Space: An Increasingly Congested and Contested Frontier

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Abstract

We are witnessing a new space race. In the past few years, the number of successful launches to low Earth orbit has been higher than at any time since Sputnik. Commercial space companies, led by SpaceX and Blue Origin, have developed reusable rockets that are fundamentally changing the economics of spaceflight and opening new markets for recreation and tourism. Large numbers of small satellites are being deployed to monitor Earth resources and deliver high speed Internet to developing countries. Meanwhile, a growing number of countries have built space programs, and a superpower rivalry between China and America has replaced the traditional competition between Russia and America. All this activity raises legal and ethical issues. Space debris is accumulating at a rapid rate, creating a hazard for humans and hardware in low Earth orbit. Currently, there is no real incentive for companies or governments to mitigate this threat. The ownership of space resources is not covered by international law and in most countries, spaceflight is subject to very little regulation. Another concern is the potential militarization of space by the major powers. As we explore space, exploitation may be taking precedence over conservation. Hopefully, the economic benefits of space will be realized while the activity grows ethically and sustainably.

Keywords: space travel, space debris, space race, space law, ethics, sustainability, commerce, regulation, militarization

El espacio: una frontera cada vez más congestionada y disputada

Resumen

Estamos asistiendo a una nueva carrera espacial. En los últimos años, el número de lanzamientos exitosos a la órbita terrestre baja ha sido mayor que en cualquier otro momento desde el Sputnik.

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Las empresas espaciales comerciales, encabezadas por SpaceX y Blue Origin, han desarrollado cohetes reutilizables que están cambiando fundamentalmente la economía de los vuelos espaciales y abriendo nuevos mercados para la recreación y el turismo. Se están desplegando grandes cantidades de satélites pequeños para monitorear los recursos de la Tierra y brindar Internet de alta velocidad a los países en desarrollo. Mientras tanto, un número creciente de países ha creado programas espaciales y una rivalidad de superpotencias entre China y Estados Unidos ha reemplazado la competencia tradicional entre Rusia y Estados Unidos. Toda esta actividad plantea cuestiones legales y éticas. Los desechos espaciales se están acumulando a un ritmo rápido, creando un peligro para los humanos y el hardware en la órbita terrestre baja. Actualmente, no existe ningún incentivo real para que las empresas o los gobiernos mitiguen esta amenaza. La propiedad de los recursos espaciales no está cubierta por el derecho internacional y, en la mayoría de los países, los vuelos espaciales están sujetos a muy poca regulación. Otra preocupación es la potencial militarización del espacio por parte de las grandes potencias. A medida que exploramos el espacio, la explotación puede estar tomando prioridad sobre la conservación. Con suerte, los beneficios económicos del espacio se harán realidad mientras la actividad crece de forma ética y sostenible.

Palabras clave: viajes espaciales, basura espacial, carrera espacial, derecho espacial, ética, sostenibilidad, comercio, regulación, militarización

太空：日益拥挤和竞争的前沿

摘要

我们正在见证一场新的太空竞赛。过去几年，向近地轨道成功发射火箭的次数比人造卫星以来的任何时候都要高。以SpaceX和Blue Origin为首的商业航天公司开发了可重复使用的火箭，从根本上改变了航天经济，并为娱乐和旅游业开辟了新的市场。大量小型卫星被部署来监测地球资源并向发展中国家提供高速互联网。与此同时，越来越多的国家建立了太空计划，中美之间的超级大国竞争取代了俄罗斯和美国之间的传统竞争。所有这些活动都会引发法律和伦理问题。太空垃圾正在快速积累，对近地轨道上的人类和硬件造成危害。目前，公司或政府没有真正的动力来减轻这一威胁。太空资源的所有权不受国际法管辖，而且在大多数国家，航天

飞行受到的监管很少。另一个担忧是大国可能将太空军事化。当我们探索太空时，开发可能优先于保护。希望太空的经济效益能够在太空活动符合伦理和可持续发展的同时得以实现。

关键词：太空旅行，太空垃圾，太空竞赛，太空法，伦理，可持续性，商业，监管，军事化

Objective

The goal of this paper is to summarize some of the implications of increasing activity in space. The commercial sector is launching large numbers of satellites to low Earth orbit, increasing the amount of space debris and corresponding hazards to orbiting hardware and astronauts. A growing number of governments are developing space programs, with concerns over military capabilities in an arena that is almost completely unregulated.

