Outer Space, Inner Consequences:
The Impact of Space Debris.

Space Debris
Noun

Any non-functional object or material left in space by human activity. This includes defunct satellites, pieces of old, destroyed, broken, or other discarded equipment that no longer serves a purpose.

Synonyms: *Space junk*, *Space waste*, *Space litter*, *Orbital debris*, *Orbital waste*, *Orbital junk*.

Executive Summary:

The original "Space Race" between the Soviet Union and the United States in the 20th century drove advancements in military technology and national pride, but today's competition is far broader. The 21st-century space race has introduced new players, from emerging nation-states to private entities with cutting-edge technologies, unlocking immense potential for resource extraction, geopolitical dominance, and scientific progress. However, the rapid increase in space activity has also introduced significant challenges, particularly the growing threat of space debris.

Human-made debris—including defunct satellites, discarded rocket parts, and smaller fragments like paint flecks—have crowded Low Earth Orbit (LEO) and Geosynchronous Earth Orbit (GEO). This debris poses escalating risks to satellites, future space missions, and even life on Earth. Unchecked debris accumulation could lead to Kessler Syndrome, a chain reaction of collisions rendering LEO unusable for decades. Additionally, the increased militarization of space has heightened geopolitical tensions as nations compete for dominance.

Despite the pressing need for action, no comprehensive international laws currently address space debris removal. Efforts to mitigate the issue have been underway since the 1990s, with initiatives such as NASA's Orbital Debris Mitigation Policy and the European Space Agency's "Zero Debris" approach. National and international policies, including the United States' National Orbital Debris Implementation Plan and the United Nations' Space Debris Mitigation Guidelines, offer frameworks for addressing the crisis, yet further action is needed. Proposals include amending the 1967 Outer Space Treaty to incorporate environmental impact mitigation protocols and expanding restrictions on military activities in space. Additionally, establishing a

Global Committee for Space Sustainability could foster international cooperation, ensuring better debris management and sustainable exploration efforts for the future.

<u>Introduction</u>:

Throughout history, the emerging narrative of the cosmos is: it is a vast area of unknown—mistakenly considered to consist of nothing. However, space exploration missions of the 20th and 21st centuries have disproved this idea and instead, found indications of unexplored planets and other resources.[1] While the initial space exploration in the 20th century may have been driven by curiosity, the current attempts have resulted from consistent scientific evidence, advanced technology and mechanization, and the potential for economic and geopolitical gain.[2] Today, new actors are venturing into space not solely for scientific discovery but for strategic dominance, resource extraction, and commercial profit.[3]

<u>The Original Space Race</u>

On October 4th, 1957, the Soviet Union (USSR) successfully launched Sputnik 1, the first artificial satellite to orbit the earth. This began the “Space Race,” fueled by two actors of the Cold War: the Soviet Union (USSR) and the United States (USA). The two competitors fought to be the first nation to establish dominance in space with the help of newly acquired advanced German missile technology post World War II.[4] Ultimately, the Space Race was a fight between democracy and communism. However, the race to land on the moon gave both nations a hand in advancing warfare technology.[5] While each nation felt this race was a symbol of patriotism, the

---

[1] Marshall, Tim. 2024. “The New Space Race | Power & Politics in the 21st Century.” *Royal Museums Greenwich*. Accessed October 26. https://www.rmg.co.uk/stories/topics/new-space-race-astropolitics-power-21st-century

[2] Koop, Avery. 2022. “Visualized: Which Countries Are Dominating Space?” *Visual Capitalist (blog)*, July 8. https://www.visualcapitalist.com/visualized-which-countries-are-dominating-space/

[3] Luetz, Neil. 2024. “The Implications of the 21st Century Space Race.” *Vanguard Think Tank*. https://vanguardthinktank.org/spacerace

[4] Marshall, Tim. 2024. “The New Space Race | Power & Politics in the 21st Century.” *Royal Museums Greenwich*.

[5] HISTORY. 2020. “The Space Race: Timeline, Cold War & Facts.” *History*, February 21. https://www.history.com/topics/cold-war/space-race

motivation behind the race ran deeper. Motivation in the United States heightened when President Kennedy publicly declared the country would land a man on the moon before the Soviets- who had previously hidden their attempts.[6]

What is New?

Today, the landscape of space exploration has transformed dramatically. The modern "Space Race" has introduced many new sets of players—with the USA, China, and Russia as the clear front-runners.[7] The race is not exclusive to them; nations, including India, Japan, the United Arab Emirates, Israel, and the European Union, have also taken their place in the lineup. However, the competition has expanded further and is now open to numerous private companies, including SpaceX, Blue Origin, Virgin Galactic, and many others.[8,9] The modern race is motivated by several factors, from economic opportunities and technological innovations to ordinary human curiosity. Yet, this new era with the rise of increased competitors brings substantial implications, from concerns of national security to the increasing pollution of space debris, jeopardizing the once-untouched arena.[10]

Why explore Space?

i. The Resources

As space exploration advances, the drive to extract its vast and untapped resources has intensified. The resources in space can be divided into minerals, gases, and liquids. Minerals

---

[6] Smithsonian National Air and Space Museum. 2023. "What Was the Space Race?" *Air and Space Museum*, August 23. https://airandspace.si.edu/stories/editorial/what-was-space-race
[7] Marshall, Tim. 2024. "The New Space Race | Power & Politics in the 21st Century." *Royal Museums Greenwich*.
[8] Edwards, Sarah. 2024. "10 Space Companies Changing Aerospace." *Thomasnet (blog)*, October 12. https://www.thomasnet.com/insights/biggest-space-companies/
[9] Gerbis, Nicholas. 1970. "10 Major Players in the Private Sector Space Race." *HowStuffWorks*, January 1. https://science.howstuffworks.com/10-major-players-in-private-sector-space-race.htm
[10] Marshall, Tim. 2024. "The New Space Race | Power & Politics in the 21st Century." *Royal Museums Greenwich*.

include gold, iron, platinum, nickel, cobalt and more.[11] The United States federal agency, National Aeronautics and Space Administration (NASA), estimates that the minerals in the asteroid belt hold an equivalent to 100 billion USD for every person on Earth, making it a highly profitable extraction.[12] Astrophysicist Neil deGrasse Tyson suggests that the world's first trillionaire will accumulate their wealth from space minerals, as no other industry offers such immense potential value.[13] This prospect has fueled both private companies and governments to invest heavily in developing space mining technologies and capabilities.[14]

Additionally, the primary gases in space—Hydrogen and Helium—hold the potential to become a clean and efficient energy source if harnessed. Further, the Moon's outer layer is believed to contain sufficient oxygen to support 8 billion people for over 100,000 years.[15] Another resource of inquiry through space exploration is water. While the liquid form may be short-supplied, the gasses, hydrogen, and oxygen offer potential for water synthesis.[16]

ii. Geopolitical Dominance & Advancement

It is clear these resources provide economic opportunities for private entities and national governments, however, another substantial motivation for space exploration is the strategic dominance in geopolitics through advancing space militarization technology. Space exploration opens new avenues for national security by enabling the development of space capabilities for defense, surveillance, and intelligence. This includes deploying assets such as satellites for real-time monitoring of adversarial forces, thus gaining a strategic advantage. Early warning

---

[11] Ibid.
[12] Ibid.
[13] Kramer, Katie. 2015. "Neil deGrasse Tyson Says Space Ventures Will Spawn First Trillionaire." *NBC News*, May 3. https://www.nbcnews.com/science/space/neil-degrasse-tyson-says-space-ventures-will-spawn-first-trillionaire-n352271
[14] Ibid.
[15] Luetz, Neil. 2024. "The Implications of the 21st Century Space Race." *Vanguard Think Tank*.
[16] Ibid.

