may, however, someday run out. Humanity continues to uncover novel risks, so we should be cautious and unified as a species moving forward.[145] If scientists in the 1920s had been asked to compile a list of existential threats that would face humanity over the following hundred years, they would have completely missed most of the risks that concern us today.[146] We too are likely ignorant of risks that could turn out to be extremely pressing. In any case, the odds are unfortunately stacked against us: because an existential event only has to happen once to destroy humanity, repeated rolls of the dice stack up quickly. A quick mathematical check reveals that for the odds of extinction to surpass 99% over the next 100 years, the odds of an existential event occurring in any given year need only be 4.5%.[147] We have not yet survived eighty years with technologies capable of causing an existential catastrophe,[148] and each year is more dangerous than the last.[149] It is crucial, then, to consider how we might achieve existential security.

C. Achieving Existential Security

Because the vast majority of existential risk is anthropogenic, it is our own choices that will have the greatest impact on our odds of

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[142] *See, e.g.*, *List of Nuclear Close Calls*, WIKIPEDIA, https://en.wikipedia.org/wiki/List_of_nuclear_close_calls (last accessed Feb. 4, 2022).
[143] Bostrom, *supra* note 137, at 461
[144] *Id*. In 1954, the US carried out another nuclear test, which ended up exploding with a yield of 15 megatons rather than the planned 6 due to an unforeseen physics reaction. We are lucky in the sense that scientists were only wrong about the outcome of this test rather than the first one. *Id*.
[145] *Id*. at 457–58.
[146] *See* ORD *supra* note 114, at 162 (citing a 1937 governmental report on future technology that did not foresee nuclear energy, antibiotics, jet aircraft, transistors, computers, computers, or anything regarding space).
[147] The formula for the probability "p" of an event occurring at least once over some period of time "t" is 1-(1-p)^t. Where t=100, p need only equal 4.501% for the result to exceed 99%.
[148] The 1945 Trinity nuclear test marked the first time a technology was deployed that had an appreciable subjective likelihood of causing an existential catastrophe. ORD, *supra* note 114, at 92.
[149] Bostrom, *supra* note 137.

survival.[150] Therefore, we must be deliberate about our policymaking. We cannot rely just on our intuitions, social attitudes, and existing policies, which are all calibrated for dealing with risks we have already encountered.[151] For example, we cannot sit back and rely on the traditional method of trial-and-error.[152] There will be no opportunity to learn from and adapt to an error that destroys us.[153] Similarly, purely *ex post* forms of punishment (liability, criminal or trade sanctions, or threats of military reprisal) are in this context insufficient deterrents for risky behavior; for, in the event of an existential catastrophe, there would be no opportunity to actualize the punishment.[154] Rather than being reactive, we must be proactive, use foresight to anticipate new types of threats, and be willing to take decisive preventive actions before a catastrophe occurs.[155]

Existential risk expert Toby Ord proposes a strategic plan for humanity that would prioritize reaching existential security before engaging in a long period of reflection about what matters most, and only then focusing on actualizing our fullest potential.[156] Reaching existential security requires making it an explicit, persistent priority to do away with sources of existential risk that threaten to prematurely end humanity's projects.[157] In particular, it is crucial to avoid letting our practices be steered astray by other tempting goals. Even well-intentioned scientific investigation can be a source of catastrophic risk, as with retrieving potentially contaminated materials from other planets or uncovering a new dangerous technology.[158] Similarly, pursuing commercial or nationalistic goals such as harvesting space resources may offer immediate gains for some but create medium- and long-term risks for all.[159] Tempering the influence of private interests is particularly difficult in the age of global financial capitalism, where money not only offers

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[150] *See* discussion *supra* Section III(B) (describing anthropogenic risk).
[151] Bostrom, *supra* note 95, at 3–4, 20–26.
[152] *Id*.
[153] *Id.* Wiener, *supra* note 104, at 76.
[154] Wiener, *supra* note 104, at 73.
[155] *Id*. at 76–77; Bostrom, *supra* note 95, at 20–21.
[156] ORD, *supra* note 114, at 189.
[157] *Id*.
[158] *See infra* Sections IV(A)(1) and (2) (discussing these risks in a space context).
[159] See *infra* Section IV (discussing specific risks from uncoordinated private and national space development).

paths to pursue one's personal goals but can also be used to alter policy and legal regimes through lobbying.[160]

Because of the strong need for international coordination and conformity on some matters,[161] tribalism, including nationalism, is another powerful influence worth acknowledging and at times resisting.[162] As social animals, humans are ill-equipped to live on their own and have therefore evolved with a propensity for social bonding and commitment to an identifiable group.[163] Competition between groups may have served humanity well in the past by helping select for certain traits, but those traits are ill-fitted for the existential threats now facing our species.[164] Intergroup hostility makes species-wide cooperation and coordination more difficult, incentivizing people to spend their lives and resources dominating each other instead of overcoming the threats we all have in common.[165]

Still, we appear to be making progress—moral attitudes are slowly changing to be more inclusive, and most technologies are leveraged for good.[166] The crucial question is whether our collective wisdom will catch up to technological development before an existential catastrophe occurs. To that end, it is worth considering the role space and space technologies may play in contributing to existential risk.

IV. EXISTENTIAL RISKS FROM SPACE DEVELOPMENT

In this Section, I identify ten sources of space-related existential risk, loosely categorized as either *sudden* or *gradual*. Sudden risks are triggered when some particular type or quantity of activity occurs and the consequences are felt over a relatively short amount of time. By contrast, gradual risks are those whose consequences scale up (e.g. linearly or

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[160] *See generally* KATHARINA PISTOR, THE CODE OF CAPITALISM: HOW THE LAW CREATES WEALTH AND INEQUALITY (2019) (discussing the mutual reinforcement of capital and legal regimes).
[161] *See supra* notes 129–141 and accompanying text.
[162] *See generally* RON NEWBY, TRIBALISM: AN EXISTENTIAL THREAT TO HUMANITY (2020) (describing one layperson's perspective about the influence of tribalism from an existential perspective).
[163] *See generally* HAROLD ISAACS, IDOLS OF THE TRIBE: GROUP IDENTITY AND POLITICAL CHANGE (1975) (describing the origin and function of tribal mentalities).
[164] Bostrom, *supra* note 95, 3–4.
[165] *See* Jay Jackson, *Realistic Group Conflict Theory: A Review and Evaluation of the Theoretical and Empirical Literature*, 43 PSYCH. RECORD 395, 395 (1993) (describing the ways intergroup hostility and feelings of outgroup prejudice can arise as a result of conflicting goals and competition over limited resources).
[166] Bostrom, *supra* note 99, at 27.

exponentially) with more activity. Preventing sudden risks generally requires that we avoid performing whatever activity generates the catastrophe (or passing whatever threshold beyond which the catastrophe would be triggered), while gradual risks may be alleviated incrementally across time.

With this categorization in hand, I identify four sudden risks: (1) dangerous asteroid trajectory-modification technologies, (2) back contamination of the Earth, (3) military and geopolitical conflict, and (4) dangers from developing extraterrestrial settlements. I also identify six gradual risks: (1) damage to Earth's biosphere or general environment, (2) space debris, (3) light pollution interfering with terrestrial astronomy, (4) risks from insufficient monitoring of rocket payloads, (5) squandering of valuable space resources, and (6) dangerous economic acceleration or disruption. I argue that all ten of these risks are exacerbated by a lack of coordination and cooperation under the current space law and policy regime.

A. Sudden Risks

1. *Dangerous asteroid trajectory-modification technologies*

People often assume a large share of existential risk comes from asteroids.[167] Accordingly, asteroid, comet, and meteor detection and deflection receives substantially more funding than research into many other sources of existential risk.[168] Scientists have devised creative ways to blast or lure celestial objects off course, some of which are being tested by NASA.[169] However, in reality, the natural risk of extinction via a large asteroid or meteor strike is extremely small.[170] Because so many potentially hazardous objects have been detected and their orbits tracked,

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[167] *See* Bostrom, *supra* note 95, at 18 (describing a "good-story bias" as applied to asteroids).

[168] *Compare* Casey Dreier, *How NASA's Planetary Defense Budget Grew By More Than 4000% in 10 Years*, PLANETARY SOCIETY (Sept. 26, 2019), https://www.planetary.org/articles/nasas-planetary-defense-budget-growth (noting approximately $150 million in annual NASA funding for planetary defense) *with Changes in Funding in the AI Safety Field,* CENTRE FOR EFFECTIVE ALTRUISM, (Feb. 1, 2017) https://www.centreforeffectivealtruism.org/blog/changes-in-funding-in-the-ai-safety-field (noting less than $10 million annual global spending on AI safety).

[169] *See* Daisy Dobrijevic, *DART asteroid mission: NASA's first planetary defense spacecraft*, SPACE.COM (Oct. 29, 2021), https://www.space.com/dart-asteroid-mission (describing NASA's in-progress Double Asteroid Redirection Test which involves crashing a satellite into an asteroid to redirect its path).

[170] ORD, *supra* note 114, at 71.

we have enough data to know that the baseline probability of an Earth-impact in an average century is about one in 1.5 million for asteroids large enough to pose an existential threat (diameters of ten kilometers or more).[171] Better yet, more than ninety-five percent of asteroids larger than one kilometer have already been detected, and none of them are on a trajectory with an appreciable chance of colliding with the Earth, bringing the odds of a threatening impact to less than one in 150 million.[172]

By contrast, there is considerable risk in deploying anti-asteroid technology. Any technology capable of deflecting an asteroid *away* from a collision course with Earth could also be used to move an asteroid *into* a collision course with Earth. Carl Sagan and Stephen Ostro make the point that "premature deployment of any asteroid orbit-modification capability, in the real world and in light of well-established human frailty and fallibility, may introduce a new category of danger that dwarfs that posed by the objects themselves."[173] Indeed, the odds of extinction by an asteroid guided towards the Earth are almost certainly much greater than one in 150 million.

