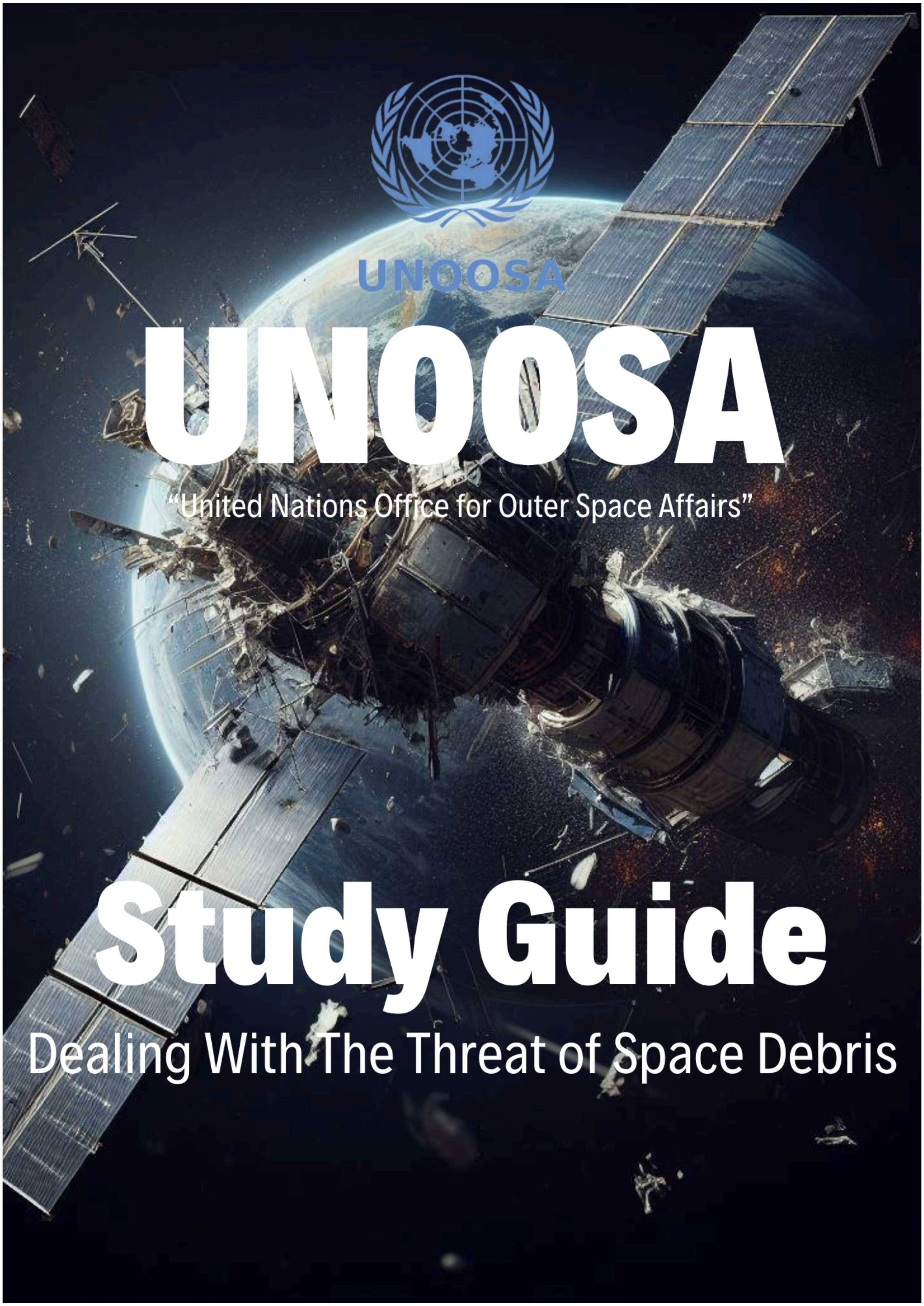

UNOOSA

UNOOSA

"United Nations Office for Outer Space Affairs"

Study Guide

Dealing With The Threat of Space Debris

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I. Letter from the Secretary-General

Distinguished Delegates and Esteemed Advisors,

It is such great honour and anticipation to take this opportunity of welcoming you all to the first ever session of the IDA Model United Nations Conference. Never before has academic knowledge exchange and rememberable diplomacy been more of a necessity, and this event will mark the start of this narrative brought to life on the 8-10 February 2025 hosted by Çanakkale Fen Mat Academy College This has been precisely incorporated to provide a platform for spirited and aspiring youth to come together to deliberate upon pressing issues of the world, find solutions to problems and enhance their knowledge in the field of world relations. “Empowering Visions, Inspiring Futures,” is our motto to represent our focus on leadership development, critical thinking, and global citizenship for all of our offerors.