satellites can detect missile launches and nuclear explosions, while satellite navigation systems deliver precise positioning and timing information for targeted operations. Additionally, space systems facilitate secure military communications, furthering a nation's defense capabilities.[17] The United States Office of the Director of National Intelligence (ODNI) summarizes in its *National Security Space Strategy* that space capabilities provide the nation and its allies unprecedented advantages in national decision-making, military operations, and homeland security.[18]

Space systems also enable effective responses to natural and man-made disasters while monitoring long-term environmental trends.[19] By strengthening emerging technologies to increase national security, nations can advance their political standing and grow global prestige. Those more actively engaged in this arena can collect their prize—colonizing new territories and securing advantages for the future. The ODNI explains that space is a domain that no nation owns but presents leadership opportunities, similar to how the United States utilized space to promote security in the 20th century.[20]

iii. Scientific Advancement and Human Discovery

Lastly, space exploration is a pathway for advancing scientific knowledge and human discovery. It furthers the modern-day understanding of the cosmos, the universe's origins, the potential for life beyond Earth, and the fundamental laws of physics. Through exploration,

---

[17] United States Space Force. 2024. "Defense Support Program Satellites." Accessed October 27. https://www.spaceforce.mil/About-Us/Fact-Sheets/Article/2197774/defense-support-program-satellites/

[18] Office of the Director of National Intelligence. 2011. *National Security Space Strategy*. Unclassified Summary. https://www.dni.gov/files/documents/Newsroom/Reports%20and%20Pubs/2011_nationalsecurityspacestrategy.pdf

[19] Ibid.

[20] Ibid.

researchers can unleash solutions for challenges on Earth, such as climate change and resource scarcity.

Implications:

The expansion of the 21st-century space race has incredibly vast and unexplored implications.[21] Advanced technology, new players, and increased launches threaten more than the atmosphere of space; they bring risks to national security, generating geopolitical tensions and environmental impacts. However, these risks are the cost of the immense potential rewards that nations seek to gain.

i. Geopolitical Tensions

The increase in space exploration raises geopolitical and national security concerns. As more countries and companies enter the space arena, the race becomes more competitive as players are after the same prize. Certain countries view space as a means to assert global influence. These countries can use space to advance their military power through space-based defense systems. Such systems include satellite surveillance, missile detection, and communication interference, likely resulting in geopolitical tensions.[22] Through the threat of space-advanced nations, adversarial nations may also develop space-based weapons to enhance their defensive capabilities, and this escalation could potentially trigger a cycle of developing more dangerous nuclear space weapons with extreme risks.

ii. Space Debris Pollution

With the modern-day exploration of space, policymakers and many more face the growing risks of the implications of *Space Debris*. In simpler terms, space debris can be defined

[21] Luetz, Neil. 2024. “The Implications of the 21st Century Space Race.” *Vanguard Think Tank*.
[22] Koop, Avery. 2022. “Visualized: Which Countries Are Dominating Space?” *Visual Capitalist (blog)*, July 8.

as "any piece of machinery or debris left by humans in space."[23] This can encompass many objects, large and small. It can include large items such as defunct satellites that have been left in orbit after their mission has ended or smaller objects such as paint flecks that have fallen off from rockets.[24]

Why is this a Threat?

Space debris is becoming one of the most pressing threats of the century, posing serious safety risks not only in space but also to Earth and humanity as a whole. Many assume outer space to be a vast and empty black hole, but the near-Earth environment is becoming increasingly crowded.[25] Chris Impey, Astrologer and distinguished professor at the University of Arizona, explains in his book *Beyond: Our Future in Space* how space will look in the coming years. In twenty years, space companies will be running regularly in thriving businesses, and in thirty, there will be small but livable colonies on the Moon and Mars. In fifty years, there will be advanced mining technologies to harvest resources from asteroids, and finally, in one hundred, there will be people born in space without ever stepping foot on Earth.[26] In the next decade alone, there are as many as 100 lunar missions planned by governments and private companies like SpaceX and Blue Origin.[27] The increased interest in space results in more visitation, which becomes extremely problematic as any equipment left behind would contribute additional debris.

---

[23] Natural History Museum. 2024. "What Is Space Junk and Why Is It a Problem?" https://www.nhm.ac.uk/discover/what-is-space-junk-and-why-is-it-a-problem.html
[24] Ibid.
[25] Impey, Chris. 2023. "Analysis: Why Trash in Space Is a Major Problem with No Clear Fix." *PBS News*, September 3. https://www.pbs.org/newshour/science/analysis-why-trash-in-space-is-a-major-problem-with-no-clear-fix
[26] Ibid.
[27] Ibid.

This might not have been such an urgent issue in the past, but with the current rapid rate and the volume of debris left behind, the situation has become far more alarming. With space becoming increasingly crowded, it leaves very little room for new missions, and the likelihood of fatal collisions continues to rise. These collisions could have far-reaching and devastating implications, not only for space missions but also for life on Earth.[28]

Space debris is particularly problematic in two key regions: Low Earth Orbit (LEO) and Geosynchronous Earth Orbit (GEO). LEO, located about 600 to 2,000 km (373 to 1,243 mi) above Earth's surface, is the preferred region for most missions due to its proximity. GEO, located 35,000 km (21,748 mi) above, is also favored as satellites in this region maintain a fixed position matching the Earth's surface as the planet rotates.[29]

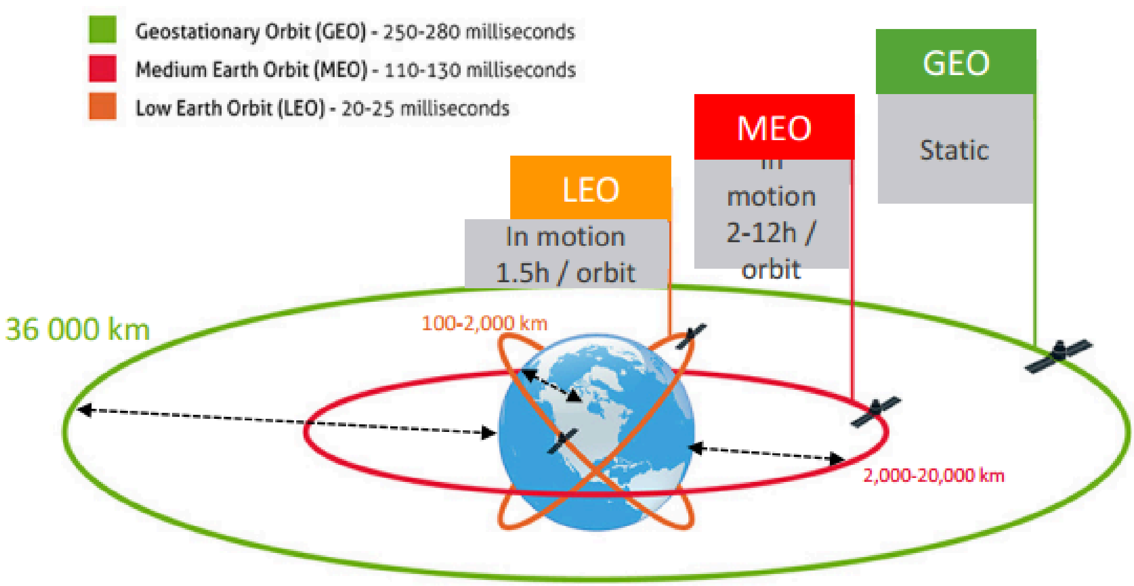


Figure 1 [30]

[28] NASA. 2024. "Space Debris - NASA." https://www.nasa.gov/headquarters/library/find/bibliographies/space-debris/
[29] Yadavalli, Karthik. 2024. "How Can We Clean up Space Debris?" *Astrobites.org*, April 18. https://astrobites.org/2024/04/18/how-can-we-clean-up-space-debris/
[30] "Differences between Leo and Geo Satellites." Accessed December 16, 2024. https://www.diteltech.com/info-detail/differences-between-leo-and-geo-satellites

In recent years, the number of objects launched into LEO has skyrocketed and the orbital graveyard has been polluted with equipment from satellites, spacecraft, probes, and landers.[31] In the figure below is an image of all tracked pieces of space debris from January 2019, it visualizes the large density of debris (white dots) bordering the Earth's surface and then a large ring much farther out, showing the impact in both LEO and GEO.