Background

Space travel is ascendant. For the first half century of human efforts to escape the Earth's gravity, the activity was the hegemony of the world's two superpowers: the United States and the Soviet Union (Hardesty & Eisman, 2007). The rivalry derived from the Cold War, and it saw the Soviet Union achieve early landmarks in space travel—the first satellite, the first human in orbit, the first spacewalk, the first soft landing on the Moon—but the United States recaptured the momentum with the first humans to land and walk on the Moon in 1969. Cooperation was exemplified by the International Space Station, which has been continually occupied for 23 years by astronauts that represent 21 different nations (Catchpole, 2008). China has a well-funded and very ambitious space program, with a dozen launches to Earth orbit each year, a successful lunar rover, and plans for a space station and a Moon base. Other countries with growing aspirations in space include India, Brazil, Japan, and Arab Emirates (Oniosun, 2023).

However, the most dramatic progress is within the commercial sector. SpaceX and Blue Origin have led the effort to lower the cost per kilogram launched to Earth orbit with reusable rockets. There are over three dozen private space companies, but these two were founded by billionaires who invested substantially from their own fortunes to sustain the development phase where there is no significant revenue stream (Davenport, 2019). SpaceX was founded in 2002 by Tesla CEO Elon Musk, and it achieved several landmarks for a private company: the first to put a liquid propellant rocket in orbit, the first to launch and recover a spacecraft, the first to send a spacecraft to the International Space Station, and the first

to reuse a booster with vertical takeoff and landing. Rockets in the Falcon 9 family have flown over 270 times, with a 99.3% success rate. Starship, which is designed for orbital and interplanetary travel, is the largest and most powerful rocket ever flown (Reddy, 2018). Blue Origin was founded in 2000 by former Amazon CEO Jeff Bezos, and the company has followed a quieter and more incremental approach to orbital flight. New Shepard is its reusable rocket for space tourism and New Glenn is its heavy lift vehicle. Along with SpaceX, Blue Origin has a contract to provide lunar lander services for NASA's Artemis program (Gudmundsson, 2018). The world space economy was worth nearly half a trillion dollars in 2021, and more spacecraft were put into orbit in the first half of 2022 than in the first half century of space exploration (Space Foundation, 2022).

Results

The Problem of Space Debris

One result of the burgeoning space activity is a growing amount of space debris. Space debris is the detritus of our activity is space, chunks of metal that serve no useful purpose, including abandoned launch vehicles, defunct satellites and spacecraft, and fragmentation debris. Nearly 16,000 satellites have been placed in Earth orbit, of which half are still functioning and 2,000 are defunct. There are 36,500 pieces of debris larger than 10 cm, and an estimated 1 million between 1 cm and 10 cm and 130 million between 1 mm and 1 cm (European Space Agency, 2023). Moving at speeds of up to 17,500 mph, even a fleck of paint can damage a spacecraft. Optical telescopes and lasers can track large pieces of debris from the ground, but orbital radar is required to track the many small pieces (Muntoni et al., 2021). The number of orbiting spacecraft has doubled in the past decade and it will increase dramatically in the next decade as a hundred companies plan to launch "constellations" of small satellites (Curzi et al., 2020). SpaceX, OneWeb, Amazon, and others aim to deliver high speed internet to developing countries, with 20,000 small satellites projected by 2030 and 60,000 by 2040 (Witze, 2019). The collision rate will inevitably increase and there is a cascading effect even without any additional launches. A possible, bleak outcome is that an exponentially increasing amount of debris will render low Earth orbit unusable (Lessler & Cour-Palais, 1978).

Space debris is a modern tragedy of the commons, a phrase originally associated with over-grazing of common land and the planet's population explosion (Hardin, 1968). A resource that everyone could benefit from is spoiled because no party has a strong incentive for conservation or protection. In space, every sovereign state has the right to use Earth orbit and no state has the right to exclude others from using it (Wang, 2013). Sometimes, the problem is compounded by bad actors. In 2007, the Chinese intentionally destroyed one of their weather satellites, causing the largest debris cloud ever generated by a single event, creating 3,500 pieces of large, trackable debris and many more small pieces. Two years later, in a

more benign but almost equally damaging event, a defunct Russian spacecraft slammed into an Iridium satellite, adding 2,300 large chunks of debris. Then, in 2021, a Russian anti-satellite test targeting one of their own satellites, generating more than 1,500 pieces of trackable orbital debris and hundreds of thousands of small pieces (Drake, 2021). Punishing poor behavior is a desirable strategy, so it was notable in late 2023 when the Federal Communications Commission in the U.S. fined TV provider Dish $150,000 for failing to move one of its satellites into a safe orbit (O'Callaghan, 2023). Mitigation strategies do exist, but governments have dragged their feet and private companies do not want to impact their bottom line. Large satellites are now built with de-orbiting mechanisms, and many small satellites are in low enough orbits that drag in the upper atmosphere does that job naturally. Technologies being considered include lasers, nets, magnets, and harpoons (Ledkov & Aslanov, 2022).