The conference this year will consist of four specially curated committees including junior and senior levels that will consider relations to current global issues. The Disarmament and International Security Committee (DISEC) will address the international threat of insurgence and terrorism. Women shall be brought to the forefront of civil society and UN Women will strive to ensure that the women are empowered, violence against them is eliminated and their effective participation in all spheres of life is promoted. The World Health Organization (WHO) will focus on one of the key areas of universal health coverage and equitable access to healthcare. Finally, there will be a session addressing the issue of space debris, ensuring that outer space is used sustainably, by the United Nations Office for Outer Space Affairs (UNOOSA). Every committee provides an opportunity for delegates to debate intensely, negotiate solutions, and sharpen their diplomatic skills.

On behalf of IDAMUN25 academic and organizational teams, I appreciate and thank you for the great contribution to making this event possible. Months of hard work and detailed planning have gone into making this conference not only an intellectually invigorating experience, but a chance for personal growth and engagement. We are excited to host you here on Çanakkale and see your passion, mind and creativities. If the rest of IDAMUN25 is anything like this, then we can only hope that it will lead to a defining chapter in your journey toward becoming tomorrow’s leaders, driving a better and more united future for our world.

Sincerely,

Gökçe Güder
Secretary General of IDA Model United Nations 2025

II. Letter from the Under-Secretary-General

Honorable Delegates,

I take great honor and excitement to officially welcome you to the United Nations Office for Outer Space Affairs (UNOOSA) Committee at IDA Model United Nations 2025. The three-day sessions from 8 to 10 February will bring us instructively together in the training grounds of Çanakkale, under the theme shared by a common purpose-vision: to explore and inspire new thinking, debate critical global issues, and innovate solutions.

The conference's theme, "Empowering Visions, Inspiring Futures," encapsulates our commitment to guiding leadership and teamwork, and fostering critical thinking in the bright minds of today who will be shaping tomorrow. This is also in line with the Committee's outlook, that we swell around an increasingly urgent global topic: the sustainable use of outer space, such as the issue of space debris, which is not only a scientific or technological issue, but also an impact on international security, environmental sustainability, and finally equitable access to the last frontier.

In this committee, we will work to address pressing questions: How do we mitigate the growing risks posed by space debris? How do we balance the sustainability of innovation in space exploration? How can we ensure that outer space remains a domain of peaceful use and shared benefit? These questions would require more than just technical solutions; they would need diplomacy, negotiation, and the ability to see from multiple perspectives.

As Under-Secretary-General of UNOOSA at IDAMUN25, I am proud to see the creativity, passion, and determination that you, the delegates, bring to this forum. Whether or not you are a seasoned MUN'er, this is most likely your first exposure to Model United Nations. Very few people have made it a successful debate topic that will shape the outcome of a couple of sessions.

Sincerely,

Ada Genlik
Under-Secretary-General of UNOOSA IDAMUN 2025

III. Introduction to the Committee: United Nations Office for Outer Space Affairs

The United Nations Office for Outer Space Affairs (UNOOSA) promotes international cooperation in the peaceful exploration and use of outer space. It supports using space science and technology to advance sustainable economic and social development. The office helps United Nations Member States develop legal and regulatory frameworks for space activities and assists developing countries in using space technology for development by integrating it into their national plans.[1]

The United Nations Office for Outer Space Affairs (UNOOSA) assists countries, particularly developing ones, in accessing and utilizing space benefits to support sustainable development. The committee achieves this through activities covering all aspects of space, including space law and applications. The committee enhances countries' capacity to develop and benefit from the space sector. In disaster risk reduction, their UN-SPIDER program helps countries use space technologies, including satellite imagery, to prevent and manage disasters effectively. The committee guides countries in understanding international space law and building or revising national space policies to align with global frameworks, which is vital as new actors join the space sector. To ensure transparency, they maintain the Register of Objects Launched into Outer Space, linking each object to its responsible nation. UNOOSA promotes sustainable development through space and the long-term sustainability of space activities. It addresses challenges such as space debris and works to preserve outer space for future generations. By collaborating with global space agencies and leaders, they address international challenges like the threat of Near-Earth Object impacts and the need for GNSS system compatibility.[2]

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[1] Robert.wickramatunga. (n.d.). *United NationsOffice for Outer Space Affairs*. About us. https://www.unoosa.org/oosa/en/aboutus/index.html

[2] Martin.Stasko. (n.d.). *Roles responsibilities*. https://www.unoosa.org/oosa/en/aboutus/roles-responsibilities.html

IV. Introduction to the Topic: Dealing with the Threat of Space Debris

"The Universe is infinite
But space has its limits
Rockets a launching
Sat'lites are orbiting
Explosions in Space
Oh what a waste
Fragments go flying
And we go crying "Space junk we've got" Man-made or not
Then comes Kessler Who knows the better
When things collide
Their debris do multiply
Thanks to partnering
And NASA's gathering
We look for ways
To manage the spray"
– S. Thuy Nguyen-Onstott.[3]

A. Introduction to Space Debris: Scope and Importance

Space junk is invisible to the naked eye but it enters low Earth orbit (LEO) when it passes beyond clouds. An orbital space junkyard is called LEO. In LEO, millions of pieces of space debris are in flight. Human-made objects make up the majority of orbital debris, including parts of spacecraft, tiny paint particles from spacecraft, rocket parts, broken satellites, and explosions of objects in orbit traveling through space at high speeds.