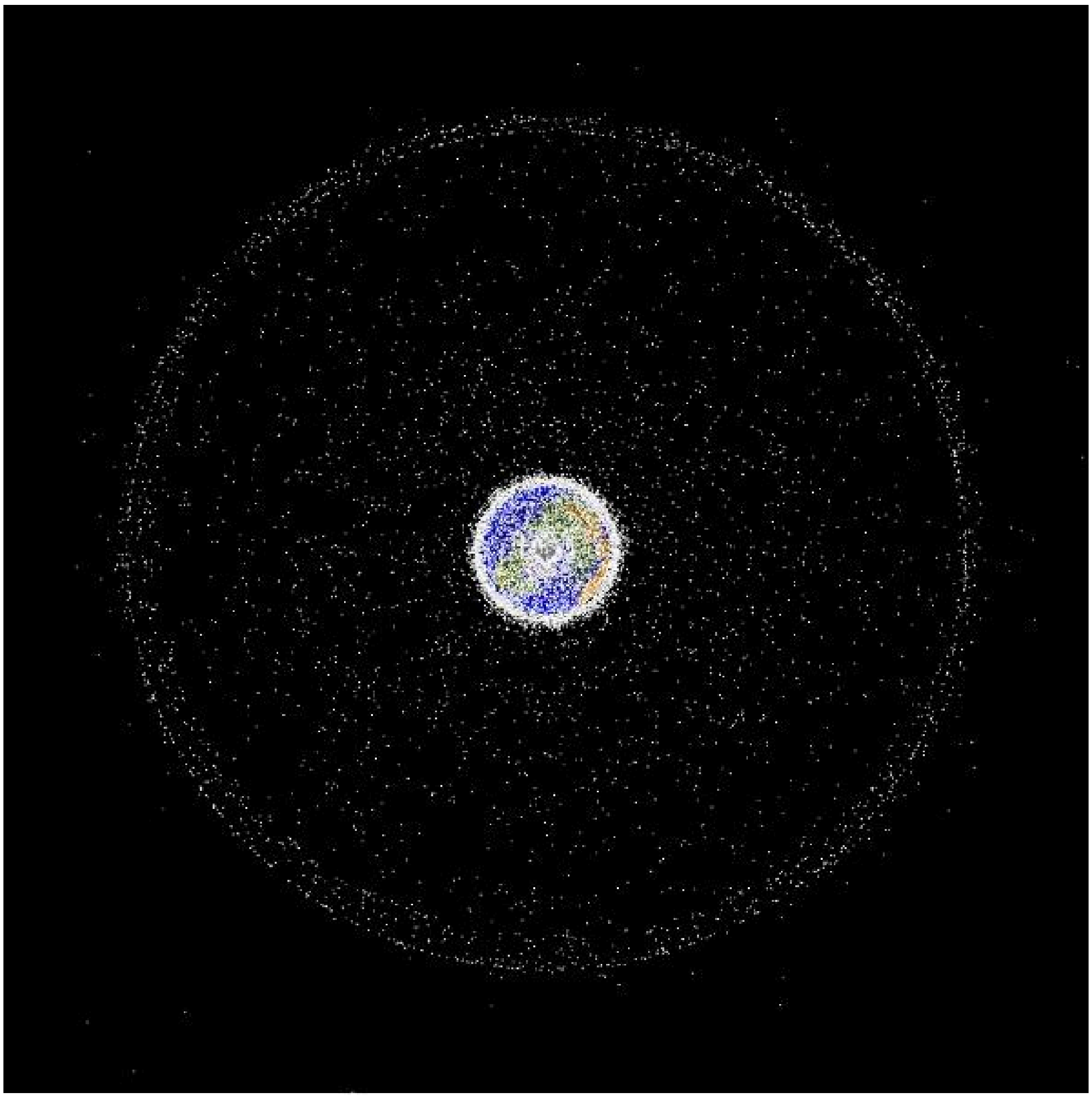


Figure 2 [32]

[31] NASA. 2024. "Space Debris - NASA."
[32] Yadavalli, Karthik. 2024. "How Can We Clean up Space Debris?" *Astrobites.org*, April 18.

From the initial space race in October 1957, with the launch of Sputnik 1 to 2003, there have been over five thousand launches, and each contributes several objects that remain in orbit. The US military tracked around 20,000 objects and has cataloged nearly 40,000 objects over the years.[33] This number does not include the countless smaller debris particles, which, despite their size, can still cause significant damage.[34] From late 2021, approximately 4,852 operational satellites were in orbit—2,944 of which belonged to the United States.[35] Data from Chapter 5, Crowding and Competition in Space of The Global Risks Report 2022, visualizes the number of objects in all orbits from 1960 to 2021 below.

[33] Aerospace.org. 2024. "Space Debris 101 | The Aerospace Corporation." *Aerospace*, August 21. https://aerospace.org/article/space-debris-101

[34] Aerospace.org. 2024. "Space Debris 101 | The Aerospace Corporation." *Aerospace*, August 21.

[35] Koop, Avery. 2022. "Visualized: Which Countries Are Dominating Space?" *Visual Capitalist (blog)*, July 8.