The risks from dangerous asteroid orbit-modification technologies are multifaceted.[174] Using asteroid redirection technology, actors may take risky actions that they perceive to be in their self-interests but actually have destructive results[175]—an eccentric billionaire or mining company, motivated by money, power, or status, redirecting an asteroid to the Earth for ease of resource exploitation; a nation, motivated by a desire to secure geopolitical or ideological advantage, using an asteroid as a threat or weapon. Even where efforts are well intentioned, some risks come from the potential for accidents such as malfunctions or miscalculations of the dangers.[176] Other risks come from coordination problems: disjointed efforts by various actors could inadvertently send an asteroid into an undesired trajectory. Also, diplomatic concerns may create additional difficulties, such as debates over how to allocate risks between certain countries during the redirection process.[177]

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[171] *Id*.
[172] *Id*.
[173] Carl Sagan & Steven Ostro, *Dangers of Asteroid Deflection*, 368 NATURE 501, 501 (1994).
[174] Bostrom, *supra* note 137.
[175] *Id*.
[176] *Id*.
[177] *See* Alexis Madrigal, *Saving Earth From an Asteroid Will Take Diplomats, Not Heroes*, WIRED (Dec. 19, 2009), https://www.wired.com/2009/12/saving-earth-from-an-asteroid/ ("[Some groups] propose to bump or tow an asteroid 'in a controlled manner' so that it misses Earth. The only problem is that such a

Then there is what Nick Bostrom describes as "the apocalyptic residual"—the near-guarantee that there are actors who would act in ways that intentionally destroy civilization.[178] Some existential risk comes from the possibility that members of the apocalyptic residual become empowered to destroy humanity.[179] Consider that members of Aum Shinrikyo, a Japanese doomsday cult, released anthrax spores from a cooling tower in 1993 in an attempt to start a pandemic, and in 1994 and 1995 carried out high-profile deadly sarin gas attacks.[180] After the attacks, police raided the group's headquarters and were astounded to find weapons-manufacturing technology, a Russian military helicopter, and enough sarin gas to kill four million people.[181] Aum Shinrikyo members hold the belief that killing people is a form of saving them from bad karma and aspire to cause a worldwide nuclear Armageddon.[182] Members of groups like Aum Shinrikyo have sought to obtain weapons capable of threatening humanity and, if successful, would likely choose to use them.[183] Orbit modification technologies could be another tool for misuse and abuse by such apocalyptic groups, especially if such technologies eventually become popularized.[184]

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process would take time and as the asteroid's trajectory changed, it would be 'pointed' at different places along a horizontal plane on Earth called the risk corridor. That's a major geopolitical problem … because it requires temporarily increasing the risk to one population … to eventually eliminate the risk for the entire Earth.")

[178] Bostrom, *supra* note 137, at 460 ("Given the diversity of human character and circumstance, for any ever so imprudent, immoral, or self-defeating action, there is some residual fraction of humans who would choose to take that action."). *See generally* Karl Umbrasas, *The Life Course of Apocalyptic Groups,* 11 J. STRATEGIC SEC. 32 (2018) (describing apocalyptic groups).

[179] Bostrom, *supra* note 137, at 460.

[180] Hiroshi Takanashi et al., *Bacillus anthracis Bioterrorism Incident, Kameido, Tokyo,* 1993, 10 EMERGING INFECTIOUS DISEASES 117, 117–20 (2004).

[181] Holly Fletcher, *Aum Shinrikyo*, COUNCIL ON FOREIGN RELATIONS (June 19, 2012), https://www.cfr.org/backgrounder/aum-shinrikyo.

[182] Umbrasas, *supra* note 178.

[183] *See, e.g.*, Danzig et al., *Aum Shinrikyo: Insights Into How Terrorists Develop Biological and Chemical Weapons*, CTR. NEW AM. SEC. (2011); *see also* K.B. Olson, *Aum Shinrikyo: Once and Future Threat*?, 5 EMERGING INFECTIOUS DISEASES, 513 (1999); *see also* ROLF MOWATT-LARSSEN, BELFER CTR. FOR SCI. & INT'L AFF., AL QAEDA WEAPONS OF MASS DESTRUCTION THREAT: HYPE OR REALITY? (2010).

[184] In one science fiction series, anti-Earth insurgents located in the outer reaches of the solar system use simple asteroid mining spacecraft to lob numerous large asteroids at the Earth to disastrous effect. *See* JAMES S. A. COREY, NEMESIS GAMES 2015.

Because of both deliberate and unintentional perils, dangerous technologies must be carefully monitored and safeguarded from falling into the wrong hands. Unless and until we can be overwhelmingly confident that orbit-modification technologies or any other dangerous emergent space technologies are safe enough to allow for use under properly regulated conditions, there is a need for international coordination to minimize the risks, potentially including restrictions or regulations on specific technology usage and the development of surveillance and enforcement capabilities. However, the current system of decentralized state supervision set in place by the OST is grossly inadequate for these purposes, in part due to the risk of dangerous activities proliferating under flags of convenience.[185]

2. *Back contamination and planetary protection*

Space development carries risks of back contamination, the transfer of potentially harmful extraterrestrial organisms or other contamination into Earth's biosphere.[186] History is ridden with examples of the harmful introduction of biota to new environments, including microbes following human migrations sparking epidemics like malaria, the bubonic plague, and smallpox,[187] and invasive species that outcompete and threaten native populations.[188] There are concerns that spacecrafts returning from missions to other celestial bodies could inadvertently carry microbial organisms or other unforeseen contaminants that, if introduced into the Earth's biosphere, might have devastating runaway effects like starting a deadly pandemic or consuming all the Earth's oxygen in a chemical chain reaction.[189] These risks are now more salient than ever thanks to increases in space activity, including independent Mars sample return missions planned by the US and China.[190]

Article IX of the OST calls on nations to adopt measures that help avoid causing "adverse changes in the environment of the Earth

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[185] See *supra* Section II(C) (describing the issue of flags of convenience).
[186] *See* Shu Boboila, *A Multi-Agency Regulatory Framework to Prevent Interplanetary Contamination, in* Hamilton et al., *supra* note 3, at 2 (noting concerns about back contamination procedures).
[187] CHARLES SUTHERLAND ELTON, THE ECOLOGY OF INVASIONS BY ANIMALS AND PLANTS 196 (Univ. of Chi. Press Ed. 2000).
[188] H. A. Mooney & E. E. Cleland, *The Evolutionary Impact of Invasive Species*, PNAS (May 8, 2001), https://www.ncbi.nlm.nih.gov/pmc/articles/PMC33232/.
[189] Wiener, *supra* note 104, at 74.
[190] Paul Marks, *Why Bringing Martian Rocks back to Earth Is a Bad Idea*, NEWSCIENTIST (Apr. 28, 2021), https://www.newscientist.com/article/mg25033323-100-why-bringing-martian-rocks-back-to-earth-is-a-bad-idea/.

resulting from the introduction of extraterrestrial matter[.]"[191] However, this provision has no history of enforcement, and in any case, spacefaring nations are permitted to vary in their approaches to preventing back contamination.[192] Given this weak legal backdrop, it is not difficult to imagine governments or private actors failing to take adequate prevention measures, whether intentionally to reduce costs and inconveniences or unintentionally due to substandard scientific understanding or misevaluation of the risks. Illustratively, in what was hailed at the time as "a major gap in the quarantine defenses,"[193] NASA itself circumvented the United States' own Congressionally-backed contamination procedures, deciding independently that it would risk exposing the atmosphere to lunar dust for the first time in order to expedite retrieval of the Apollo 11 astronauts.[194] The fact that such decisions are left to space actors exacerbates a public goods problem where the costs of mitigation are borne fully by those who would only receive a fraction of the overall benefit.[195] Coordination is needed to secure conformity in actors' commitments to avoiding back contamination.

3. *Military and geopolitical conflict*

Military and geopolitical conflict is one of the most significant direct and indirect sources of existential risk.[196] One major risk comes from the direct threat of nuclear war.[197] Thousands of nuclear weapons

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[191] *Supra* note 19.
[192] Victoria Sutton, *Planetary Protection and Regulating Human Health: A Risk that is Not Zero*, 19 HOUS. J. HEALTH L. & POL'Y 71, 85 (2020). The US and China currently follow COSPAR's nonbinding recommendations. COSPAR POLICY ON PLANETARY PROTECTION (2021), https://cosparhq.cnes.fr/assets/uploads/2021/07/PPPolicy_2021_3-June.pdf.
[193] *Space: Is the Earth Safe from Lunar Contamination?*, TIME MAG. (June 13, 1969), http://content.time.com/time/subscriber/article/0,33009,942095,00.html.
[194] *See* Wiener, *supra* note 104, at 74 ("When the Apollo 11 capsule returned to earth from landing on the moon in 1969, it splashed down at sea and the ship approached to retrieve it. While the original quarantine protocol had called for the astronauts to remain inside the sealed spacecraft until it was lifted onto the ship's deck and into the quarantine facility, 'NASA officials began to have second thoughts about the discomforts the astronauts would endure if they were confined too long in a hot spacecraft buffeted by ocean waves. . . Deciding to trade one risk for another, NASA, without fanfare, changed its recovery plan.'").
[195] *See supra* Section III(B) (describing the public goods problems inherent in existential risk mitigation).
[196] *See* ORD, supra note 114, at 175–176 (noting that great power conflicts make up a greater share of total existential risk than any individual risk).
[197] Joseph Cirincione, *The Continuing Threat of Nuclear War, in* GLOBAL CATASTROPHIC RISKS, *supra* note 102, at 382.

sit on hair-trigger alert with a non-negligible chance of use each year, sometimes even due to mistakes.[198] Enough nuclear detonations might render the global environment unsuitable for human life.[199] Additionally, geopolitical rivalries push the boundaries of research into other dangerous technologies, such as nanotechnology or bioweapons that could be deployed to even more devastating effect.[200] Such rivalries also foster distrust that makes cooperation on other issues, such as climate change, more difficult.[201]

Space development can and does serve as a source of destabilization and conflict, both in space and on the Earth.[202] First, as commercial interests become increasingly important and competitive, they raise the stakes of control over space and invite aggressive behaviors.[203] In addition to the enormous commercial and strategic value of Earth's orbital planes,[204] the asteroid belt between Mars and Jupiter is estimated to be worth quintillions of dollars.[205] A new space race may be

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[198] *Id.* ("In January 1995, a global nuclear war almost started by mistake. Russian military officials mistook a Norwegian weather rocket for a US submarine-launched ballistic missile. Boris Yelstin became the first Russian president to ever have the 'nuclear suitcase' open in front of him. He had just a few minutes to decide if he should push the button that would launch a barrage of nuclear missiles. Thankfully, he concluded that his radars were in error.").

[199] *Id*.

[200] *See, e.g.*, Ali Nouri & Christopher F. Chyba, *Biotechnology and Biosecurity*, *in* GLOBAL CATASTROPHIC RISKS, *supra* note 102, at 451 (noting the development of dangerous biotechnology by geopolitical rivals).

[201] *See supra* note 131 and accompanying text (describing freeriding incentivized by national self-interest).