Most "space debris" travels at incredible speeds, reaching up to 18,000 miles per hour—nearly seven times faster than a bullet. This high velocity, combined with the sheer amount of debris in

[3] *Space debris - NASA*. (n.d.). NASA. https://www.nasa.gov/headquarters/library/find/bibliographies/space-debris/

low Earth orbit (LEO), poses significant safety risks to current and future space-based operations, explorations, and services, affecting both people and property in space and on Earth.

LEO has become an orbital graveyard for several reasons. Notably, the intentional destruction of China's Fengyun-1C satellite in 2007 and the accidental collision of an American and a Russian spacecraft in 2009 have collectively increased the large debris population in LEO by about 70%, heightening the risk of collisions for spacecraft operating in this region.

Currently, no international laws mandate the cleanup of debris in LEO, which has become known as the world's largest garbage dump.

In contrast NASA established its Orbital Debris Program in 1979 at the Johnson Space Center in Houston, Texas. The program focuses on reducing the creation of new debris and developing technology to track and remove existing debris.

Managing space junk is not the responsibility of any single nation; instead, it is a shared duty of all space faring countries. Addressing this challenge represents both a global problem and an opportunity to safeguard the space environment for future exploration and missions.[4]

B. Key Terms & Acronyms

COPUOS	- (UN) Committee on the Peaceful Uses of Outer Space
ESA	- European Space Agency
GEO	- Geosynchronous Orbit
IADC	- Inter-Agency Space Debris Coordination Committee
IAF	- International Astronautical Federation
LEO	- Low Earth Orbit

[4] *Space debris - NASA*. (n.d.-b). NASA. https://www.nasa.gov/headquarters/library/find/bibliographies/space-debris/

LDEF	- Long Duration Exposure Facility
NASA	- (US) National Aeronautics and Space Administration
RCS	- Radar Cross Section
UN	- United Nations

- **Space Debris** - Non-functional objects in orbit around Earth.
- **Low Earth Orbit (LEO)** - The region of space close to Earth where much of the debris is concentrated.
- **Orbital Debris** - Synonymous with space junk; includes broken satellites, rocket parts, and fragments from collisions.
- **Kessler Syndrome** - A scenario where collisions between debris create a cascading effect, generating even more debris.
- **Anti-Satellite (ASAT) Tests** - Deliberate destruction of satellites creating debris (e.g., Fengyun-1C test).
- **Defunct Satellites** - Non-operational satellites remaining in orbit.
- **Rocket Stages** - Spent rocket stages left in orbit after launches.
- **Orbital Graveyard** - A term for regions densely populated with debris.
- **Active Debris Removal (ADR)** - Efforts to physically remove debris from orbit.
- **Debris Tracking** - Monitoring the location and movement of space junk.
- **Space Traffic Management (STM)** - Coordination of satellite operations to minimize debris creation.
- **Liability Convention** - International treaty addressing responsibility for damage caused by space objects.
- **Payload Launch Traffic** - Communication and data exchanges between systems or teams during the preparation and execution of a payload launch, ensuring coordination and success

V. Historical Background of Space Debris Threats

A. The Space Race Era

The Space Race started as an arms race between the militaries of the United States of America and the Soviet Union. World War II had shown to the world that rocket technology would be a key point in modern warfare, therefore the U.S. and Russia prepared themselves for a race to have the most superior technology. As technology progressed and powerful intercontinental ballistic missiles (ICBMs) -which have a range of approximately 3500 miles (5600 kilometers)-[5] were developed by both countries which caused the arms race to open a path to another race—the Space Race.[6] From the mid-1950s to 1975, the United States and the Soviet Union struggled to surpass each other in rocket technology and space research. Both superpowers spent an excessive amount of their resources developing space-capable rockets, putting artificial satellites into orbit, designing and building orbiter ships, training astronauts, launching manned space missions and, eventually, venturing to land men on the Moon and bring them home safely. Unlike other aspects of the Cold War, the Space Race was a very public phenomenon. Every ground-breaking invention, test, launch or milestone was advertised and feted with broad media coverage, verging on propaganda. Both the US and USSR time after time claimed to be ahead of the other country in space exploration. But in reality, their successes were quite evenly shared over the duration of the Space Race.