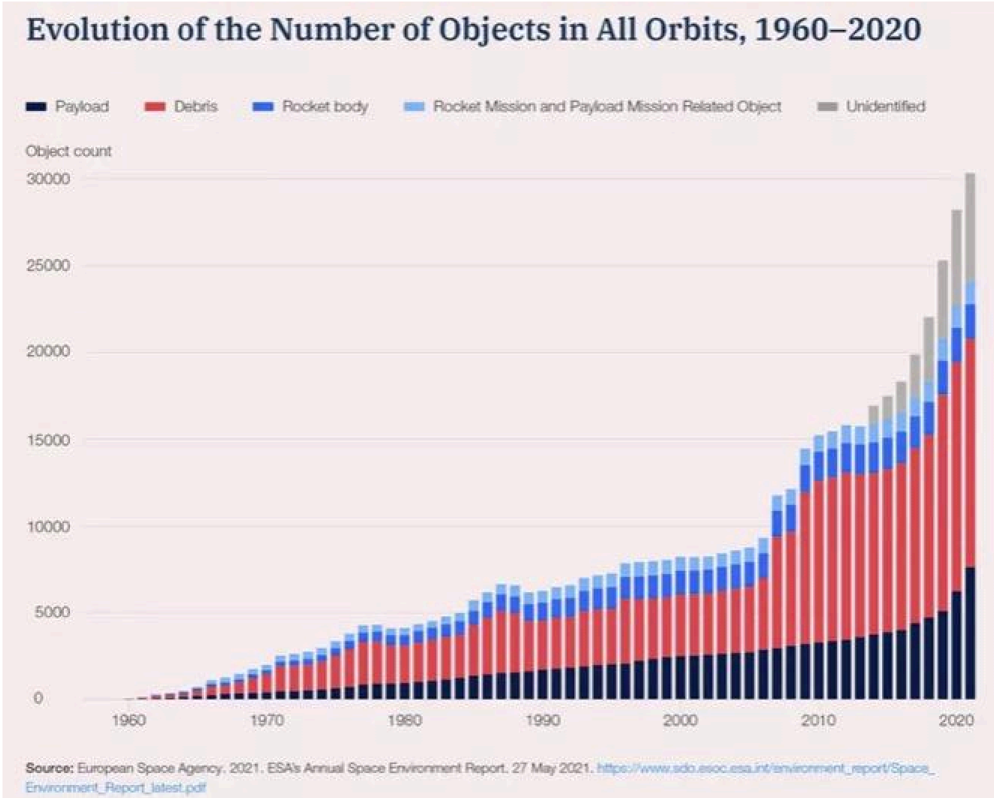


Figure 3 [36]

Currently, there are approximately 7,7000 satellites near Earth orbit, and it is estimated to expand by several hundred thousand by 2027.[37] Space debris moves at very high speeds, reaching up to 18,000 miles per hour in some cases, which is approximately seven times faster than a bullet, making collisions catastrophic.[38] A single collision can generate thousands of particles of space debris.[39] Astrophysicist Johnathan McDowell explains in an interview with Space.com, "It's going to be like an interstate highway, at rush hour in a snowstorm, with

---

[36] Global Risks Report. 2022. *Global Risks Report 2022: Chapter 5. Crowding and Competition in Space*. World Economic Forum. https://www.weforum.org/publications/global-risks-report-2022/in-full/chapter-5-crowding-and-competition-in-space/#chapter-5-crowding-and-competition-in-space

[37] Impey, Chris. 2023. "Analysis: Why Trash in Space Is a Major Problem with No Clear Fix." *PBS News*, September 3.

[38] NASA. 2024. "Space Debris - NASA."

[39] Luke, Charlotte. 2021. "Explainer: What Is Space Junk and How Does It Affect the Environment?" *Earth.Org*, September 6. https://earth.org/space-junk-what-is-it-what-can-we-do-about-it/

everyone driving much too fast."[40] The European Space Agency (ESA) estimates that there are currently 29,000 pieces of space debris larger than 10 cm in Earth's orbit, 670,000 objects larger than 1 cm, and over 170 million particles larger than 1 mm.[41] These tiny pieces of debris move at 15,000 mph, which is 10 times faster than a bullet, and with that speed, even a fleck of paint can puncture a spacesuit or destroy sensitive electronics.[42] When pieces of debris collide with one another, they break into thousands of smaller pieces, creating even more debris, increasing the risk of further collisions. This chain reaction or domino effect is known as the "*Kessler Syndrome,"* which was founded by NASA scientist Donald Kessler in 1978. The images below illustrate the increasing volume of tracked space debris and active spacecraft orbiting Earth over time.

[40] Pultarova, Tereza. 2023. "How Many Satellites Can We Safely Fit in Earth Orbit?" *Space.com*, February 27. https://www.space.com/how-many-satellites-fit-safely-earth-orbit
[41] "How Many Space Debris Objects Are Currently in Orbit?" Accessed December 16, 2024. https://www.esa.int/Space_Safety/Clean_Space/How_many_space_debris_objects_are_currently_in_orbit#:~:text=More%20than%20170%20million%20%2D%20for%20sizes%20larger%20than%201%20mm
[42] Impey, Chris. 2023. "Analysis: Why Trash in Space Is a Major Problem with No Clear Fix." *PBS News*, September 3.

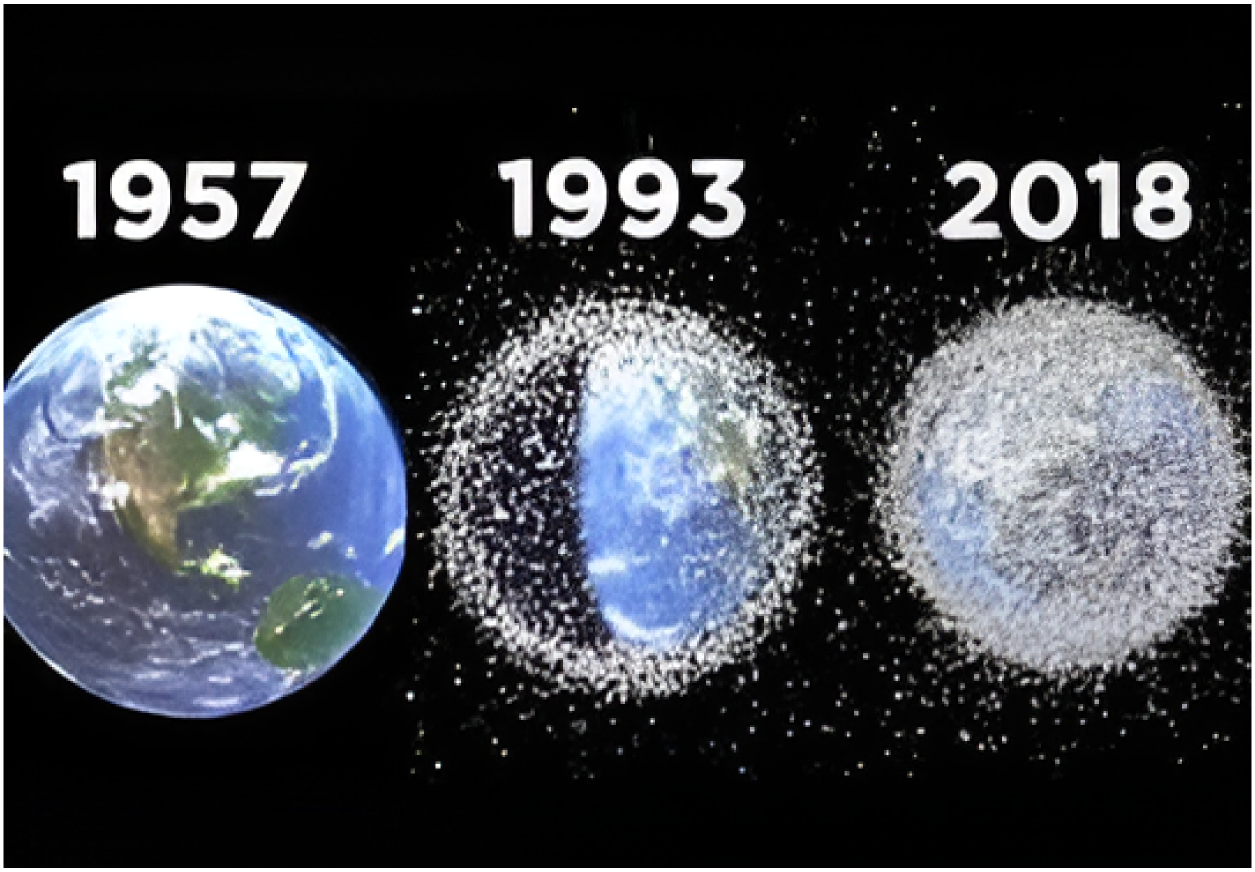


Figure 4 [43]