[202] Stuart Clark, *'It's Going to Happen': Is the World Ready for War in Space?*, GUARDIAN (Apr. 15, 2018), https://www.theguardian.com/science/2018/apr/15/its-going-to-happen-is-world-ready-for-war-in-space.

[203] *Id*. *See also* DEUDNEY, *supra* note 10, at 198 ("It is unclear why[, to space expansionists,] the often violent conflicts over mineral resources on Earth would not also expand into space.").

[204] *See* Akhil Rao, *The Economics of Orbit Use: Theory, Policy, and Measurement* iii, (2019) (Ph.D. thesis, University of Colorado), https://www.pnas.org/content/117/23/12756 (noting the economic value of orbit use to be on the scale of trillions of dollars).

[205] Bi India Bureau, *Asteroids Contain Metals Worth Quintillions of dollars—But Mining Them Won't Necessarily Make You Richer Than Bezos or Musk* , BUS. INSIDER (https://www.businessinsider.in/science/space/news/asteroids-contain-metals-worth-quintillions-of-dollars-but-mining-them-wont-necessarily-make-your-richer-than-bezos-or-musk/articleshow/83989878.cms (June 30, 2021), https://www.businessinsider.in/science/space/news/asteroids-contain-metals-worth-quintillions-of-dollars-but-mining-them-wont-necessarily-make-your-richer-than-bezos-or-musk/articleshow/83989878.cms.

emerging to stake claims to these resources as well as the even more limited ones available on the Moon and Mars.[206] Economic competition is historically the most significant factor precipitating global conflict,[207] especially in conditions permitting colonial powers to exercise territorial influence from afar.[208] These tensions are further exacerbated by the ubiquity of dual-use technologies in space,[209] which has already caused tension between commercial company SpaceX and China's military.[210] Given this backdrop, one researcher describes space conflict as "absolutely inevitable[.]"[211]

Second, space weaponization may upset the fragile equilibria underpinning mutually-assured destruction. In the age of nuclear deterrence, strategic stability involves a complex combination of factors, including crisis stability—the propensity of actors to not escalate conflict, even in times of crisis—and arms race stability, the propensity to avoid deployments that incentivize first strikes.[212] Space-based military assets complicate these factors, sometimes unpredictably.[213] Unlike ground-based missiles, space-based weapons have easy and quick access to attacks anywhere on the globe, leaving few opportunities for early-warning, prevention, and retaliation systems to activate in time to be effective—decreasing crisis stability.[214] From space, it is also easier to strike without it being clear which actor is responsible, reducing the

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[206] Justin Bachman, *New Space Race Shoots for Moon and Mars on a Budget*, WASH. POST (Aug. 22, 2021), https://www.washingtonpost.com/business/new-space-race-shoots-for-moon-and-mars-on-a-budget/2021/08/20/5f7a0eac-01c7-11ec-87e0-7e07bd9ce270_story.html.
[207] Daron Acemoglu et al., *A Dynamic Theory of Resource Wars*, 127 Q. J. ECONS. 283, 283 (2012).
[208] *See generally* THOMAS RID & THOMAS KEANEY, UNDERSTANDING COUNTERINSURGENCY WARFARE: DOCTRINE, OPERATIONS, AND CHALLENGES (2010) (describing the heightened risks of conflict among colonial powers); *see also* DEUDNEY, *supra* note 10, 345–46 (describing the link between expansionism and conflict as applied to space).
[209] *See supra* notes 61–65 and accompanying text (describing dual-use technologies in space).
[210] Li Xiaoli, *Starlink's expansion, military ambitions alert world*, CHINA MILITARY ONLINE (May 5, 2022), http://eng.chinamil.com.cn/view/2022-05/05/content_10152439.htm.
[211] Clark, *supra* note 202 (quoting Michael Schmitt).
[212] Christopher Chyba, *New Technologies & Strategic Stability*, 149 DAEDALUS 150, 155 (2020) (describing space weaponization).
[213] Jürgen Altmann, *Space Laser Weapons: Problems of Strategic Stability*, 19 BULL. PEACE PROPOSALS 343, 347 (1988).
[214] DEUDNEY, *supra* note 10, at 235.

perceived risk of retaliation and therefore raising the risk of a first strike.[215]

Also, satellites function as force multipliers, which creates risks. Satellites have brought about a so-called "accuracy revolution" which has increased the ability of missiles to hit targets precisely.[216] With sufficiently detailed information about the positions of enemy forces—perhaps guided by artificial intelligence[217]—the risks rise that an actor may launch an attack in an attempt at a disarming first strike.[218]

The strategic importance of satellites makes the deployment of ASATs a particularly pressing problem. Satellites serve as a cornerstone in modern warfare and deterrence via early warning, surveillance, and the command, control, and communication of nuclear forces. ASATs are therefore crucial tools in disabling an adversary's ability to retaliate. If ASAT capacity reaches a critical mass, then an actor may perceive that the scales have tipped in favor of a first strike. Also, even if an ASAT is used in a limited strike and not as part of a comprehensive first strike plan, a blinded adversary may believe it is under a more severe attack and quickly retaliate with its arsenals. Furthermore, even if ASATs are not actually used at all, their mere deployment increases the risk of accidental or inadvertent warfare escalation. If satellites unexpectedly go offline, a nation may believe it is under attack. With constellations of military satellites travelling at high velocities in an environment increasingly filled with space debris, false alarms are inevitable and may be attributed to an adversary's ASAT.

Finally, space weaponization lends itself to the creation of more devastating and costly forms of warfare. For one, conflict in space would create enormous amounts of space debris.[219] Many weapons have a large area of effect, the most noteworthy of which are nuclear weapons which, when exploded in or near space, would disable swaths of both civil and military satellites.[220] (Many people may overlook the fact that any nuclear state equipped with ballistic missiles possesses latent, indiscriminate ASATs.)[221] Worse still, humanity continues to devise new

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[215]Chyba, *supra* note 212; *see also* Gwern Branwen, *Colder Wars*, www.gwern.net/Colder-Wars (last visited Feb. 1, 2022) (considering hypothetical first-strike scenarios).
[216] DEUDNEY, *supra* note 10, at 159.
[217] Chyba, *supra* note 212.
[218] Chyba, *supra* note 212; DEUDNEY, *supra* note 10, at 161.
[219] Ramin Skibba & Undark, *The Ripple Effects of a Space Skirmish*, ATLANTIC (July 12, 2020), https://www.theatlantic.com/technology/archive/2020/07/space-warfare-unregulated/614059/.
[220] DEUDNEY, *supra* note 10, 165–66.
[221] *Id*.

destructive techniques to mar each other.[222] In the context of space there is already discussion of weaponized asteroids or planetoids,[223] mass drivers exploited for kinetic bombardment,[224] and planet-killing nuclear, antimatter bombs, or geoengineering devices developed by enemies of the Earth.[225] To prevent such speculative weapons from being made real, there is a strong need for confidence-building measures and progress towards norms of disarmament and demilitarization.

4. *Risks from developing extraterrestrial settlements*

Becoming a multiplanetary civilization may need to be an essential part of humanity's long-term strategy for achieving existential security.[226] Many existential risks are global in scope, not extraglobal; so, having a self-sustaining extraterrestrial settlement[227] would raise the chances that humanity survives what would otherwise be an existential catastrophe.[228] With such a settlement, a planet-wide catastrophe would be overwhelmingly tragic but at least not species ending, giving humanity a chance to learn from its mistakes. It is undeniably a good idea to also heavily invest in specific existential risk mitigation measures, such as researching safe technology development. However, it is also important to recognize that it is a tall order to get all of our precautions sufficiently right the first time. There is considerable value in

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222 *See also The Most Dangerous Space Weapons Ever*, SPACE.COM (Dec. 21, 2016), https://www.space.com/19-top-10-space-weapons.html.
223 DEUDNEY, *supra* note 10, at 176.
224 *Id*. at 177.
225 *Id*. at 207–11.
226 NEWITZ, *supra* note 2.
227 There are substantial differences between "settlement" and "colonization;" it is crucial to examine these differences to avoid perpetuating colonialist or imperialist thoughts and practices in space. *See* Mike Wall, *Bill Nye: It's Space Settlement, Not Colonization,* SPACE.COM (Oct. 25, 2019), https://www.space.com/bill-nye-space-settlement-not-colonization.html (describing some objectionable features of colonialism in the space context).
228 Of the known existential risks, many of them would likely only affect a single planet: asteroid impact, supervolcanic eruption, climate change, and environmental damage, including from a nuclear war. Some existential risks might affect multiple planets, depending on the circumstances: stellar explosion or other cosmic events, pandemics, unaligned artificial intelligence, or some other dangerous emergent technology. For these risks, a multiplanetary civilization still has more opportunities to survive—for example, with sufficient quarantining protocols, a pandemic might be prevented from spreading between planets.

diversifying our existential risk mitigation strategy by including both specific and general mitigation measures.[229]

While the development of extraterrestrial settlements may be useful in a long-term strategy for human development, it would not be worth rushing for if it came at the cost of imposing even small degrees of existential risk.[230] Because of the long time horizons involved in establishing self-sustaining settlements that genuinely do not rely on Earth,[231] they may be of little use for existential security in the near term.[232] Also, the opportunity costs in delaying may be very small or even nonexistent, as technologies in the future will likely make the development of self-sustaining settlements easier, safer, and faster. In fact, if technology growth is rapid enough, then a space settlement that

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[229] *See* Owen Cotton-Barratt et al., *Defence in Depth Against Human Extinction: Prevention, Response, Resilience, and Why They All Matter*, 11 GLOB. POL. 271, 272 (2020) (describing a multilayered strategy for existential security including prevention, response, and resilience).

[230] Nick Bostrom, *Astronomical Waste: The Opportunity Cost of Delayed Technological Development*, 15 UTILITAS 308, at *5 (2003) ("Because the lifespan of galaxies is measured in billions of years, whereas the time-scale of any delays that we could realistically affect would rather be measured in years or decades, the consideration of risk trumps the consideration of opportunity cost. For example, a single percentage point of reduction of existential risks would be worth (from a utilitarian expected utility point-of-view) a delay of over 10 million years. Therefore, if our actions have even the slightest effect on the probability of eventual colonization, this will outweigh their effect on when colonization takes place.").