The competition between the two superpowers began in October 1957, when the USSR became the first country to launch a man-made satellite into orbit. Sputnik I (the name is Russian for "traveller" or "wanderer") was tiny in comparison to modern satellites, weighing just 90 kilograms. It circled the Earth at a speed of 28,000 kilometers per hour, orbiting once every 90

[5] *The Editors of Encyclopaedia Britannica. (2024, November 15). ICBM | Intercontinental, nuclear, ballistic. Encyclopedia Britannica. https://www.britannica.com/technology/ICBM*

[6] *What was the space Race? (2023, August 23). National Air and Space Museum. https://airandspace.si.edu/stories/editorial/what-was-space-race*

minutes. In November 1957 the Soviets launched Sputnik II, their second orbiting satellite and the first to include a living creature, a dog named Laika. Two months later the US Army and Air Force launched their first satellite, Explorer I . In July 1958 President Dwight Eisenhower ordered the formation of a devoted space agency, the National Aeronautics and Space Administration (NASA). Within six months NASA had launched the first communications satellite, SCORE, which beamed down a message from Eisenhower. The following month (January 1959) the Soviets got ahead again with the launch of Luna I, the first man-made satellite to leave Earth and take up orbit around the Sun. In September 1959 the Soviets also landed a probe, Luna II, on the surface of the Moon. A Soviet cosmonaut named Yuri Gagarin became the first man in space when his ship, Vostok I, completed an orbit of the Earth in April 1961. John Glenn, flying in Friendship VII, became the first American in space in February 1962. The first woman in space was a Soviet cosmonaut named Valentina Tereshkova, in June 1963. Another Soviet cosmonaut, Alexey Leonov, completed the first spacewalk in March 1965. In December 1968, three US astronauts onboard Apollo VIII became the first men to orbit the Moon, circling it ten times before returning safely to Earth. Then, in July the following year, two astronauts from Apollo XI, Neil Armstrong and Edwin ‘Buzz’ Aldrin, landed safely on the Moon’s surface. The Space Race eventually came to a conclusion in 1975 with the launching of the Apollo-Soyuz project, the first joint US-Soviet space mission.[7]

Neil Armstrong’s landing on the Moon from the spaceship Apollo XI, on July 20, 1969.

[7] *Alphahistory. (2018, April 30). The space Race. The Cold War. https://alphahistory.com/coldwar/space-race/*

B. The Kessler Syndrome

During the Space Race, spent rockets, satellites and other space trash have accumulated in orbit increasing the likelihood of collision with other debris. Sadly, collisions create more debris creating a runaway chain reaction of collisions and more debris known as the Kessler Syndrome after the man who first proposed the issue, Donald Kessler, in 1978. The Kessler Syndrome is a phenomenon in which the amount of junk in orbit around Earth reaches a point where it just creates more and more space debris, causing bigger problems for satellites, astronauts and mission planners.[8] Once collisional cascading begins, the risk to satellites and spacecraft increases until the orbit is no longer usable. Kessler proposed it would take approximately 30 to 40 years for such a threshold to be reached and today, some experts think we are already at critical mass in low-Earth orbit at about 560 to 620 miles (900 to 1,000 kilometers).[9]

VI. Current Situation

Space debris is an issue of global concern that threatens our continued use of near-Earth space for the benefit of humankind.[10] Satellites in orbit underpin our modern lives. With the beginning of the space age in 1957, various spacecraft, rockets, etc. were sent into space for space studies, but no one thought about what would happen when their functions ended.[11] All of these spacecraft that have ceased to function since 1957 have created space debris.

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[8] *Wall, M. (2022, July 14). Kessler Syndrome and the space debris problem. Space.com. https://www.space.com/kessler-syndrome-space-debris*

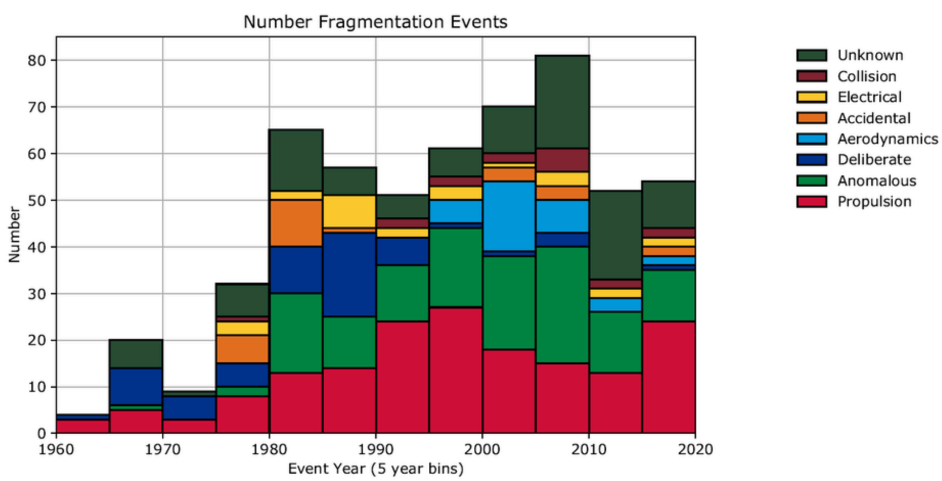
[9] *Riley, H. F. (2023, October 16). Micrometeoroids and Orbital Debris (MMOD) - NASA. NASA. https://www.nasa.gov/centers-and-facilities/white-sands/micrometeoroids-and-orbital-debris-mmod/*