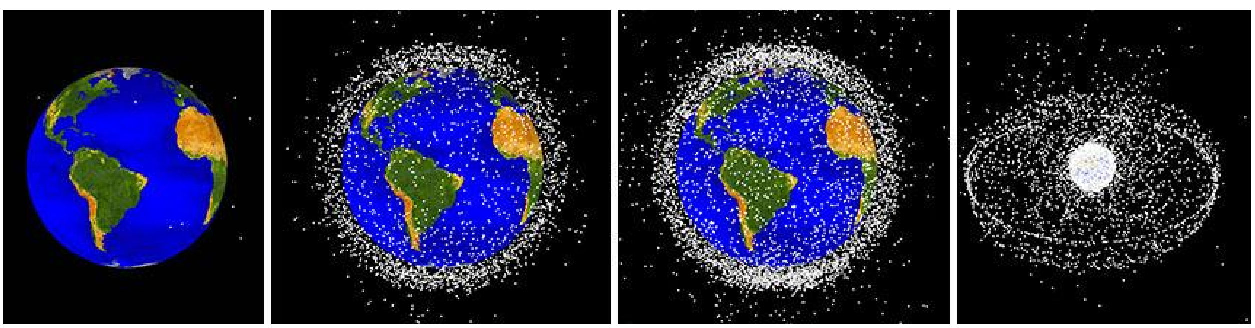


Figure 5 [44]

[43] Dhanapal, Durai, Janagam Durai Dhanapal, and Ilayarasan Udhayakumar. 2023. "Issues of Space Debris and Sustainable Development Practices." *Journal of Development Economics and Management Research Studies*, January. https://www.researchgate.net/publication/367021464_Issues_of_Space_Debris_and_Sustainable_Development_Practices

[44] Whiting, Melanie. 2016. "Destruction Junction—What's Your Function?" *Roundup Reads*. NASA Johnson Space Center, November 18. https://roundupreads.jsc.nasa.gov/roundup/553

Given the high speeds and increasing volume of debris in LEO, both current and future space-based services, exploration efforts, and operations present significant safety risks to people and property, both in space and on Earth. Past incidents, such as the deliberate destruction of the Chinese Fengyun-1C spacecraft in 2007 and the accidental collision between the inactive Russian satellite Cosmos 2251 and the active American communication satellite Iridium 33 in 2009, have significantly increased the orbital debris population in low Earth orbit (LEO) by about 70%, elevating the risk of collisions for spacecraft operating in this region.[45,46] The 2009 collision, which occurred approximately 804 km (499.6 mi) above Siberia, resulted in approximately 2,000 pieces of debris at least 10 cm in diameter, along with thousands more smaller fragments. It is estimated that over 50% of the debris from Iridium 33 will remain in orbit for at least a century, and the debris from Cosmos 2251 will remain for at least 20 to 30 years.[47]

The problem extends beyond space, with severe consequences reaching down to Earth. As space debris re-enters our atmosphere, it poses a direct threat to the environment and human safety. Eventually, as some debris from LEO gradually loses momentum, it will descend toward Earth's atmosphere and regenerate heat, contributing to global warming.[48] Larger debris, including remnants from Russian Proton rockets, are scattered across the Altai region of eastern Siberia. This debris includes highly toxic rocket fuel unsymmetrical dimethylhydrazine (UDMH), which contaminates soil and water, threatening local plants and animals. This pollution also jeopardizes the food sources of nearby residents, posing serious health risks,

---

[45] NASA. 2024. "Space Debris - NASA."
[46] Luke, Charlotte. 2021. "Explainer: What Is Space Junk and How Does It Affect the Environment?" *Earth.Org*, September 6.
[47] Ibid.
[48] Ibid.

including cancer.[49] In 2007, twenty-seven individuals from the Ust-Kansky District of Altai were hospitalized due to cancer-related complications, with many crediting the rocket fuel contamination as the likely suspect.[50]

Despite these dangers, there are no substantial international laws in place to address debris removal in LEO, leading to what has been described as the “world's largest garbage dump,” with nearly 6,000 tons of debris currently orbiting Earth.[51] If space exploration continues to grow at its current pace, the Institute for Environment and Human Security at the United Nations University estimates that more than 100,000 spacecraft will be launched by 2030.[52] This substantial increase could create a surge of collisions, which could further add to *Kessler Syndrome* and, if it occurred, could make LEO orbits unusable for decades, jeopardizing missions to the Moon, Mars, and beyond.[53]

The process of the root causes and effects of space debris can be visualized in Appendix A.

<u>Current Efforts:</u>

In response to the increasing threat of space debris, numerous nations and non-profit and private entities have launched initiatives to mitigate space debris. Efforts to address the problem first began in the 1990s with The National Aeronautics and Space Administration (NASA)

---

[49] BBC News. 2012. “Russians Say Space Rocket Debris Is Health Hazard.” *BBC News*, August 4. https://www.bbc.com/news/world-europe-19127713

[50] Luke, Charlotte. 2021. “Explainer: What Is Space Junk and How Does It Affect the Environment?” *Earth.Org*, September 6.

[51] NASA. 2024. “Space Debris - NASA.”

[52] United Nations University. 2024. “5 Things You Should Know about Space Debris.” *United Nations University’s Institute for Environment and Human Security*, December 4. https://unu.edu/ehs/series/5-things-you-should-know-about-space-debris

[53] Cacion, Alessandro. 2022. “Space Explained: How Much Space Junk Is There?” *Inmarsat*, December 19. https://www.inmarsat.com/en/insights/corporate/2022/how-much-space-junk-is-there.html

Orbital Debris Mitigation Policy and Guidelines. The U.S. National Space Policy of 2006 and 2010 emphasized the need to follow the guidelines, which focus on controlling debris release, choosing safe flight paths, and ensuring space equipment is properly disposed of after missions.[54] In 2002, the Inter-Agency Space Debris Coordination Committee (IADC), composed of different country's space agencies, established global guidelines that became internationally recognized and adopted as the standard. However, Holger Krag, ESA's Head of Space Debris Officer in Germany, estimates that only half of all space missions adhere to these guidelines. He explains that with the increasing activity in space, companies are unlikely to invest in the costly technology needed to remove malfunctioning satellites from orbit.[55]

Recently, the European Space Agency (ESA) has taken significant steps towards space sustainability by adopting a "Zero Debris" approach, with plans for implementation by 2025. ESA's updated "Space Debris Mitigation" guidelines and policy built from a decade of collaboration introduce stricter requirements from its 2023 agenda to limit debris production in orbits by 2030. The agency is working toward a framework that ensures a net-neutral contribution to space debris.[56]

Head Officer Krag explains that while space activity is increasing rapidly, the technology to manage the risks, especially the buildup of space debris, needs to catch up.[57] The goal of becoming "debris neutral" means that once a mission is finished, all leftover objects in Earth's orbit should be cleaned up. If the mission doesn't clear the debris itself, specialized vehicles must

---

[54] Luke, Charlotte. 2021. "Explainer: What Is Space Junk and How Does It Affect the Environment?" *Earth.Org*, September 6.
[55] Ibid.
[56] "ESA's Zero Debris Approach." Accessed December 16, 2024. https://www.esa.int/Space_Safety/Clean_Space/ESA_s_Zero_Debris_approach
[57] Luke, Charlotte. 2021. "Explainer: What Is Space Junk and How Does It Affect the Environment?" *Earth.Org*, September 6.

be sent to remove it.[58] In 2022, the ESA's Concurrent Design Facility, in collaboration with all ESA sites across Europe and 270 experts from industry, government agencies, and academia, was able to highlight and publish eight key recommendations to achieve their goal.[59]