[231] By current estimations, a genuinely self-sustaining settlement will take hundreds of years to establish, given the difficulty of adapting to harsh space environments. Kelsey Piper, *The case against colonizing space to save humanity*, VOX (Oct. 22, 2018), https://www.vox.com/future-perfect/2018/10/22/17991736/jeff-bezos-elon-musk-colonizing-mars-moon-space-blue-origin-spacex; *see also* DEUDNEY, *supra* note 10, 363–64 (noting it is very uncertain how long self-sustaining settlements would take, but estimating "several centuries"). Further, optimistic estimates do not fully consider the degree of dependence a space settlement would have on Earth. *See* Patrick Wilson et al., *Systems for Resource Equality in Martian Society from* Foundation to Independence, in Hamilton et al., *supra* note 3, 88–92.

[232] Marko Kovic, *Risks of space colonization*, 126 FUTURES 102638, at *4 (2021) ("Early colonization efforts are unlikely to mitigate existential risks as much as targeted existential risk mitigation strategies because the early stages of colonization are bound to be small in scale and fragile. Early habitats would in effect do next to nothing to mitigate existential risks, so creating those early habitats as quickly as possible would do very little in terms of existential risk mitigation.").

starts later may actually be the one that becomes self-sustaining sooner.[233]

Unfortunately, the development of space settlements may in fact create more existential risk. First, the process of establishing a settlement may be costly in ways that negatively impact survival prospects for Earth. The development of a settlement, such as on Mars, would demand many resources from the Earth. For example, although Mars is known to have some in situ water, a settlement will likely still demand tremendous amounts of fresh water from the Earth, which could exacerbate resource tensions underpinned by climate change.[234]

Second, as humanity becomes increasingly dispersed across space, various other risks rise. There is no guarantee about the types of political, cultural, or other social traditions that may emerge.[235] Some space settlement advocates consider this to be a virtue, but it may also be a vice. One disadvantage is that existence of extraterrestrial settlements may make it more difficult to surveil and enforce against existentially-risk activities,[236] such as the development of dangerous artificial intelligence.[237]

Another disadvantage is that the development of a space diaspora may guarantee the emergence of deadly interplanetary conflict.[238] Expansion across the solar system would almost certainly result in extreme diversities in human culture and governance which, when combined with high effective distances and the inevitable capacity to readily inflict destruction on each other, creates a breeding ground for

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[233] A similar hypothesis in interstellar travel contexts is the "incessant obsolescence postulate," according to which the speed of technology development makes it more advantageous to launch later rather than sooner, because the later, more advanced ships will pass the earlier, less advanced ships en route. *See* Andrew Kennedy, *Interstellar Travel—The Wait Calculation and the Incentive Trap of Progress*, 59 J. OF THE BRIT. INTERPLANETARY SOC'Y. 239, 242 (2006) (describing a calculation for optimal start times in situations of of rapid technological growth). A delayed-start settlement may have more technologically advanced foundations compared to its earlier counterpart that enhance reliability, better conserve finite resources, and speed up the process of becoming self-sustaining.
[234] Wilson et al., *supra* note 231, at 89.
[235] Phil Torres, *Space colonization and suffering risks: Reassessing the "maxipok rule"*, 100 FUTURES 74, 74 (2018); DEUDNEY, *supra* note 10, at 220.
[236] DEUDNEY, *supra* note 10, at 208, 359.
[237] *Id*. at 360.
[238] *See id*. at 356 (describing nine reasons space expansion will trend towards conflict).

intense rivalries.[239] Solar system-wide common governance and mutual restraints may be very difficult to create and sustain.[240] In the explosion of culture, there will also almost certainly be some actors who desire to cause widespread harm.[241] Given humanity's track record on Earth, it is difficult to imagine a populated solar system without a generous serving of violence. If the means of destruction are sufficiently high, as would be nearly guaranteed in a scenario where the technology necessary to support expansive space settlement exists, then the result may be an increase in overall existential risk.[242]

In sum, humanity may eventually benefit from settling off of Earth, but it needs to get its act together before setting off on a course that leads to ruination. The current open-access space regime does not contemplate such needs; actors continue to race towards developing space settlements before knowing (or without caring) whether a peaceful future is possible, and if so, how it may be guaranteed. Crucially, such questions must be addressed before expansion is too far underway. Once started, space expansion might be impossible to stop or even regulate, such as if a settlement becomes both self-sustaining and politically independent from the Earth.[243] Also, the foundations of any space expansion effort may have an enormous influence on whether the path ends in peace or conflict.[244] For example, upon reflection, we may find that settlements founded by people with peaceful ideologies and robust governance systems are less likely to eventually cause conflict than settlements founded for the sole purpose of profit maximization or under heterogeneous or libertarian ideologies. Here, as elsewhere, it is better to be cautious and coordinated than speedy and reckless.

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[239] *Id*. at 357; Torres, *supra* note 235, at 79 ("[E]xpansion into space will generate phylogenetic and ideological diversity that could yield profoundly disparate types of civilizations. The species who comprise these civilizations could have entirely different normative preferences, moral tendencies, and even scientific institutions. Some will almost certainly be violence-inclined, thus giving others an incentive to strike first. Even more, diversity with respect to cognition, emotionality, and language will undercut the mutual trust needed for otherwise irenic civilizations to avoid spirals of militarization or defect in prisoner's dilemma predicaments. Thus, a colonized cosmos would be an arena poised and spring-loaded for violence.")

[240] DEUDNEY, *supra* note 10, at 357; *see also* notes 178–184 and accompanying text (describing the "apocalyptic residual").

[241] Torres, *supra* note 235, 77–78.

[242] *Id*. at 80–81 (discussing so-called "weapons of total destruction").

[243] DEUDNEY, *supra* note 10, at 363.

[244] See *infra* notes 327–329 and accompanying text (describing governance of the cosmic commons).

B. Gradual Risks

1. *Biosphere damage and environmental approaches*

Many potential extinction scenarios involve modification to Earth's environment.[245] Runaway anthropogenic climate change, in the worst-case (albeit unlikely) scenarios, could trigger amplifying feedback loops—the same process that apparently led to Venus becoming the inhospitable planet we see today.[246] More concerning in the near term are the stressors that climate change is sure to cause—climate change, already a major geopolitical issue, may leave us more prone to other existential risks, such as war over depleting resources.[247] Another worrying scenario is that actors could deploy geoengineering techniques intending to reverse climate change, but end up inadvertently rendering Earth's environment uninhabitable.[248]

The point generally emphasizes the need for global coordination, but it also directly implicates space policies. For example, the risks of geonengineering technologies being deployed on Earth may be related to the development of similar techniques for terraforming Mars.[249] Also, rocket engine exhaust impacts the atmosphere.[250] As byproducts of the launch process, emissions of chlorine, alumina, and black carbon directly into the sensitive stratosphere can cause ozone depletion and other forms of climate change.[251] While rocket pollution is only one of many contributors to climate change, the full scope of the problem is not yet well understood, and other climate change contributors are generally not slowing down. Furthermore, dramatic increases in space activity fueled by increasingly frequent rocket launches could strain an already

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[245] ORD, *supra* note 114, at 102–112. *See also* David Frame & Myles R. Allen, *Climate Change and Global Risk*, *in* GLOBAL CATASTROPHIC RISKS, *supra* note 97, at 265 (describing the difficulty in quantifying climate change risks).
[246] Luckily, while the science is far from settled, current research suggests that such results are unlikely due to anthropogenic effects. ORD, *supra* note 114, at 104.
[247] *Id*. at 103.
[248] *See* ANNUAL REPORT OF THE GOVERNMENT CHIEF SCIENTIFIC ADVISER. INNOVATION: MANAGING RISK, NOT AVOIDING IT 117 (2014) (describing geoengineering risk scenarios).
[249] DEUDNEY, *supra* note 10, at 207.
[250] Nicole Mortillaro, *Rocket Launches Could Be Affecting Our Ozone Layer, Say Experts*, CBC NEWS (Apr. 22, 2021), https://www.cbc.ca/news/science/rocket-launches-environment-1.5995252.
[251] *Id*.

weakened atmosphere. Launches have increased exponentially since at least 2002.[252]

Space activities may also indirectly affect environmental risks on Earth. Some scholars worry about opportunity costs—some of the resources that go to space activities might otherwise have been put towards better environmental uses.[253] Others worry that emphasizing the viability of extraterrestrial settlements may contribute to moral hazard, a situation under economic thought where perceived protection from risks cause actors to lack incentive to guard against those risks. In the worst case, the fervor of space expansion may contribute to a "disposable planet mentality" under which some actors neglect to protect the Earth (perhaps as a "lost cause").[254]

On the other hand, space activities also have some environmental benefits. Satellites have a litany of uses in detecting climate change and identifying potential interventions.[255] Also, the first photographs of Earth from space cultivated a sense of fragility and shared humanity that helped give rise to the environmental movement in the late 1960s and early 1970s, as well as shaped it into a global project rather than one focused on localized concerns.[256] Similarly, many astronauts report experiencing a so-called "overview effect": a cognitive shift in awareness from seeing Earth first-hand from space, leading to a sense of awe, shared humanity, and respect for nature.[257] Experiments have been

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[252] Spencer Kaplan, *Successful U.S. Space Launches*, AEROSPACE SEC. (June 30, 2020), https://aerospace.csis.org/data/u-s-space-launch/.
[253] DEUDNEY, *supra* note 10, 239.
[254] *Id*. *See also* John Bonazzo, *Stephen Hawking Says Humans Have No Long-Term Future on Earth*, OBSERVER (June 21, 2017), https://observer.com/2017/06/stephen-hawking-space-human-survival/ (characterizing Stephen Hawking's view as the Earth being a "lost cause").
[255] Emanuela Barbiroglio, Satellite Science is Helping the Environment, from Farms to Oceans, Forbes (Sep. 23, 2020), https://www.forbes.com/sites/emanuelabarbiroglio/2020/09/23/satellite-science-is-helping-the-environment-from-farms-to-oceans/?sh=692c9e1876e4.
[256] Mike Wall, Earth Day at 50: How Apollo 8's Earthrise' photo helped spark the first celebration, SPACE.COM (Apr. 22, 2020), https://www.space.com/earthrise-image-apollo-8-earth-day-50th-anniversary.html; *see generally* Benjamin Lazier, *Earthrise; or, The Globalization of the World Picture*, 116 AM. HIST. REV. 602 (2011) (discussing philosophical and historical dimensions of the "Earthrise" photograph).
[257] David Yaden et al., *The overview effect: Awe and self-transcendent experience in space flight*. 3 PSYCHOL. OF CONSCIOUSNESS: THEORY, RES. & PRAC. 1, 1 (2016).

devised to replicate this effect upon the Earth using sensory-deprivation tanks and virtual reality headsets.[258]

Whether the net effect of environmental impacts from space activities is positive or negative, most environmental impacts mere externalities to space actors.[259] Various measures, including central planning, may help facilitate more of the positive—and less of the risky—environmental effects of space activities.[260]

2. *Space debris*

Space debris is a negative externality of space development. Most orbital debris is human-generated, such as pieces of spacecraft and boosters, inoperable satellites, remnants of explosions (such as from military weapons tests), equipment and trash from crewed missions, and solidified liquids and byproducts from rocket engines—even frozen shards of human urine.[261] Debris poses hazards to all forms of space activity, including those conducted by satellites, spacecraft, and space telescopes.[262] When traveling at the high speeds necessary to remain in orbit, even the smallest objects, such as flecks of paint, can strike with the force of a bowling ball.[263] Impacts can also occur on the surface of the Earth, where larger objects often reach the ground intact. NASA

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[258] U.S. NATIONAL LIBRARY OF MEDICINE CLINICAL TRIALS ARCHIVE, *Flotation-REST and Virtual Reality of The Overview Effect*, https://clinicaltrials.gov/ct2/history/NCT04155268?V_3 (last visited Jan. 1, 2022).