[10] *ESA and UNOOSA illustrate space debris problem*. (n.d.). https://www.esa.int/Space_Safety/Space_Debris/ESA_and_UNOOSA_illustrate_space_debris_problem

[11] *The current state of space debris*. (n.d.). https://www.esa.int/Space_Safety/Space_Debris/The_current_state_of_space_debris

It is a matter of global concern that intimidates our continued use of near-Earth space for the advantage of society. Space may seem enormous, but the orbits around Earth in which satellites locate are a finite natural resource. Some collisions, explosions and debris from the destruction of satellites in space orbit at high speeds, posing serious risks to planets and spacecraft. Many technologies we use in our daily lives are based on space technologies, and this space debris issue poses an increasingly greater risk to space technologies every day.[12]

In more than 60 years of space activities, more than 6050 launches have resulted in some 56450 tracked objects in orbit, of which about 28160 remain in space and are regularly tracked by the US Space Surveillance Network and maintained in their catalogue, which covers objects larger than about 5-10 cm in low-Earth orbit (LEO) and 30 cm to 1 m at geostationary (GEO) altitudes. Only a small fraction - about 4000 - are intact, operational satellites today. This large amount of space hardware has a total mass of more than 9300 tonnes.[13]



[12] Martin.Stasko. (n.d.-c). *UNOOSA and ESA release updated infographics about space debris*. https://www.unoosa.org/oosa/en/informationfor/media/unoosa-and-esa-release-infographics-and-podcasts-about-space-debris.html

[13] *About space debris*. (n.d.). https://www.esa.int/Space_Safety/Space_Debris/About_space_debris

Unfortunately, 12 accidental fragmentations have occurred in the last 20 years and this number is increasing every day.[14]

A. The Volume of Space Debris in Earth's Orbit

All up to date published articles record all man-made objects currently in Earth orbit. The number of debris objects appraised based on statistical models to be in orbit are: 40500 space debris objects greater than 10 cm, 1100000 space debris objects greater than 1 cm to 10 cm, 130 million space debris objects greater than 1 mm to 1 cm.[15] As the area covered by space debris increases each day, the dimensions of the dangers it can create also increase.
Scientists expect that a collision with a 1 mm object could destroy subsystems, a collision with a 1 cm object would disable the satellite, and a collision with a 10 cm object would destroy any satellite.Scientists have unfortunately stated that a collision with an energy-mass ratio exceeding 40 J/g would lead to disaster.[16]

B. Types of Space Debris

According to the sources of ESA space debris is divided into 3 groups. These are payloads, rockets and mission-related objects. Payloads are generally caused by the wear and tear of satellites and their collisions.Rockets remains of stages used to propel missions in orbit. This also includes fragments produced by wear ,tear and collisions. The last category includes one mission-related object:all space vehicles and materials that have completed their mission are considered within this category, such as dropped tools, screws, cables, cameras etc.[17]

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[14] *The current state of space debris*. (n.d.-b). https://www.esa.int/Space_Safety/Space_Debris/The_current_state_of_space_debris

[15] *Space Environment Statistics · Space Debris User Portal*. (n.d.-b). SDUP. https://sdup.esoc.esa.int/discosweb/statistics/

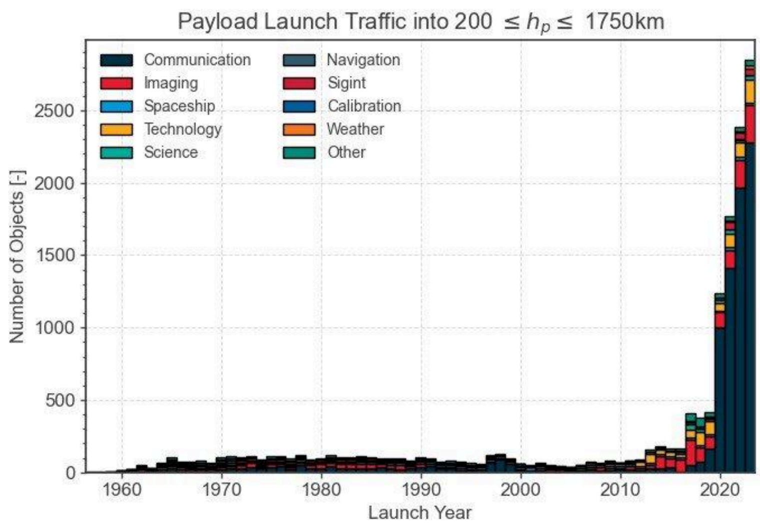
[16] *How many space debris objects are currently in orbit?* (n.d.). https://www.esa.int/Space_Safety/Clean_Space/How_many_space_debris_objects_are_currently_in_orbit

[17] *Space Environment Statistics · Space Debris User Portal*. (n.d.). SDUP. https://sdup.esoc.esa.int/discosweb/statistics/

C. Notable Recent Space Debris Event

As a result of interviews and research conducted in 2024, it was stated that space debris was growing at an accelerated rate.