Similarly, in 2022, The White House released a "National Orbital Debris Implementation Plan," which provides an interagency strategy to guide the government's actions and provide a framework for space sustainability due to both intended and unintended debris. It details 43 specific actions across three key areas: 1) Debris Mitigation, 2) Tracking and Characterization of Debris, and 3) Remediation of Debris.[60]

The debris mitigation plan aims to improve spacecraft designs to prevent debris creation, establish best practices, enhance collision avoidance systems, and develop add-on devices to track and remove debris. Next, under the tracking and characterization section, the goal is to foster technologies that can detect and track debris, improve models predicting debris locations, and research methods to track smaller, hard-to-detect debris. Finally, the debris remediation section emphasizes investing in technologies to remove or reduce space debris actively, developing standards for debris removal systems, and exploring international cooperation on debris removal policies.[61]

---

[58] "ESA's Zero Debris Approach." Accessed December 16, 2024. https://www.esa.int/Space_Safety/Clean_Space/ESA_s_Zero_Debris_approach
[59] Ibid.
[60] National Orbital Debris Implementation Plan. 2022. *National Orbital Debris Implementation Plan*. Executive Office of the President of the United States, Orbital Debris Interagency Working Group Subcommittee on Space Weather, Security, and Hazards of the National Science and Technology Council, July. https://www.whitehouse.gov/wp-content/uploads/2022/07/07-2022-NATIONAL-ORBITAL-DEBRIS-IMPLEMENTATION-PLAN.pdf
[61] Ibid.

In 2010, the United Nations Office for Outer Space Affairs (UNOOSA) established its "Space Debris Mitigation Guidelines" to promote the peaceful use of outer space. The guidelines provide voluntary measures to reduce the risks posed by space debris, including designing spacecraft to minimize debris generation during normal operations, incorporating safety measures to prevent accidental break-ups, and estimating and limiting the chances of collisions in orbit. They also recommend refraining from activities that generate long-lived debris, particularly intentional destruction, and ensuring stored energy is safely depleted at the end of a spacecraft's mission. Additionally, spacecraft should be removed from LEO after missions or relocated to prevent long-term presence, and objects should be kept from interfering with the Geosynchronous Earth Orbit (GEO) region.[62]

Recommendations:

Various measures can be employed to mitigate space debris, such as strengthening existing treaties to reflect the modern-day use of space or establishing a global body to oversee space debris management and exploration efforts.

1. Amending the 1967 Outer Space Treaty

The 1967 Outer Space Treaty was introduced by the United States and the Soviet Union to the United Nations General Assembly to establish a foundational framework for peaceful international space exploration and cooperation.[63] The treaty sets the foundation for the exploration and use of outer space, ensuring it is used for peaceful purposes and the benefit of all

---

[62] "Space Debris Mitigation Guidelines of the Committee on the Peaceful Uses of Outer Space ." United Nations Office for Outer Space Affairs: United Nations , 2010. https://www.unoosa.org/pdf/publications/st_space_49E.pdf

[63] Kimball, Daryl. 2024. "The Outer Space Treaty at a Glance." *ArmsControl.org*, July. https://www.armscontrol.org/factsheets/outer-space-treaty-glance.

humanity, even for economic or scientific development. It prohibits the national appropriation of celestial bodies, the placement of weapons of mass destruction in space, and military activities on the moon and other celestial bodies.[64] The treaty promotes international cooperation in space exploration, scientific investigation, and the protection of astronauts. States are responsible for their activities in space, including those of private entities, and are liable for any damage caused by objects they launch. It establishes rules for the return of objects and astronauts and encourages transparency in space activities. Any party can propose amendments, and states may withdraw from the treaty with proper notification.[65]

However, this treaty faces several limitations in today's rapidly evolving space arena, from outdated provisions to ambiguous frameworks. For instance, it did not anticipate how vast space exploration has become and what threat that brings. The treaty does not include regulations for environmental impacts, addressing the growing problem of space debris. Without explicit agreements and details on how to manage the debris, space operations have become increasingly more dangerous and costly.[66] In addition to the gaps from the environmental standpoint, the Space Treaty is outdated in military activities, too. While it prohibits the placement of weapons in space, it is vague on other military operations such as the modern-day space-based defense systems (e.g., satellite surveillance and missile detection). The treaty also prohibits national appropriation of celestial bodies but does not include resource extraction by private entities or

---

[64] Ibid.
[65] United Nations Office for Outer Space Affairs. 2010. *Space Debris Mitigation Guidelines of the Committee on the Peaceful Uses of Outer Space*. January. https://www.unoosa.org/pdf/publications/st_space_49E.pdf.
[66] Aerospace.org. 2024. "Space Debris 101 | The Aerospace Corporation." *Aerospace*, August 21.

governments.[67] As space mining becomes more feasible, the ambiguity creates potential gaps that the treaty needs to address.

Amending the Outer Space Treaty is essential to address these gaps and adequately reflect today's space. The amendments would strengthen provisions to account for the growing participation and technological advancements. The provisions should include the following:

i. Protocols for environmental impact mitigation to recognize harms such as space debris. This could be enforced by mandating launching nations and entities to employ environment-sustainable materials and technologies in spacecraft equipment that minimize or remove debris after missions. This could also include requiring safe deorbiting of defunct objects.
ii. Broadening the prohibition on military activities by restricting recent space weaponry and satellite warfare technologies, including space-based defense systems.
iii. Clarifying the responsibilities of partakers and enforcing stricter repercussions for damages. While the treaty currently holds nations accountable for the activities of private entities, the framework should be expanded to explicitly outline the obligations—along with clear penalties for non-compliance.

By incorporating these amendments, the 1967 Outer Space Treaty can evolve to meet the demands of 21st-century space exploration. Modernizing the treaty will ensure that space remains peaceful, cooperative, and environmentally sustainable while providing clearer guidelines for debris mitigation, space militarization, and private sector involvement.

---

[67] United Nations Office for Outer Space Affairs. 2010. *Space Debris Mitigation Guidelines of the Committee on the Peaceful Uses of Outer Space*. January.

2. Establishing a Global Committee for Space Sustainability:

To build off the efforts of global agencies and nations, such as the European Space Agency (ESA), The United States Office of Science and Technology Policy (OSTP), and The United Nations Office for Outer Space Affairs (UNOOSA) expanding national initiatives into a broader, universal effort could be the next step.

Establishing a global committee to create a universal program that enforces guidelines and conducts space regulation can help preserve the space environment and hold all parties accountable. The global committee should:

i. Streamline and consolidate the existing efforts from various nations and organizations into a unified, global committee.
ii. Collect funding by mandatory contributions from the largest emitting nations and leading private entities by taxing space exploration activities.
iii. Mandate environmental impact assessments for all space activities, including satellite launches, space mining, and lunar or asteroid exploration.
iv. Research both hazardous materials and environmentally sustainable materials in spacecraft equipment to encourage the use of eco-friendly materials.

By establishing a dedicated body, with involvement from all spacefaring nations and companies, the committee can oversee initiatives and research that help reduce space debris, protect the environment, and create accountability for participants.

Challenges:

However, these recommendations come with notable challenges. Amending an international treaty requires unanimous agreement among all 115 signatory nations, which could result in lengthy negotiations and significant opposition from countries with competing interests.[68] For example, those prioritizing space defense or commercial space mining may resist certain amendments. Even if amendments are ratified, enforcing them could be difficult as there are no established international mechanisms for monitoring or penalizing non-compliance. This could weaken the effectiveness of new provisions, especially concerning private companies.