[259] Environmental impacts tend to be dispersed across large numbers of people and across long periods of time. *See* Malcolm Fairbrother, *Externalities: why environmental sociology should bring them in*, 2 ENVTL. SOC. 375, 376 (2016) (defining environmental externalities).

[260] *See generally* Andy Lawrence et al., *The case for space environmentalism*, 6 NAT. ASTRONOMY 428 (2022) (discussing various measures for managing space environmental consequences).

[261] Daria Diaz, *Trashing the Final Frontier: An Examination of Space Debris from a Legal Perspective*, 6 TUL. ENVIRON. L. J. 369, 371–72 (1993) ("In 1984, the Solar Max satellite was permanently disabled after it collided thousands of times with what may have been nearly invisible pieces of rocket fuel or satellite fragments. Scientists who examined the aforementioned debris also discovered microscopic shards of human urine.") (footnote omitted).

[262] *Id*.

[263] *See* Gunnar Leinberg, *Orbital Space Debris*, 4 J.L. & TECH. 93, 998 (1989) (noting that "[a] 3 mm piece of space debris traveling at 10 km/sec. has as much kinetic energy as a 12 lb bowling bowl travelling at 60 mph," and that the Challenger shuttle collision with a 0.2 mm paint fleck "le[ft] a crater approximately 2.4 mm across and 0.63 mm deep that cost $50,000 to replace").

estimates that on average one cataloged piece of debris has fallen back to the Earth each day for the past 50 years.[264]

Space debris experiences a feedback loop: the more debris there is in orbit, the more likely there are to be collisions, which themselves create more debris.[265] This exponential cascading effect is the reason space debris poses an existential concern. In a phenomenon known as Kessler Syndrome, once a critical density of debris is reached, a runaway chain reaction of collisions may render entire orbital planes unusable or even functionally impassable.[266] The effects of Kessler Syndrome will dramatically raise the length of time humanity remains a one-planet civilization. Besides any potential risks posed by a loss of crucial space technologies, a land-locked humanity would be vulnerable to numerous other existential risks, including the eventual exhaustion of Earth's resources.[267] Unlike with ocean shipwrecks, most satellite debris sinks very slowly, remaining in orbit for centuries.[268] Unfortunately, according to some computational models, we have already passed the "tipping point" for runaway debris—and we did so just 40 years after inventing space flight.[269] Even without any more space activity, collisions will continue ramping up.[270] Take, for example, the 2009 collision between a defunct Soviet satellite and an active U.S. company's communication satellite, which destroyed both and created over 2,000 pieces of new debris which themselves will go on to cause new collisions and debris.[271] And because of the nature of exponential growth, the overwhelming majority of collisions will occur long after the process is out of control—probably before any acceleration in collisions is even detectable.[272]

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[264] *Frequently Asked Questions: Orbital Debris*, NASA, https://www.nasa.gov/news/debris_faq.html (last visited Feb. 4, 2022).
[265] Mike Wall, *Kessler Syndrome and the Space Debris Problem*, SPACE.COM (Nov. 15, 2021), https://www.space.com/kessler-syndrome-space-debris.
[266] *Id*.
[267] Bostrom, *supra* note 95, at 11.
[268] Raffi Khatchadourian, *The Elusive Peril of Space Junk*, NEW YORKER (Sept. 21, 2020), https://www.newyorker.com/magazine/2020/09/28/the-elusive-peril-of-space-junk.
[269] Donald J. Kessler & Phillip D. Anz-Meador, *Critical Number of Spacecraft in Low Earth Orbit: Using Satellite Fragmentation Data to Evaluate the Stability of the Orbital Debris Environment*, *in* PROCEEDINGS OF THE THIRD EUROPEAN CONFERENCE ON SPACE DEBRIS 265 (2001).
[270] *Id*.
[271] National Aeronautics and Space Administration, *International Space Station Again Dodges Debris*,15 ORBITAL DEBRIS Q. NEWS, July 2011, at 1.
[272] Humans are notoriously bad at intuiting the effects of exponential growth. *See* Martin Schonger and Daniela Sele, *Intuition and exponential growth: bias and the roles of parameterization and complexity*, 68 MATHEMATISCHE

International space law currently imposes virtually no costs for creating space debris.[273] Governmental compliance with debris-prevention and mitigation measures is voluntary.[274] While countries may be held liable for actual damages caused by their space objects, it is rarely possible to trace and prove whose debris fragment was the ultimate cause of a collision, let alone that the damage was due to one party's negligence.[275] Active debris removal efforts are further frustrated by the fact that the technologies necessary to remove space junk can also be used to destroy an opponent's satellites.[276] Distrust not only prevents adequate cooperation, it also incentivizes space pollution. For example, US, Russia, and China have repeatedly used space to test anti-satellite weapons responsible for thousands of pieces of orbital debris[277] without legal consequence.[278] Coordination is necessary to craft measures which would internalize the costs of creating space debris, foster trust necessary to facilitate active debris removal, and prevent geopolitical or economic

SEMESTERBERICHTE 221, 233 (2021) (describing exponential growth bias and the need for policymakers to override their intuitions when dealing with exponential growth).

[273] *See* Akhil Rao et al., *Orbital-Use fees Could more Than Quadruple the Value of the Space Industry*, 117 PNAS 12756, 12756 (2020) ("[S]atellite operators do not account for costs they impose on each other via collision risk.").

[274] *See* U.N. COPUOS, *Compendium on Space Debris Mitigation Standards Adopted by States and International Organizations*; UN Doc. A/AC.105/C.2/2016/CRP.16, Apr. 5, 2016 (inviting, not requiring, states to participate in debris-prevention and mitigation).

[275] *See* Timothy G. Nelson, *Regulating the Void: In-Orbit Collisions and Space Debris*, 40 J. SPACE L. 105, 107 n.10 (2014) (noting the destruction of at least five satellites that might have been due to space debris, though experts cannot be certain).

[276] Rada Popova & Volker Schaus, *The Legal Framework for Space Debris Remediation as a Tool for Sustainability in Outer Space*, 5 AEROSPACE 55, at *10 (2018).

[277] Brian Weeden, *Through a Glass, Darkly: Chinese, American and Russian Anti-Satellite Testing in Space*, THE SPACE REV. (Mar. 17, 2014), https://www.thespacereview.com/article/2473/1. *See also, Space Debris from Anti-Satellite Weapons*, UNION OF CONCERNED SCIENTISTS (2008), https://www.ucsusa.org/sites/default/files/2019-09/debris-in-brief-factsheet.pdf (noting that Chinese and American weapon testing was a significant source of orbital debris).

[278] *See Britain Concerned by Chinese Satellite Shoot-Down*, SPACE WAR (Jan. 19, 2007), http://www.spacewar.com/reports/Britain_Concerned_By_Chinese_Satellite_Shoot_Down_999.html (noting Britain's position that the 2007 Chinese ASAT test does not contravene international law).

rivalries from continuing to incentivize the pollution of our orbital commons.[279]

3. *Light pollution*

Light pollution—the presence of artificial light in otherwise dark conditions—is one of space development's externalities. Satellites and even small debris in orbit reflect sunlight, appearing in the sky as points of light that directly and indirectly impede observations made by ground-based telescopes.[280] Whenever space objects come into frame, they appear as stark white streaks on the delicate, long-exposure instruments that are attempting to observe much more distant and faint phenomena.[281] Already, there is nowhere left on Earth where astronomers can view the stars without space-based light pollution: Even where individual space objects are not in view, the collective cloud of metal scatters light back into the atmosphere, currently increasing the brightness of the night sky by about ten percent.[282] In addition, non-visible communications between satellites and receivers on the ground can adversely impact observations by radio telescopes.[283]

The impacts of light pollution are still being researched, but they appear to include harms to human health, the environment, and the economy.[284] Further, interference with Earth-based astronomy is concerning from the standpoint of existential risk mitigation for three reasons. First, telescopes play a crucial role in detecting cosmic threats to the Earth like asteroids and comets, solar flares, gamma-ray bursts, close encounters with large objects like black holes, and potentially threatening extraterrestrial beings.[285] The vast majority of astronomy is done from

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[279] *See* Hobe & Chen, *supra* note 30, at 40 ("[E]nacting binding rules for space debris mitigation might be the only avenue available today to prevent and to minimize the growing orbital population of space debris.").

[280] Mark Strauss, *Orbital Debris Creates a New Problem: Light Pollution,* SMITHSONIAN MAG. (June 2021), https://www.smithsonianmag.com/air-space-magazine/bright-lights-big-problem-180977824.

[281] *Id.*

[282] *Id.*

[283] *SKAO Needs Corrective Measures From Satellite 'Mega-Constellation' Operators To Minimise Impact On Its Telescopes*, SKAO (Oct. 7, 2020), https://www.skatelescope.org/news/skao-satellite-impact-analysis/.

[284] Tim B. Hunter & David L. Crawford, *Economics of Light Pollution*, CAMBRIDGE U. PRESS (Apr. 12, 2016), https://www.cambridge.org/core/journals/international-astronomical-union-colloquium/article/economics-of-light-pollution/17753488673F087EF3E1477A33E04730.