In 2023, payload launch traffic reached its highest level ever. Collision and explosion protection procedures are also increasing due to increased traffic and debris. In spite of



improvements in mitigation efforts, the absence of compliance and remediation meant that 2023 still saw a net increase in the space debris population. If we extrapolate current trends into the future, as before, catastrophic collision numbers could rise significantly. This could lead to 'Kessler syndrome', in which certain orbits become increasingly risky and ineffective over time as debris continues to collide and fragment, creating a cascading effect.

Space exploration is mostly done between the moon and the earth. However, the increasing space debris in this region makes these explorations dangerous, which is another reason why we need to keep this area clean. Stricter debris mitigation guidelines are needed in this deteriorating situation.

The 2024 Space Environment Report checked all the tracked objects against the 25 year-compliance in effect in 2023. In the next edition, ESA's new mitigation guidelines published in November 2023 will be the bar to measure against. Among other changes, this will lower the time to evacuate valuable orbits down from 25 to 5 years. ESA aims to significantly limit the production of debris in Earth and Moon orbits by 2030 with its project called the “zero-debris approach”. Zero-debris approach includes eight recommendations : guarantee successful disposal, improve orbital clearance, avoid in-orbit collisions, avoid internal break-ups, prevent the intentional release of space debris, improve on-ground casualty risk assessment, ensure dark and quiet skies, extend protections beyond the designated regions. Globally, the zero debris charter is written for and by a diverse community in Europe and beyond that is committed, together, to caring for our space environment now and for future generations. Since its publication, the Agreement has been signed by 12 countries, and more than 100 commercial and non-commercial organizations have signed or committed to sign the Agreement.

ESA has updated its debris mitigation requirements and standards, which govern how the Agency's missions are designed, built, flown and disposed of; setting the rules for any company or institution that works with ESA on its missions. ESA is directly involved in technology and capability development to prevent and counteract space debris, while also enabling and stimulating European industry to pioneer in-space sustainability solutions.[18]

VII. Impact of Space Debris

Space debris presents significant threats to active satellites, space missions, and crewed spacecraft such as the International Space Station (ISS). Moving at speeds of up to 28,000 km/h, even tiny fragments can cause serious damage upon impact. For instance, the ISS has frequently had to execute evasive maneuvers to steer clear of potential debris collisions.[19]

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[18] *ESA Space Environment Report 2024*. (n.d.). https://www.esa.int/Space_Safety/Space_Debris/ESA_Space_Environment_Report_2024

[19] Gregersen, E. (2024, November 22). *Space debris | Facts, Removal, & Examples*. Encyclopedia Britannica. https://www.britannica.com/technology/space-debris

Tackling the issue of space debris is vital for ensuring the long-term viability of space activities. Solutions involve designing satellites to reduce debris creation, establishing end-of-life disposal protocols, and advancing technologies for active debris cleanup. Global cooperation and strict compliance with space debris mitigation standards are critical to safeguarding the orbital environment for future generations. [20]

A. Threat to Space Infrastructure

Millions of pieces of space debris are posing significant risks to operational satellites. According to NASA, even a tiny 1-centimeter paint fragment can cause damage equivalent to a 550-pound object traveling at 60 miles per hour on Earth. These debris threatens the 1,738 active satellites that support essential communication, commerce, travel, and security systems. Damage to these systems can have widespread effects due to hidden interdependencies,for instance, GPS systems that not only provide navigation but also coordinates airline routing and enables timing synchronization in banking, finance, and power networks. Modern military technologies, such as guided missiles, drones, and intelligence systems, also heavily rely on functional satellites.

NASA and the Department of Defense Space Surveillance Network track approximately 21,000 larger debris objects in Low Earth and Geosynchronous Orbits, but the most hazardous pieces—millions of smaller fragments—remain untracked. Trends such as the growing use of small satellites, increased private sector investment in space exploration and advancements in anti-satellite military technologies are accelerating the proliferation of debris. Anti-satellite missile tests by China and the United States have generated thousands of debris fragments, while collisions like the 2009 crash between an Iridium communications satellite and a defunct Russian satellite added 2,300 new debris pieces. The rise of affordable small satellites, such as the $40,000 CubeSat, has enabled widespread satellite launches by students, companies, and researchers such as SpaceX's plans to deploy 12,000 small satellites into Low Earth Orbit. The increasing volume of debris creates two primary risks: the potential pollution of orbits to the point of rendering them unusable and the looming threat of the Kessler Syndrome.