International Competition

The new space race is quite different from the one that started with Sputnik. When the United States and the Soviet Union raced to put humans in space and go to the Moon, it was a technological spear tip of a Cold War crisis with existential overtones. Current competition has three themes (Pekkanen, 2019). Democratization means that space is not the hegemony of the world's only two superpowers but is engaged in by a growing list of countries for national prestige or industrial benefit (Goswamy & Garretson, 2020). Examples include Japan, India, Brazil, South Africa, Turkey, and United Arab Emirates, many of which have created their own space agencies. Commercialization is being driven by technology that offers faster, cheaper, and more consistent space access. It ranges from Earth-focused activities from low orbit to off-Earth settlements. Militarization is a sign of a shifting world order and new geopolitical rivalries. Space technologies often have dual uses in the commercial and military sectors, exemplified by the Space Shuttle payload, which were roughly equally split between civilian and military purposes. China is the superpower with outsized ambitions in space (Goswami, 2018). It was the third country to put a person in space in 2003, ending a 4-year duopoly. Now, the Chinese routinely launch over 100 spacecraft per year, they have landed two robotic rovers on the Moon and one on Mars, and they are completing their own space station.

In the United States, the formation of a sixth branch of the Armed Forces, the Space Force, was a sign that space was viewed as a new arena for competition and potential conflict (Ruff et al., 2022). The irony is that pursuit of control or dominance in space is unlikely to make the U.S. safer. This is an example of the "security dilemma" in international relations, where a State, having no aggressive intention and seeking only to preserve its own security, takes steps which trigger a fear reaction in another State, causing that second State to take its own steps to preserve its own security from the per-

ceived threat of the first State (Grunert, 2022). In 2021, the Office of the Director of National Intelligence released a report that said China was working on an array of technologies to weaponize space and their aim was to match or exceed U.S. capabilities to gain military, economic, and prestige benefits (Gould, 2021). Also in 2021, Defense One summarized the concerns: the secrecy of China's military space program, the potential for conflict over the ownership of lunar sites, and the ways that satellites could be used to detect and destroy hypersonic missiles (Defense One, 2021). The Center for Strategic and International Studies has laid out the threat and the strategies to avoid them. Their report, titled "Defense Against the Dark Arts," is littered with quotes and images from the Harry Potter books (Harrison et al., 2021).

Legal and Ethical Issues

Space is the new "Wild West." There are very few laws and regulations that govern what countries or people can do off-Earth, or how they do it. The United Nations Outer Space Treaty of 1967 says that no country can own the Moon or any part of it and that celestial bodies should only be used for peaceful purposes (United Nations, 1967). This treaty was important in prohibiting nuclear weapons in space, but it says nothing about companies and individuals, and it says nothing about how space resources can and cannot be used. The Moon Agreement of 1979 held that the Moon and its natural resources are the common heritage of humanity, but none of the major space-faring countries have signed it (United Nations, 1979). Other issues have been tackled with a "Rescue Agreement" that deals with the return of astronauts from deep space, a "Liability Convention" to address damage caused by deep space objects, and a "Registration Agreement" to keep track of all objects launched into space. U.N. oversight continues through the work of the Committee on the Peaceful Uses of Outer Space, which has 112 members, and which meets every year (United Nations, 2023). This group has approved 21 non-binding sustainability guidelines, and for the first time in 50 years is considering new treaties.