Similarly, establishing a global committee may also face resistance. Some nations may view the creation of an international body with authority over their space activities as a threat to national sovereignty. Additionally, consolidating diverse national policies and initiatives under a single framework could introduce bureaucratic hurdles, slowing the committee's ability to act efficiently. Without a clear enforcement mechanism or the authority to impose penalties, the committee's rule could be ignored, leading to minimal impact on actual space debris mitigation.

Conclusion:

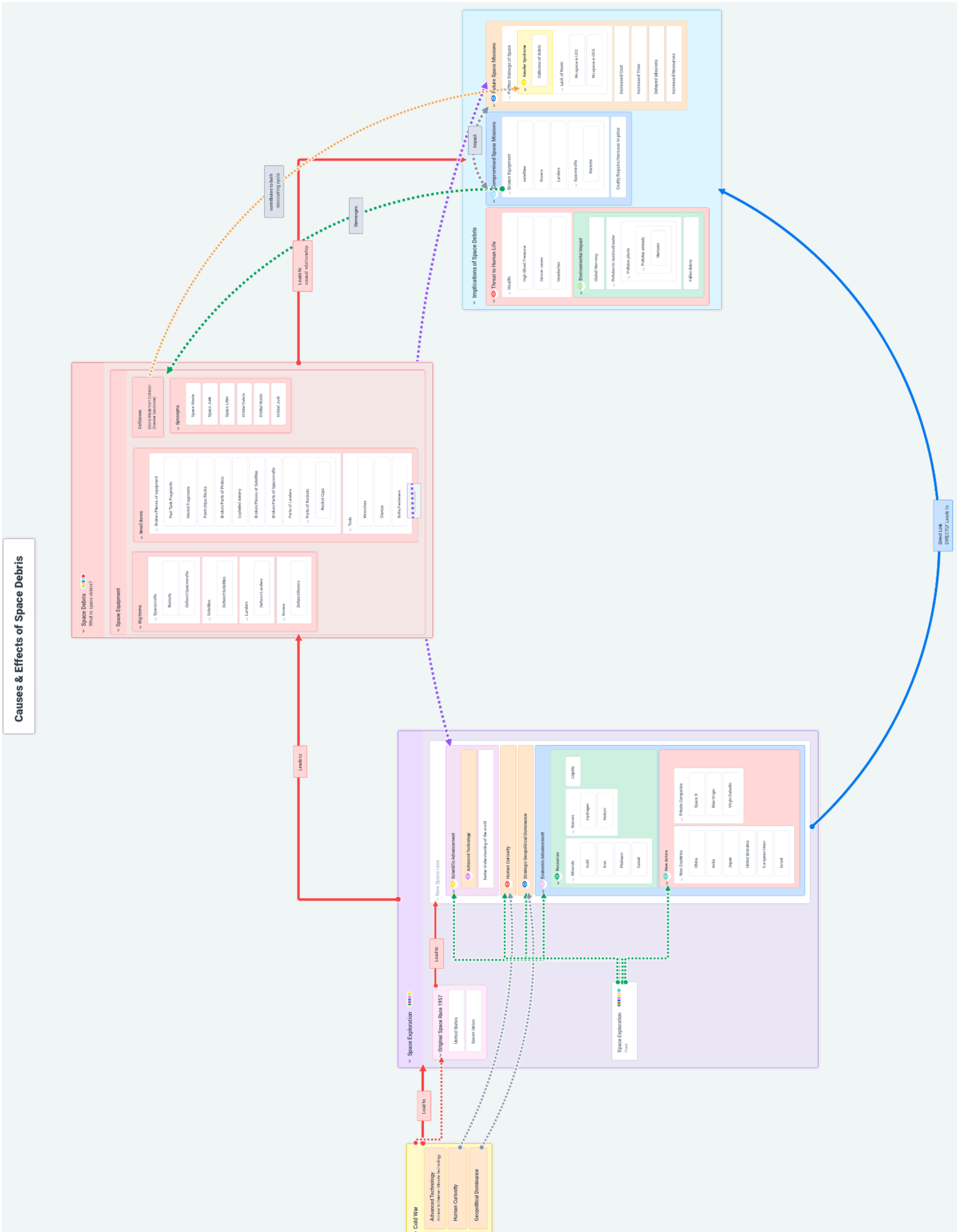
Space debris is quickly becoming one of the most pressing challenges in modern space exploration and sustainability, posing serious risks to the future of space missions and life on Earth. The growing accumulation of space debris in LEO and GEO creates severe risks for space missions, environmental health, and human safety. The consequences of this debris, moving at catastrophic speeds, can trigger a chain reaction known as the Kessler Syndrome. With projections indicating a substantial rise in space activity over the following decades, the urgency for effective mitigation strategies is crucial.

---

[68] Ibid.

Current efforts, including international guidelines and initiatives like NASA's Orbital Debris Mitigation Policy and the European Space Agency's Zero Debris approach, have set foundational steps toward tackling this issue. However, these efforts are still insufficient to keep up with the rapid pace of space activity. To prevent deepening the situation, proposed solutions include updating international treaties, enhancing debris tracking technologies, and creating a Global Committee for Space Sustainability. Without coordinated global action, the rising threat of space debris could jeopardize not only space missions but also the sustainability of life on Earth.

Appendix A



References

1. Marshall, Tim. 2024. "The New Space Race | Power & Politics in the 21st Century." *Royal Museums Greenwich*. Accessed October 26. https://www.rmg.co.uk/stories/topics/new-space-race-astropolitics-power-21st-century.
2. Koop, Avery. 2022. "Visualized: Which Countries Are Dominating Space?" *Visual Capitalist (blog)*, July 8. https://www.visualcapitalist.com/visualized-which-countries-are-dominating-space/.
3. Luetz, Neil. 2024. "The Implications of the 21st Century Space Race." *Vanguard Think Tank*. https://vanguardthinktank.org/spacerace.
4. Marshall, Tim. 2024. "The New Space Race | Power & Politics in the 21st Century." *Royal Museums Greenwich*.
5. HISTORY. 2020. "The Space Race: Timeline, Cold War & Facts." *History*, February 21. https://www.history.com/topics/cold-war/space-race
6. Smithsonian National Air and Space Museum. 2023. "What Was the Space Race?" *Air and Space Museum*, August 23. https://airandspace.si.edu/stories/editorial/what-was-space-race
7. Marshall, Tim. 2024. "The New Space Race | Power & Politics in the 21st Century." *Royal Museums Greenwich*.
8. Edwards, Sarah. 2024. "10 Space Companies Changing Aerospace." *Thomasnet (blog)*, October 12. https://www.thomasnet.com/insights/biggest-space-companies/.
9. Gerbis, Nicholas. 1970. "10 Major Players in the Private Sector Space Race." *HowStuffWorks*, January 1. https://science.howstuffworks.com/10-major-players-in-private-sector-space-race.htm
10. Marshall, Tim. 2024. "The New Space Race | Power & Politics in the 21st Century." *Royal Museums Greenwich*.
11. Ibid.
12. Ibid.
13. Kramer, Katie. 2015. "Neil deGrasse Tyson Says Space Ventures Will Spawn First Trillionaire." *NBC News*, May 3. https://www.nbcnews.com/science/space/neil-degrasse-tyson-says-space-ventures-will-spawn-first-trillionaire-n352271.
14. Ibid.
15. Luetz, Neil. 2024. "The Implications of the 21st Century Space Race." *Vanguard Think Tank*.
16. Ibid.