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[20] *About space debris*. (n.d.-b).
https://www.esa.int/Space_Safety/Space_Debris/About_space_debris

Efforts to address space debris face challenges due to the global nature of space activities necessitating international cooperation. Governments and private companies are actively working on solutions. In particular, former U.S. President George W. Bush proposed a terrestrial GPS system called eLoran, though budget cuts led to its cancellation in 2008. The UN Office for Outer Space Affairs has introduced seven guidelines aimed at reducing debris, focusing on limiting harmful activities such as intentional satellite destruction. Meanwhile, private companies like SpaceX and Boeing recognize the risks and are developing technologies to track debris and provide data to satellite operators, fostering a growing industry around debris management.[21]

B. Environmental Impact

The space industry often portrays itself as a key ally in the fight against climate change, and at first glance, this seems reasonable. Space exploration has advanced our understanding of Earth, and satellite technologies have made resource management more efficient. However, the reality is far less idealistic. The industry is experiencing a surge of unprecedented investments, leading to an exponential increase in the number of objects launched into space each year. If this trend continues unchecked, we risk compromising the long-term usability of space and creating an environmental crisis that could undermine efforts to combat climate change on Earth.

The current growth trajectory is unsustainable. Over the past 60 years,around 11,000 satellites have been launched, with 7,000 still in orbit. But by the end of this decade, that figure could rise to hundreds of thousands as private enterprises like Elon Musk's Starlink and Amazon, along with countries such as China, build massive constellations in Low Earth Orbit (LEO). Some of these mega-constellations will consist of tens of thousands of satellites, each with a lifespan of five to ten years, contributing to a growing accumulation of space debris. This debris not only clutters orbital paths but also poses a hazard to other objects passing through.

The environmental risks of such debris are significant. Increased light pollution could hinder astronomical research, while satellite re-entries could release harmful alumina into the upper atmosphere, disrupting solar radiation and harming the environment. Additionally, these

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[21] Pods. (2020, March 10). Space debris poses growing threat to satellite infrastructure | Global Resilience Institute. Global Resilience Institute. https://globalresilience.northeastern.edu/space-debris-poses-growing-threat-to-satellite-infrastructure/

mega-constellations could stifle competition and innovation if a single company or nation dominates a particular orbital space. Without immediate action, the rapid expansion of the space sector threatens both the environment in orbit and our planet's future.[22]

C. Economic Consequences

The OECD report highlights the significant costs associated with space debris, noting that protection and mitigation efforts are already a financial burden for satellite operators.[23] These expenses include designing debris-resistant satellites, conducting surveillance and tracking, maneuvering satellites to avoid collisions, and sometimes replacing entire missions.

For geostationary satellites, the OECD estimates these measures account for 5–10% of total mission costs, which can reach hundreds of millions of dollars. In low Earth orbit, the proportion of costs per mission may exceed this range.

Despite these high costs, failing to address space debris would be even more catastrophic. A substantial buildup of debris could trigger the 'Kessler syndrome,' where collisions create a chain reaction of further debris, leading to what the OECD calls "an ecological tipping point" that might render some orbits permanently unusable for human activities.[24]

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[22] *What's the environmental impact of space debris and how can we solve it?* (2024, September 10). World Economic Forum. https://www.weforum.org/stories/2022/07/environmental-impact-space-debris-how-to-solve-it/

[23] Undseth, M., C. Jolly and M. Olivari (2020), "Space sustainability: The economics of space debris in perspective", OECD Science, Technology and Industry Policy Papers, No. 87, OECD Publishing, Paris, https://doi.org/10.1787/a339de43-en.

[24] *The cost of space debris*. (n.d.). https://www.esa.int/Space_Safety/Space_Debris/The_cost_of_space_debris

VIII. International Efforts and Agreements

The issue of space debris and its impact on space sustainability has been a growing concern that requires collective action from all nations since the past 50 years. Over the past decade, the number of spacefaring nations has increased, as proven by the number of satellites launched by emerging space nations and by an increase in the number of applications for United Nations Committee on the Peaceful Uses of Outer Space (UN COPUOS) membership from emerging member states. More recently, there has been a huge increase in emerging space nations stating their commitment to join the COPUOS Long-term Sustainability (LTS) 2.0 Working Group, as well as nations who have preferred to join as signatories to initiatives such as "Net Zero Space" (e.g., Azercosmos, EgSA, GISTDA), and the Artemis Accords (e.g., Nigeria, Rwanda, and Angola). All of these initiatives share a common goal of promoting the sustainable and responsible use of space to ensure the long-term sustainability of space activities, including: the recognition of the need for sustainable practices,the importance of promoting cooperation in long-term sustainability between all nations,the support of international guidelines and best practices and the recognition of the increasing role and contribution of emerging space nations.[25]

A. The Role of International Organizations

Space sustainability is a critical concern in the face of the expanding global space economy and the following surge in satellite launches. With the increasing risk of collisions and the need for safe and responsible utilization of near-Earth orbits, the importance of addressing space debris is increasing. International guidelines have been established to encourage responsible space activities, but compliance is incoherent among nations and not regulated by any international body. Concerted efforts are needed to ensure the long-term sustainability of space activities and to mitigate the risks associated with operating in a debris congested environment.