Scientists have argued that the orbital space environment should be seen as a "global commons," so worthy of protection (Lawrence et al., 2022). National geopolitical interests will dominate unless the United Nations acts. The U.S. Congress passed the Commercial Space Launch Competitiveness Act in 2015, which recognizes the right of Americans to own any space resources that they harvest and encourages the commercial exploitation of asteroids (Molloy, 2015). In 2020, NASA rolled out the Artemis Accords, broad but non-binding principles for peaceful cooperation in space (NASA, 2023). They have been signed by 28 countries, but not China or Russia. The billionaires who run private space companies are loosely constrained by the Federal Aviation Administration in low Earth orbit, but they are unconstrained as they venture off-Earth, and they have grandiose plans (Rubenstein, 2022). Rapidly growing activity in space has an environmental impact and so its sus-

tainability is in doubt (Miraux, 2022). Ethical considerations deserve more attention than they have been given so far (Schwartz & Milligan, 2021). We should embrace stewardship of the space environment, the rule of law, and the human rights of those who choose to live off-Earth. Humanity is at an inflection point. Space is a blank slate and as we write our future there, both utopian and dystopian scenarios are possible. Hopefully, we can avoid the mistakes that have tarnished the legacy of civilizations on Earth.

Conclusion

Activity is space is surging. It is entering a new phase, where the efforts of governments are being eclipsed by investment from the private sector. An analogy can be made with the development of the Internet (Impey, 2021). In the pioneering phase of the Internet, Claude Shannon wrote the foundational paper on information theory in 1948 and J.R. Licklider authored a white paper in 1960 that fully envisaged a worldwide computing network and data in the cloud. The analogous phase of space exploration was Konstantin Tsiolkovsky's treatise on rocketry in 1903 and Robert Goddard's first launch of a liquid-fueled rocket in 1926. In next phase, the nascent activity is incubated by the U.S. military-industrial complex. For the Internet, this was the creation of the ARPANET, the first computer network, in 1969, and the development of e-mail around the same time. For space, it was the formation of NASA in 1958 and the evolution of military rockets into the Saturn V rocket under the leadership of Wernher Von Braun. Subsequently, activity moves into the civilian research sector. The modern Internet was facilitated by the development of the first web browser in 1990 by Tim Berners-Lee. Through the 1980s and 1990s, NASA gained experience in space through the costly Space Shuttle and International Space Station programs. Starting in the mid-1990s, restrictions on commercial Internet traffic were removed, and the result was a rapid growth in economic activity as culture and commerce were transformed by the Internet. We are currently witnessing an analogous transformation of space travel where the consequences could be equally profound.

Conflicts of Interest

The author has no conflicts of interest to report. Some of the ideas discussed in this article were presented in a paper published in *Studia Humana* in 2021, and a non-technical summary of the same themes was published in the online newspaper *The Hill* in 2022.

References

Catchpole, J.E. (2008). *The International Space Station: Building for the future.* Praxis.

Curzi, G., Modenini, D., & Totora, P. (2020). Large constellations of small satellites: a survey of near future challenges and missions. *Aerospace, 7*(9), 133–151. https://doi.org/10.3390/aerospace7090133

Davenport, C. (2019). *The space barons: Elon Musk, Jeff Bezos, and the quest to colonize the cosmos***.** PublicAffairs.

Defense One. (2021). *Mission Space***.** https://www.govexec.com/media/d1-mission-space.pdf

Drake, N. (2021). Russia just blew up a satellite – here's why that spells trouble for spaceflight. *National Geographic***.** https://www.nationalgeographic.com/science/article/russia-just-blew-up-a-satellite-heres-why-that-spells-trouble-for-spaceflight

European Space Agency. (2023). Space debris by the numbers, European Space Agency. https://www.esa.int/Space_Safety/Space_Debris/Space_debris_by_the_numbers

Gould, J. (2010). China aims to weaponize space, says intel community report. *Defense News***.** https://www.defensenews.com/congress/2021/04/14/china-aims-to-weaponize-space-says-intel-community-report/

Hardesty, V., & Eisman, G. (2007). *Epic rivalry: The inside story of the Soviet and American space race*. National Geographic Society.

Harrison, T., Johnson, K., &Young, M. (2021). Defense against the dark arts in space: protecting space systems from counterspace weapons. *Center for Strategic and International Studies***.** https://csis-website-prod.s3.amazonaws.com/s3fs-public/publication/210225_Harrison_Defense_Space.pdf

Hardin, G. (1968). The tragedy of the commons. *Science, 162*(3859), 1243–1248. https://doi.org/10.1126/science.162.3859.1243

Goswami, N. (2018). China in space: ambitions and possible conflict. *Strategic Studies Quarterly***,** *12*(1), 74–97. http://www.jstor.org/stable/26333878

Goswamy, N., & Garretson, P.A. (2020). *Scramble for the skies: the great power com-*

petition to control the resources of outer space. Lexington Books.