[285] Ethan Siegel, *This Is Why We Can't Just Do All Of Our Astronomy From Space*, FORBES (Nov. 27, 2019),

the Earth, in part because telescopes on the ground offer some unique advantages compared to their space-based counterparts.[286]

Second, the insights generated by astronomy have been and will continue to be crucial for understanding humanity's origins, current circumstances, and possible futures. Much of our current understanding of life on our planet comes from observations about the rest of the universe, and there remains much to learn, including considerations that will affect our perceptions of existential risk.[287]

Third, there may be as-yet undiscovered psychological ramifications if humanity's visual relationship with the stars is altered or eventually cut off for the first time in our history. Direct exposure to space objects, such as witnessing a planet through a telescope, appears to have positive effects on creativity, awe, and respect for nature.[288] Conversely, the alteration of our sky may tend towards negative, risk-raising traits such as reduced compassion.[289] In one imaginative story by Isaac Asimov, characters on a planet perpetually bathed in sunlight witness the stars for the first time—and it drives them mad.[290]

As technology drives the costs of access to space lower, increases in light pollution will likely accelerate. The number of satellites is on track to triple by 2028.[291] Even a single mega-constellation like SpaceX's Starlink will radically affect the skies—if fully deployed, Starlink satellites alone will visually outnumber the stars.[292] Because no national or international laws address the issue, stakeholders currently must rely on the goodwill of space actors to limit additional light

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https://www.forbes.com/sites/startswithabang/2019/11/27/this-is-why-we-cant-just-do-all-of-our-astronomy-from-space/#6e5433112704 (noting this is cheaper than going to space).

[286] *Id*.

[287] *See supra* note 120 (describing the importance of the search for extraterrestrial life in indirectly estimating existential risk).

[288] *See infra* notes 255–258 and accompanying text (describing psychology related to views of/from space).

[289] *See generally* Analeigh Dao, *Emotional and Social Responses to Stargazing: What Does It Mean To Lose the Dark?* (Honors Project at Ill. Wesleyan U.) (2016), https://digitalcommons.iwu.edu/psych_honproj/180/ (conducting preliminary psychology experiments relating to stargazing).

[290] ISAAC ASIMOV, NIGHTFALL (1941).

[291] Therese Wood, *Who Owns Our Orbit: Just How Many Satellites Are There in Space?*, WORLD ECON. F. (Oct. 23, 2020), https://www.weforum.org/agenda/2020/10/visualizing-easrth-satellites-sapce-spacex.

[292] Brian Resnick, *The Night Sky is Increasingly Dystopian*, VOX (Jan. 29, 2020), https://www.vox.com/science-and-health/2020/1/7/21003272/space-x-starlink-astronomy-light-pollution.

pollution by refraining from launches and coating satellites in non-reflective material.[293] Space actors only marginally bear the costs of light pollution but would fully bear the costs of mitigation—a classic public goods problem.

Worse still is the prospect of obtrusive advertisements from space. Companies for years have entertained the possibility of bright space billboards rivaling the moon in size in brightness,[294] which led the US to pass a domestic ban on obtrusive space advertising.[295] That did not stop American company Rocket Lab from launching a bright, reflective satellite designed solely to produce the brightest possible glint visible from the Earth. The satellite, which was proudly proclaimed as being "visible from anywhere on the globe" and the brightest object in the night sky,[296] served no purpose besides creating publicity.[297] Astronomers criticized the launch as a form of "space graffiti."[298] (The company, headquartered in California, was able to bypass American law by utilizing a subsidiary in New Zealand and launching from there, demonstrating the issue of flags of convenience.[299])

Private advertising companies continue to capitalize on a growing interest in space billboards. One Russian-based company, which nearly secured a contract for an orbital advertisement with Pepsi, offers the tagline: "Space has to be beautiful. With the best brands our sky will amaze us every night."[300] While Pepsi eventually abandoned the project for fear of disapprobation,[301] there remains a need to bring private initiatives into accordance with public interests, especially as the commercial value of space skyrockets.

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[293] *Id*.

[294] *See, e.g.*, Greg Miller, *It's a Bird! A Plane! It's an Ad? Billboard Idea Launches Flight*, LOS ANGELES TIMES (Aug. 4, 1993), https://www.latimes.com/archives/la-xpm-1993-08-04-mn-20350-story.html.

[295] 49 U.S.C. § 70109a (2010) (prohibiting obtrusive space advertising).

[296] Michael McGowan, *'Space graffiti': astronomers angry over launch of fake star into sky*, THE GUARDIAN (Jan. 26, 2018), https://www.theguardian.com/world/2018/jan/26/space-graffiti-astronomers-angry-over-launch-of-fake-star-into-sky.

[297] The company stated that the mission was for public awareness, creating "a bright symbol and reminder to all on Earth about our fragile place in the universe." Caleb Scharf, *Twinkle, Twinkle, Satellite Vermin*, SCI. AM. (Jan. 25, 2018), https://blogs.scientificamerican.com/life-unbounded/twinkle-twinkle-satellite-vermin/.

[298] McGowan, *supra* note 296.

[299] *Id.*, *see also supra* Section II(C) (discussing flags of convenience).

[300] Jeff Foust, *Pepsi Drops Plan to Use Orbital Billboard*, SPACE.COM (Apr. 16, 2019), https://www.space.com/pepsi-drops-orbital-billboard-plans.html.

[301] *Id*.

4. *Payload monitoring and forward contamination*

In 2019, an Israeli space organization made history when it became the first nongovernmental entity to place an object on the Moon.[302] Unfortunately, it failed to stick the landing. When the *Beresheet* lander crashed, it spilled its cargo across a portion of the lunar surface.[303] Four months after the crash, the press discovered that among the wreckage was a capsule containing human DNA samples and tardigrade micro-animals, the only creatures known to be capable of living in the vacuum of space.[304] The decision to include the samples was made at the last minute by a single venture capitalist and not disclosed to anyone—including the lunar lander operators—until after the crash.[305] Scientists lament that event may have compromised the Moon as a "pristine environment" to conduct research and search for evidence of extraterrestrial life, and legal experts point out that Article IX of the OST requires states to prevent such contamination from occurring.[306] Still, there was no legal fallout—in fact, the company quickly announced plans for a second mission[307] and the venture capitalist, regarding his mission as a success, proudly remarked, "I'm the first space pirate. . . . We didn't tell them we were putting life in this thing. . . . Space agencies don't like last-minute changes. So we just decided to take the risk."[308]

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302 Christine Lundsford, *Israel's 1st Moon Lander: The SpaceIL Beresheet Lunar Mission in Pictures*, SPACE (Feb. 19, 2019), https://www.space.com/43188-israel-first-moon-lander-spaceil-beresheet-photos.html (explaining that *Beresheet* was co-developed by a private nonprofit organization and an Israeli state-owned corporation as part of the Google Lunar X Prize competition which offered $30 million in prizes to the first privately funded teams to successfully operate a rover on the Moon).
303 Daniel Oberhaus, *A Crashed Israeli Lunar Lander Spilled Tardigrades on the Moon*, WIRED (Aug. 5, 2019, 6:55 PM), https://www.wired.com/story/a-crashed-israeli-lunar-lander-spilled-tardigrades-on-the-moon/.
304 *Id.*
305 *Id.*
306 Kameron Virk, *Tardigrades: 'Water Bears' Stuck on the Moon After Crash*, BBC NEWS (Aug. 7, 2019), https://www.bbc.com/news/newsbeat-49265125.
307 Zachary Keyser, *SpaceIL Heading Back to Space, Mission to Mars on the Horizon*, JERUSALEM POST (Nov. 28, 2019, 11:09 AM), https://www.jpost.com/Israel-News/SpaceIL-co-founder-Beresheet-II-ready-for-lift-off-in-three-years-Mars-on-the-horizon-608939.
308 Chris Taylor, *'I'm the first space pirate!' How tardigrades were secretly smuggled to the moon*, MASHABLE (Aug. 9, 2019), https://mashable.com/article/smuggled-moon-tardigrade.

This was not the first time a launch included unauthorized payloads.[309] In 2018, a Silicon Valley startup smuggled four satellites onto an Indian rocket after being denied permission by the Federal Communications Commission (FCC) due to the objects being too small to reliably track in orbit.[310] Afterwards, the FCC Commissioner issued a $900,000 fine, stating that "[t]he size of the penalty imposed is probably not significant enough to deter future behavior, but the negative press coverage is likely to prevent this company and others from attempting to do this again."[311] And yet just one week later the company successfully raised twenty-five million dollars in funding to deploy 150 more of the contraband satellites, based no doubt in part on the proven "success" of its mission.[312]

Payload monitoring is a crucial keystone in regulating the space environment and enforcing space law.[313] As long as there is space activity, there will always be some risk of individual actors evading or bypassing authority.[314] Still, the risks are heightened where private actors are permitted to shop for flag states unable or unwilling to closely monitor, or where states themselves are not subject to oversight from a centralized authority.[315]

Aside from the importance of law and policy enforcement, the existential concerns of poor payload monitoring and enforcement are multifaceted. For example, it is not difficult to imagine the dangers that

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309 Christopher D. Johnson et al., *The Curious Case of the Transgressing Tardigrades (part 1)*, SPACE REV. (Aug. 26, 2019), https://www.thespacereview.com/article/3783/1.
310 Caleb Henry, *FCC Fines Swarm $900,000 for Unauthorized Smallsat Launch,*, SPACENEWS (Dec. 20, 2018), https://spacenews.com/fcc-fines-swarm-900000-for-unauthorized-smallsat-launch/.
311 *Id*.
312 Devin Coldewey, *Swarm Technologies Raises $25M to Deploy its Own 150-Satellite Constellation*, TECHCRUNCH (Jan. 24, 2019), https://techcrunch.com/2019/01/24/swarm-technologies-raises-25m-to-deploy-its-own-150-satellite-constellation/.
313 Christopher D. Johnson et al., *The Curious Case of the Transgressing Tardigrades (part 2)*, SPACE REV. (Sep. 3, 2019), https://www.thespacereview.com/article/3786/1.
314 *See* Fabrice Langrognet, *A Brief History of Smuggling*, BORDER CRIMINOLOGIES BLOG (Nov. 27, 2015), https://www.law.ox.ac.uk/research-subject-groups/centre-criminology/centreborder-criminologies/blog/2015/11/brief-history (describing the long history of smuggling in other contexts).
315 *See* Section II(C) (describing the enforcement risks following from flags of convenience).

could come from various actors smuggling weapons of mass destruction into space.[316]

But the *Beresheet* example makes acute the risks even of "forward contamination" from microorganisms like tardigrades. While not directly threatening like back contamination might be, forward contamination may indirectly have existential implications. In particular, it may frustrate investigation into other celestial bodies, which is crucial for understanding the Earth.[317] For example, the search for extraterrestrial life may reveal important facts about humanity's origins and fate that help determine paths to existential security and navigate around potential existential pitfalls.[318] But polluting Earth-based life forms and DNA makes it much more difficult for scientists to discern whether some organism originated on Earth or elsewhere.[319] Also, contamination is functionally irreversible[320] and scientists may have completely different needs dozens or hundreds of years from now.[321] The scarcity of accessible asteroids, planets, and moons in our solar system makes conservation of their unaltered and uncontaminated state extremely valuable.[322]

The current international legal regime is highly decentralized, permitting states to develop their own payload monitoring practices.[323] At minimum, there is a need for international consensus and enforcement of minimum standards for payload monitoring to avoid a race to the bottom in national standards. Depending on how severe the risks are from poor payload monitoring, it may even be best for space access to be limited and internationally coordinated in order to ensure sufficient oversight of what goes into (or comes out of) space.