17. United States Space Force. 2024. "Defense Support Program Satellites." Accessed October 27. https://www.spaceforce.mil/About-Us/Fact-Sheets/Article/2197774/defense-support-program-satellites/
18. Office of the Director of National Intelligence. 2011. *National Security Space Strategy*. Unclassified Summary. https://www.dni.gov/files/documents/Newsroom/Reports%20and%20Pubs/2011_nationalsecurityspacestrategy.pdf.
19. Ibid.
20. Ibid.
21. Luetz, Neil. 2024. "The Implications of the 21st Century Space Race." *Vanguard Think Tank*.
22. Koop, Avery. 2022. "Visualized: Which Countries Are Dominating Space?" *Visual Capitalist (blog)*, July 8.
23. Natural History Museum. 2024. "What Is Space Junk and Why Is It a Problem?" https://www.nhm.ac.uk/discover/what-is-space-junk-and-why-is-it-a-problem.html.
24. Ibid.
25. Impey, Chris. 2023. "Analysis: Why Trash in Space Is a Major Problem with No Clear Fix." *PBS News*, September 3. https://www.pbs.org/newshour/science/analysis-why-trash-in-space-is-a-major-problem-with-no-clear-fix.
26. Ibid.
27. Ibid.
28. NASA. 2024. "Space Debris - NASA." https://www.nasa.gov/headquarters/library/find/bibliographies/space-debris/.
29. Yadavalli, Karthik. 2024. "How Can We Clean up Space Debris?" *Astrobites.org*, April 18. https://astrobites.org/2024/04/18/how-can-we-clean-up-space-debris/.
30. "Differences between Leo and Geo Satellites." Accessed December 16, 2024. https://www.diteltech.com/info-detail/differences-between-leo-and-geo-satellites.
31. NASA. 2024. "Space Debris - NASA."
32. Yadavalli, Karthik. 2024. "How Can We Clean up Space Debris?" *Astrobites.org*, April 18.
33. Aerospace.org. 2024. "Space Debris 101 | The Aerospace Corporation." *Aerospace*, August 21. https://aerospace.org/article/space-debris-101.
34. Aerospace.org. 2024. "Space Debris 101 | The Aerospace Corporation." *Aerospace*, August 21.
35. Koop, Avery. 2022. "Visualized: Which Countries Are Dominating Space?" *Visual Capitalist (blog)*, July 8.
36. Global Risks Report. 2022. *Global Risks Report 2022: Chapter 5. Crowding and Competition in Space*. World Economic Forum.

https://www.weforum.org/publications/global-risks-report-2022/in-full/chapter-5-crowding-and-competition-in-space/#chapter-5-crowding-and-competition-in-space.

37. Impey, Chris. 2023. "Analysis: Why Trash in Space Is a Major Problem with No Clear Fix." *PBS News*, September 3.
38. NASA. 2024. "Space Debris - NASA."
39. Luke, Charlotte. 2021. "Explainer: What Is Space Junk and How Does It Affect the Environment?" *Earth.Org*, September 6. https://earth.org/space-junk-what-is-it-what-can-we-do-about-it/
40. Pultarova, Tereza. 2023. "How Many Satellites Can We Safely Fit in Earth Orbit?" *Space.com*, February 27. https://www.space.com/how-many-satellites-fit-safely-earth-orbit.
41. "How Many Space Debris Objects Are Currently in Orbit?" Accessed December 16, 2024. https://www.esa.int/Space_Safety/Clean_Space/How_many_space_debris_objects_are_currently_in_orbit#:~:text=More%20than%20170%20million%20%2D%20for%20sizes%20larger%20than%201%20mm.
42. Impey, Chris. 2023. "Analysis: Why Trash in Space Is a Major Problem with No Clear Fix." *PBS News*, September 3.
43. Dhanapal, Durai, Janagam Durai Dhanapal, and Ilayarasan Udhayakumar. 2023. "Issues of Space Debris and Sustainable Development Practices." *Journal of Development Economics and Management Research Studies*, January. https://www.researchgate.net/publication/367021464_Issues_of_Space_Debris_and_Sustainable_Development_Practices.
44. Whiting, Melanie. 2016. "Destruction Junction—What's Your Function?" *Roundup Reads*. NASA Johnson Space Center, November 18. https://roundupreads.jsc.nasa.gov/roundup/553
45. NASA. 2024. "Space Debris - NASA."
46. Luke, Charlotte. 2021. "Explainer: What Is Space Junk and How Does It Affect the Environment?" *Earth.Org*, September 6.
47. Ibid.
48. Ibid.
49. BBC News. 2012. "Russians Say Space Rocket Debris Is Health Hazard." *BBC News*, August 4. https://www.bbc.com/news/world-europe-19127713.
50. Luke, Charlotte. 2021. "Explainer: What Is Space Junk and How Does It Affect the Environment?" *Earth.Org*, September 6.
51. NASA. 2024. "Space Debris - NASA."
52. United Nations University. 2024. "5 Things You Should Know about Space Debris." *United Nations University's Institute for Environment and Human Security*, December 4. https://unu.edu/ehs/series/5-things-you-should-know-about-space-debris.

53. Cacion, Alessandro. 2022. "Space Explained: How Much Space Junk Is There?" *Inmarsat*, December 19. https://www.inmarsat.com/en/insights/corporate/2022/how-much-space-junk-is-there.html
54. Luke, Charlotte. 2021. "Explainer: What Is Space Junk and How Does It Affect the Environment?" *Earth.Org*, September 6.
55. Luke, Charlotte. 2021. "Explainer: What Is Space Junk and How Does It Affect the Environment?" *Earth.Org*, September 6.
56. "ESA's Zero Debris Approach." Accessed December 16, 2024. https://www.esa.int/Space_Safety/Clean_Space/ESA_s_Zero_Debris_approach.
57. Luke, Charlotte. 2021. "Explainer: What Is Space Junk and How Does It Affect the Environment?" *Earth.Org*, September 6.
58. "ESA's Zero Debris Approach." Accessed December 16, 2024. https://www.esa.int/Space_Safety/Clean_Space/ESA_s_Zero_Debris_approach.
59. Ibid.
60. National Orbital Debris Implementation Plan. 2022. *National Orbital Debris Implementation Plan*. Executive Office of the President of the United States, Orbital Debris Interagency Working Group Subcommittee on Space Weather, Security, and Hazards of the National Science and Technology Council, July. https://www.whitehouse.gov/wp-content/uploads/2022/07/07-2022-NATIONAL-ORBITAL-DEBRIS-IMPLEMENTATION-PLAN.pdf.
61. Ibid.
62. "Space Debris Mitigation Guidelines of the Committee on the Peaceful Uses of Outer Space ." United Nations Office for Outer Space Affairs: United Nations , 2010. https://www.unoosa.org/pdf/publications/st_space_49E.pdf.
63. Kimball, Daryl. 2024. "The Outer Space Treaty at a Glance." *ArmsControl.org*, July. https://www.armscontrol.org/factsheets/outer-space-treaty-glance.
64. Kimball, Daryl. 2024. "The Outer Space Treaty at a Glance." *ArmsControl.org*, July.
65. United Nations Office for Outer Space Affairs. 2010. *Space Debris Mitigation Guidelines of the Committee on the Peaceful Uses of Outer Space*. January. https://www.unoosa.org/pdf/publications/st_space_49E.pdf.
66. Aerospace.org. 2024. "Space Debris 101 | The Aerospace Corporation." *Aerospace*, August 21.
67. United Nations Office for Outer Space Affairs. 2010. *Space Debris Mitigation Guidelines of the Committee on the Peaceful Uses of Outer Space*. January.
68. Ibid.