Grunert, J. (2022). Outer space policy and the "security dilemma": is America destined for space conflict? *Studies in Space Law, Volume 18*, 165–240. https://doi.org/10.1163/9789004524064_006

Gudmundsson, S.V. (2018). *Blue Origin: riding the wave of disruption in the space industry*. https://dx.doi.org/10.2139/ssrn.3179135

Impey, C.D. (2021). Unbound: ethics, law, sustainability, and the new space race. *Studia Humana, 10*(4), 1–17. https://doi.org/10.2478/sh-2021-0020

Kessler, D.J., & Cour-Palais, B.G. (1978). Collision frequency of artificial satellites: the creation of a debris belt. *Journal Geophys. Res. Space Physics, 83*(A6), 2637–2646. https://doi.org/10.1029/JA083iA06p02637

Lawrence, A. et al. (2022). The case for space environmentalism. *Nature Astronomy, 6*, 428–435. https://doi.org/10.1038/s41550-022-01655-6

Molloy, M. (2015). Asteroid mining made legal after passing of "historic" space bill in U.S. *The Telegraph*. https://www.telegraph.co.uk/news/worldnews/northamerica/usa/12019740/Who-owns-space-Asteroid-mining-made-legal-in-US-after-passing-of-2015-space-bill.html.

NASA. (2023). The Artemis Accords. *NASA*. https://www.nasa.gov/specials/artemis-accords/img/Artemis-Accords-signed-13Oct2020.pdf

O'Callaghan, J. (2023). Why the first-ever space junk fine is a big deal. *MIT Technology Review*. https://www.technologyreview.com/2023/10/05/1080999/first-space-junk-fine/

Oniosun, T.I. (2023). *A Holistic Framework for Classifying Countries in the Space Sector*. https://dx.doi.org/10.2139/ssrn.4602331

Ledkov A., & Aslanov, V. (2022). Review of contact and contactless active space debris removal approaches. *Progress in Aerospace Sciences, 134*, 100858. https://doi.org/10.1016/j.paerosci.2022.100858

Miraux, L. (2022). Environmental limits to the space sector's growth. *Science of the Total Environment, 806*(4). https://doi.org/10.1016/j.scitotenv.2021.150862

Muntoni, G., Montisci, G., Pisanu, T., Andronico, P., & Valente, G. (2021). Crowded space: a review of radar measurements for space debris monitoring and track-

ing. *Applied Sciences, 11*(4), 1364–1381. https://doi.org/10.3390/app11041364

Pekkanen, S.M. (2019). Governing the new space race. *American Journal of International Law Unbound, 113*, 92–97. https://doi.org/10.1017/aju.2019.16

Reddy, V.S. (2018). The SpaceX effect. *New Space, 6*(2), 125–134. https://doi.org/10.1089/space.2017.0032

Rubenstein, M.J. (2022). *Astrotopia: the dangerous religion of the corporate space race*. University of Chicago Press.

Ruff, J.W.A., Stelmach, G., & Jones, M.D. (2022). Space for stories: legislative narratives and the establishment of the US Space Force. *Policy Sciences, 55*, 509–553. https://doi.org/10.1007/s11077-022-09455-5

Schwartz, J.S.J., & Milligan, T. (2021). "Space ethics" according to space ethicists. *The Space Review*. https://www.thespacereview.com/article/4117/1

Space Foundation. (2022). *The Space Report 2022 Q2*. Space Foundation. https://www.spacefoundation.org/2022/07/27/the-space-report-2022-q2/

United Nations. (1967). Treaty on principles governing the activities of states in the exploration and use of outer space, including the Moon and other celestial bodies. *United Nations*. https://www.unoosa.org/oosa/en/ourwork/spacelaw/treaties/introouterspacetreaty.html

United Nations. (1979). Agreement governing the activities of states on the Moon and other celestial bodies. *United Nations*. https://www.unoosa.org/oosa/en/ourwork/spacelaw/treaties/intromoon-agreement.html

United Nations. (2023). Space Law, United Nations Office for Outer Space Affairs. *United Nations*. https://www.unoosa.org/oosa/en/ourwork/spacelaw/index.html

Wang, P. (2013). Tragedy of commons in outer space – the case of space debris. *64th International Astronautical Congress, 56th IISL Colloquium on the Uses of Outer Space (E7)*. https://dx.doi.org/10.2139/ssrn.2260856

Witze, A. (2019). SpaceX launch highlights threat to astronomy from "megaconstellations." *Nature, 575*, 268–269.