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[316] *See* Section IV(A)(3) (discussing military and conflict risks). For a general discussion of nuclear risks from nonstate actors, *see* Gary Ackerman & William C. Potter, *Catastrophic Nuclear Terrorism: A Preventable Peril*, in GLOBAL CATASTROPHIC RISKS, *supra* note 102, at 402.
[317] Schwartz, *supra* note 5, at 58.
[318] *Id*. *See also* Bostrom, *supra* note 120 (discussing how the discovery of extraterrestrial fossils—or lack thereof—should affect our belief that humanity will go extinct).
[319] Schwartz, *supra* note 5.
[320] *Id*.
[321] *Id*.
[322] Samuel Roth, *Developing a Law of Asteroids: Constants, Variables, and Alternatives*, 54 COLUM. J. TRANSNAT'L L. 827, 864 (2016).
[323] *See* Section II(C) (discussing flags of convenience).

5. *Squandering of space resources*

Currently, most space resources are subject to a classic tragedy of the commons—nonexcludable and rivalrous. Individual space actors therefore have incentives to exploit space resources quickly before others do the same. For the finite resources in our solar system such as water (to enable habitability), metals (for building structures), and energy sources (for fueling space travel and habitats), the way humanity chooses to allocate uses in the short-term may have crucial long-term repercussions. The vast distances between solar systems and galaxies make it exceedingly difficult to reach new stars and their planets—impossible given current technologies, though perhaps feasible in the future. By burning through our system's resources before having the technology necessary to put them to sufficiently high uses, humanity may be inadvertently stranding itself, condemned to pass away before exploring the rest of the universe,[324] perhaps at the hands of a steadily expanding sun.[325]

One researcher worries that the natural resources needed to sustain a high-tech civilization are being used up, and if some cataclysm destroys the technology we have, it may not be possible to climb back up even to present levels.[326] Another hypothesizes that our "cosmic commons" could be burnt up in a colonization race via self-replicating mining drones.[327] While these are relatively long-term scenarios, they have important implications for policymaking because near-term choices may determine whether humanity goes down a track that inevitably leads to these outcomes. For example, once a cosmic race has begun, it may be difficult or impossible to stop—both for social and physical reasons.[328]

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[324] ANDERS SANDBERG, STUART ARMSTRONG & MILAN ĆIRKOVIĆ, THAT IS NOT DEAD WHICH CAN ETERNAL LIE: THE AESTIVATION HYPOTHESIS FOR RESOLVING FERMI'S HYPOTHESIS 10–18 (2017) (discussing exploitable energy sources and their limits).

[325] Klaus-Peter Schröder & Robert Connon Smith, *Distant Future of the Sun and Earth Revisited*, 386 MON. NOT. R. ASTRON. SOC. 155, 155 (2008).

[326] Bostrom, *supra* note 95, at 11.

[327] ROBIN HANSON, BURNING THE COSMIC COMMONS: EVOLUTIONARY STRATEGIES FOR INTERSTELLAR COLONIZATION (1998); *see also* Bostrom, *supra* note 95, at 14.

[328] Anders Sandberg, *Space Races: Settling the Universe* Fast, FUTURE OF HUMAN. INST. (Jan. 24, 2018), https://www.fhi.ox.ac.uk/wp-content/uploads/space-races-settling.pdf ("When occurring over large distances the ability to enforce coordination disappears, and this means that if no or bad ground rules were established before causal contact was lost there can be major waste."); Kevin Kohler, *Cosmic Anarchy and Its Consequences*, MEDIUM (Feb. 11, 2019), https://medium.com/@KevinKohlerFM/cosmic-anarchy-and-its-consequences-b1a557b1a2e3.

The only feasible way of avoiding these outcomes may therefore be to prevent them from ever beginning. And "[t]here are good reasons to think that the line of no return is located very early in space expansion and that it might be very difficult to avoid sliding across it."[329]

Unfortunately, humanity's current trajectory points in the direction of wasteful competition. In oceans, another open-access global commons, overfishing continues to decimate economies and ecosystems.[330] In space, countries and companies are already ramping up for a race to acquire asteroid resources. Meanwhile, plans to establish human settlements on moons and other planets will make gratuitous use of in situ resources. Global coordination may be needed to bring space resource usage into accordance with humanity's long-term interests.

6. *Economic acceleration or disruption*

Proponents of space development sometimes point to the economic gains that might come from harvesting space resources.[331] However, what is hailed as a virtue may in fact also be a threat. Faster economic growth may well contribute to wellbeing[332] or altruistic behaviors,[333] but it may also undermine existential security by accelerating risky technological development or harmful practices like environmentally destructive consumption before humanity is capable of responsible management.[334] Emerging research seeks to determine

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[329] DEUDNEY, *supra* note 10, at 363.
[330] *See* FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS, THE STATE OF WORLD FISHERIES AND AQUACULTURE: MEETING THE SUSTAINABLE DEVELOPMENT GOALS, 91, CC License No. BY-NC-SA 3.0 IGO (2018) (noting that the percentage of fish harvested at unsustainable levels has risen from 10% to 33% in just 40 years).
[331] *See, e.g.*, Weinzierl *supra* note 7, at 177 (stating that companies have economic goals ranging from asteroid mining to colonizing the moon and Mars).
[332] *See generally* Tyler Cowen, *Caring about the Distant Future: Why it Matters and What it Means,* 74 U. CHIC. L. REV. 5 (2007); TYLER COWEN, STUBBORN ATTACHMENTS: A VISION FOR A SOCIETY OF FREE, PROSPEROUS, AND RESPONSIBLE INDIVIDUALS (2018) (discussing effects of economic acceleration).
[333] BENJAMIN FRIEDMAN, THE MORAL CONSEQUENCES OF ECONOMIC GROWTH 1 (2005).
[334] Leopold Aschenbrenner, *Existential Risk and Growth* 1 (Global Priorities Inst., Working Paper No. 6, 2020); Kine Aurland-Bredesen, The Optimal Economic Management of Catastrophic Risk (2019) (Ph.D. dissertation, Norwegian University of Life Sciences) (on file with author); Philip Trammell, *Existential Risk and Exogenous Growth*, GLOBAL PRIORITIES INSTITUTE 1, 1 (2021).

whether faster economic growth generally increases or decreases existential risk.[335]

The benefit of economic growth comes from mitigating certain "state" risks—getting through a "time of perils."[336] At any given level of progress (or "state"), we face a certain amount of existential risk—currently, for example, from nuclear war, pandemics, and the like.[337] These risks, however, are likely temporary.[338] Once humanity has progressed far enough, these risks could approach zero: Society could become wise enough to take existential risks seriously, coordinate, and act accordingly, leveraging safeguarding technologies to everyone's benefit.[339] Speeding up economic growth may reduce the total time spent subject to these risks.[340]

On the other hand, at given points in the trajectory of economic development, transitions could occur that generate existential risks.[341] For example, humanity may uncover a technology so dangerous and easy to use that extinction is nearly guaranteed to follow—perhaps artificial general intelligence, or a mechanism allowing individuals to craft lethal pathogens from their homes.[342] It may be better to slow down economic growth so that dangerous transitions will happen later, after society has sufficiently progressed to handle the risks.[343]

Whether faster economic growth increases or decreases existential risk seems to depend largely on how much overall existential risk comes from being in dangerous states, on the one hand, or from undergoing dangerous transitions, on the other.[344] The literature on this topic is still young and developing.[345] Until we reach some clarity—especially on near-term transition risks—it is probably better to avoid introducing major economic disruptions in either direction.[346]

For example, it may be wise to avoid rushing to harvest asteroids for resources. Even a single asteroid can contain thousands of

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[335] Aschenbrenner, *supra* note 334, at 1.
[336] *Id*.
[337] *Id*.
[338] *Id*.
[339] *Id*.
[340] *Id*.
[341] Id. at 1–2.
[342] Bostrom, *supra* note 132 143, at 461.
[343] Aschenbrenner, *supra* note 334, at 22.
[344] *Id.* at 4.
[345] *See* ORD, *supra* note 114, at 205–09 (summarizing issues related to differential development).
[346] *Id*. at 209.

quintillions of dollars in resources such as rare metals.[347] Even setting aside questions of transition risks in general, introducing such large quantities of materials into the market may itself upset various equilibria[348] and trigger a catastrophe, such as a war.[349] Of course, none of these considerations matter much to individual actors chasing down profits that might otherwise be claimed by someone acting more quickly.[350] A lack of coordination incentivizes actors to pursue economic-growth activities at a faster rate than may be safe.[351]

V. Proposals

I have argued that existential risk mitigation is overwhelmingly important yet disturbingly neglected as a goal in space development law and policy. The broadest concern is therefore to emphasize existential security as the North Star in debates about law, policy, and academic scholarship. While there are many other tractable interests at stake—commercial, scientific, and geopolitical—these must be evaluated through the lens of existential risk mitigation and sometimes give way to the more important concern.

Space law and policy must evolve to give legal effect to the importance of existential risk mitigation. International law, especially space law, may be in a crucial formative period. The United Nations recently announced a progressive new agenda focused on global and long-term problems.[352] As a part of that agenda, a keystone conference in 2023 will include "a multi-stakeholder dialogue on outer space" for governments to "seek high-level political agreement on the peaceful,

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[347] Shriya Yarlagadda, *Economics and the Stars: The Future of Asteroid Mining and the Global Economy*, HARV. INT'L REV. (Apr. 8, 2022), https://hir.harvard.edu/economics-of-the-stars.
[348] Jeffrey S. Kargel, *Metalliferous Asteroids as Potential Sources of Precious Metals*, 99 J. GEOPHYSICAL RSCH. 21129, 21129 (1994) (discussing a potential market collapse); *see also* Andreas Schmidt & Daan Juijn, *Economic Inequality and the Long-Term Future* 10–17 (Global Priorities Inst., Working Paper No. 4, 2021) (discussing the potential effects of economic inequality on existential risk).
[349] *See* Stephen Walt, *Will a Global Depression Trigger Another World War?* FOREIGN POLICY (May 13, 2020), https://foreignpolicy.com/2020/05/13/coronavirus-pandemic-depression-economy-world-war/ (discussing the risks of geopolitical conflict from economic disruption).
[350] *See* Hardin, *supra* note 36 (discussing the tragedy of the commons).
[351] *Id*.
[352] United Nations Secretary-General, *Our Common Agenda*, at 3–4, U.N. Sales No. E.21.I.8 (2021).

secure and sustainable use of outer space."[353] The United Nations correctly notes that existing international arrangements provide "only general guidance" on "the permanent settlement of celestial bodies and responsibilities for resource management[,]" and the new agenda considers a move toward "a global regime[.]"[354]

This would be wise. I have argued that space is subject to glaring externalities and collective action problems that make the current uncoordinated approach irresponsible. One natural solution would be to make space and its resources a closed-access commons, accessible only by orderly international agreement. Such a regime is envisioned by the 1979 Moon Treaty which would declare the Moon the "common heritage of [hu]mankind,"[355] a legal status that currently applies to the deep seabed and ocean floor.[356]

Under the common heritage framework, the deep seabed is subject to a variety of provisions that ameliorate the risks that stem from its being a global commons. As outlined in Table 2, these provisions as applied to space and its resources may be helpful in reducing existential risk along multiple fronts.

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[353] *Id.*
[354] *Id.*
[355] *Supra* note 13.
[356] United Nations Convention on the Law of the Sea art. 1, para. 1, Dec. 10, 1982, 1833 U.N.T.S. 3, 397; 21 I.L.M. 1261.

Common Heritage Element	**Explanation**	**Space-Related Existential Security Benefit**
Non-appropriation by public or private actors	All rights in the resources of the Area are vested in humankind as a whole; no State can claim sovereignty or sovereign rights over the Area and its resources; no private appropriation is permitted.	Prevents race to acquire resources with destructive externalities such as space debris.
Common management & regulation	All resources and resource-extraction activities in the Area are organized and controlled by an international authority on behalf of humankind as a whole; the rules, regulations, and procedures are binding on all member States, regardless of individual consent.	Avoids coordination problems such as dangerous practices following from flags of convenience.
Non-military purposes	The Area may only be used for peaceful, non-military purposes.	Reduces risk of geopolitical conflict or development of dangerous technology; promotes confidence for cooperation in other areas such as those involving dual-use technology.
Environmental protection and preservation for future generations	An international authority is required to ensure effective protection of the environment from harmful effects of activities, protect and conserve the natural resources of the Area, and prevent damage to local organisms that may exist in the Area.	Reduces risk of contamination (forward and back) and squandering of cosmic commons.

Benefit-sharing	Activities in the Area must be carried out for the benefit of humankind as a whole; an international authority is to provide for equitable sharing of benefits derived from activities in the Area, taking into particular consideration the interests of developing States.	Reduces the risks that follow from economic inequality;[357] reduces likelihood of defectors from international regime.

Table 2. Left and center columns adapted from Jennifer Frakes, The Common Heritage of Mankind Principle and the Deep Seabed, Outer Space, and Antarctica: Will Developed and Developing Nations Reach a Compromise? *21 WISCONSIN INT'L L. J. 409, 411–413 (2003); Aline Jaeckel et al.,* Conserving the Common Heritage of Humankind—Options for the Deep-Seabed Mining Regime*, 78 MARINE POL. 150, 152 (2017).*

The Moon Treaty itself already has considerable support with eighteen state parties.[358] The United States' influential opposition was based on the Treaty's perceived tension with free enterprise and private property rights[359]—concerns that may matter more from a nationalistic perspective, but less from one focused on existential security. While using the Moon Treaty's common heritage approach as a model for a future space law regime is certainly not a panacea, it is rare to find a move whose many dimensions each plausibly stand to reduce existential risk in different ways. There is a need for further thought into space law regimes structured specifically around promoting international coordination and minimizing existential risk,[360] as well as means of generating State support for such proposals.[361]

There is also in general a need for stronger consideration of future generations.[362] For example, democratic institutions could

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[357] *See* Schmidt & Juijn, *supra* note 348, at 11–12 (describing the potential existential risks of inequality).
[358] Agreement Governing the Activities of States on the Moon and Other Celestial Bodies, Dec. 5, 1979, 1363 U.N.T.S. 3.
[359] *Hearing before the Subcomm. on Science, Technology, and Space of the Comm. of Commerce, Science, and Transportation*, 96th Cong. (1980).
[360] DEUDNEY, *supra* note 10, at 372 (describing numerous legal and policy measures for minimizing existential risk related to space).
[361] *See, e.g.*, Wilson et al., *supra* note 232, 73–77 (identifying features of a potential "Mars Treaty" that would promote international cooperation).
[362] *See, e.g.*, Beth Daley, *How to create a government that considers future generations*, THE CONVERSATION (Dec. 31, 2020), https://theconversation.com/how-to-create-a-government-that-considers-future-

incorporate stakeholder representation of future generations, perhaps through constitutional provisions (as may arise under future space settlements) addressing the paramount need to safeguard humanity's future and providing for appropriate enforcement mechanisms.[363]

Similarly, it may be necessary to prohibit and punish deliberate or reckless impositions of existential risk under international law.[364] International law is justified as an institution to protect basic human rights—not just those that accrue to individuals, but also to humanity collectively. If genocide is fit to be persecuted under international law, then so too may be *omnicide* (the threatening of all current human life) and *postericide* (the threatening of humanity's future).[365]

This approach would use international law to punish risky behaviors, which is typically a function of domestic law. Countries routinely punish risky activities, such as drunk driving, regardless of whether an accident actually results. These laws usefully serve as ex ante deterrents of costly behaviors. International law, on the other hand, typically operates ex post to achieve accountability for misconduct that has already caused actual harm. Unfortunately, an ex-post approach to existential risk is inappropriate in part because extinction, should it occur, would not leave anybody around to be punished. Laws against imposing existential risks must therefore kick in at some point before extinction occurs. The key question is where to place the probability threshold for activities that are risky enough to merit punishment: too low and the law would be overbearing; too high and the law would be ineffective as a preventative measure. This task is not trivial, but it is probably achievable. One scholar proposes that we can make imprecise yet accurate determinations that the probability of an outcome has been increased by some given conduct.[366] More consideration of similar proposals is necessary.

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generations-148947 (describing methods for enhancing governmental consideration of future generations).

[363] For considerations in constitutional drafting, see Thomas Ginsburg, Zachary Elkins & James Melton, *The Lifespan of Written Constitutions*, U. CHI. L. SCH., Oct. 15, 2009, https://www.law.uchicago.edu/news/lifespan-written-constitutions.

[364] Catriona McKinnon, *Endangering Humanity: An International Crime?,* 47 CANADIAN J. PHILOSOPHY 395, 407–12 (2017) (arguing in favor of incorporating a new offense of postericide into the body of international criminal law).

[365] *Id*.

[366] Henry Shue, *Deadly Delays, Saving Opportunities: Creating a More Dangerous World?, in* CLIMATE ETHICS: ESSENTIAL READINGS 147–48 (2010). Under this approach, for actions involving potential massive loss, the threshold

Space law is a particularly good domain to consider adopting and enforcing crimes against omnicide and postericide, not only because space law is still fundamentally incomplete but also because space activities overwhelmingly concern humanity's future. If all goes well in the very long term, the vast majority of human life (and humanity's descendants) will be elsewhere than Earth. This approach would give direct legal effect to the fact that space is particularly important for future generations.

In general, space is a promising realm for promoting unification around humanity's common interests.[367] While early space efforts may have been primarily motivated by geopolitical competition, they nonetheless inspired multitudes around the world to view Earth as tiny, fragile, and connected.[368] Stories about space invite vivid imaginations of humanity's possible futures and bring into stark contrast the difficulties facing us today.[369] Space policy has served as an effective vehicle for international cooperation in the past (such as with the International Space Station) and may continue to contribute to the development of a planetary common identity,[370] but it may equally be used to promote greed and worsen conflicts.[371] Anyone involved in space law and policy (or anyone who might become involved, such as in democratic processes) should consider ways to help encourage caution and coordination, even—and especially—where we may require a sharp turn away from our current trajectory.[372]

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likelihood of loss is met where a) the mechanism by which the losses would occur is well understood, b) the conditions for the mechanism's occurrence are accumulating, and c) prevention costs are not excessive in light of the magnitude of possible losses and other important demands on resources. Using this approach, litigating questions of probability is unnecessary beyond establishing that the conduct in question meets a certain minimal level of likelihood. *Id*.

367 DEUDNEY, *supra* note 10, 228, 256–57.

368 *See supra* notes 256–258 and accompanying text (describing historical effects of early Earthrise photographs); s*ee generally* Alan Logan et al., *Project Earthrise: Inspiring Creativity, Kindness and Imagination in Planetary Health*, 11 CHALLENGES 19 (2020) (discussing connections between space history, utopian thinking, and imagination); SAGAN *supra* note 1 (discussing a vision of shared humanity inspired by space).

369 Logan et al. *supra* note 368.

370 DEUDNEY, *supra* note 10, 228, 256–57.

371 *Id*. 366–81 (arguing that space is more likely to serve as a vehicle for greed and conflict without a radical change in direction).

372 *See, e.g.*, Kovic, *supra* note 232, *11–*12 (describing potential shifts in space governance for existential risk mitigation from extraterrestrial settlements).

Isaac Asimov makes the point that it is entirely up to us whether humanity experiences an existential catastrophe.[373] Crafting a responsible body of space policy and law requires deliberate and persistent dedication to safeguarding our future. This Article has been an attempt to refocus discussions of space development in terms of what matters most. While the current space law regime is rife with externalities and collective action problems that generate existential risk, sensible changes may help space instead become an eventual avenue for achieving existential security.

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[373] ISAAC ASIMOV, A CHOICE OF CATASTROPHES: THE DISASTERS THAT THREATEN OUR WORLD 362 (1979) ("[T]here are no catastrophes that loom before us which cannot be avoided; there is nothing that threatens us with imminent destruction in such a fashion that we are helpless to do something about it. If we behave rationally and humanely; if we concentrate coolly on the problems that face all of humanity, rather than emotionally on such nineteenth century matters as national security and local pride; if we recognize that it is not one's neighbors who are the enemy, but misery, ignorance, and the cold indifference of natural law—then we can solve all the problems that face us. We can deliberately choose to have no catastrophes at all.").