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[25] *International cooperation. (n.d.). https://www.esa.int/Space_Safety/Space_Debris/International_cooperation*

1. The Space Sustainability Rating (SSR)

The Space Sustainability Rating (SSR) provides a composite indicator scoring methodology of both quantitative and qualitative modules for evaluating the sustainability of space missions, with the goal of incentivizing responsible behaviors in space. The SSR is a pioneering initiative financed by the World Economic Forum (WEF) through their Global Future Council on Space that evaluates a wide range of mission characteristics and operator behaviors from launch, through operations, to the spacecraft's end-of-life.[26] The Space Sustainability Rating was designed by an international consortium that included the European Space Agency(ESA), the Massachusetts Institute of Technology (MIT), the University of Texas at Austin, and Bryce Tech. The SSR is now operated by a non-profit association based in Switzerland called the Space Sustainability Rating. The SSR sets an example in defining space sustainability by proposing a way to measure it, focusing on in-space sustainability.

The SSR employs a tiered scoring system to assign ratings, wherein each of the six module scores are given specific weights and aggregated to determine a final tier rating of Bronze (40-55%), Silver (56-70%), Gold (71-80%), or Platinum (>80%) as can be seen below:

<u>Bronze:</u> The mission meets the pre-requisite requirements to apply for an SSR. The SSR applicant demonstrates willingness to increase mission's sustainability. Current sustainable practices need to be incorporated into the mission.

<u>Silver:</u> The mission incorporates current sustainability practices with areas to improve upon. The SSR applicant demonstrates consideration for the orbital environment in design and operation of the mission.

<u>Gold:</u> The SSR applicant demonstrates currently accepted best practices for sustainability in all aspects of the mission. The mission has minimal impacts on the orbital environment beyond the necessary use.

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[26] *Space Sustainability Rating. (n.d.). World Economic Forum. https://www.weforum.org/projects/space-sustainability-rating/*

Platinum: The mission incorporates innovative methods for improving the orbital environment that go beyond common best practices. The SSR applicant demonstrates sustainable practices that enhance sustainability outcomes across all aspects of the mission.[27]

The Space Sustainability Rating offers several opportunities for rising space nations to profit as part of ongoing work efforts to promote sustainability in their national space activity. Moreover, the SSR can serve as a platform for emerging space nations to promote global efforts for space sustainability. At the national scale, the SSR also supports the process by which emerging space nations set up or improve their national space regulations. By using the SSR, emerging space nations can form a clear and structured approach to space debris mitigation and sustainable space operations. This allows them to strengthen national and regional legal and regulatory frameworks, keep up with international standards, and actively participate in the global effort to ensure the long-term sustainability of outer space.

2. UN COPUOS Long-Term Sustainability Working Group

The Working Group on the "Space2030" Agenda was established by the Committee on the Peaceful Uses of Outer Space (COPUOS) in accordance with the General Assembly resolution " Fiftieth anniversary of the first United Nations Conference on the Exploration and Peaceful Uses of Outer Space: space as a driver of sustainable development[28]", that called upon the Committee "to continue to develop, on the basis of the results of the UNISPACE+50 process, a "Space2030" agenda and implementation plan and to provide the General Assembly with the outcome of its work for consideration by the Assembly". In 2018, the Committee included a new item entitled "'Space2030' agenda" on its agenda and agreed to establish the Working Group on the "Space2030" Agenda under that item.[29] There are also other groups and

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[27] *Spaces Sustainability Rating. (2023). The Space Sustainability Rating: Fostering responsible behavior in space activities (IAC-22-A6.8.E9.1x70969).*
[28] *United Nations Office for Outer Space Affairs. (2018). Resolution adopted by the General Assembly on 5 December 2018: International cooperation in the peaceful uses of outer space (A/RES/73/6).*
[29] *Sklikacova. (n.d.). Working Groups of the Committee and its Subcommittees. https://www.unoosa.org/oosa/en/ourwork/copuos/working-groups.html*

subcommittees helping the LTS work group like STSC(Scientific and Technical Subcommittee) which was originally tasked with evaluating the implementation of recommendations made by the Second United Nations Conference on the Exploration and Peaceful Uses of Outer Space, the Working Group presently considers a number of issues, such as the use of space technology for socio-economic development in the context of the UN Conference on Sustainable Development and the post-2015 development agenda, global health and organizational matters. But still, one of the primary focuses of the subcommittee has been to mitigate the space debris and establish a safe and clean space environment.[30]

B. Space Debris Mitigation Guidelines

The United Nations Committee on the Peaceful Uses of Outer Space has paid particular attention to the issue of preventing and minimizing the creation of space debris. Every year, States and organizations exchange information on their space debris research at the Committee's Scientific and Technical Subcommittee. One important result of those discussions has been a set of Space Debris Mitigation Guidelines, which were encouraged by the General Assembly in 2007. In addition to scientific research, the national and international legal aspects of space debris mitigation measures are being discussed by the Legal Subcommittee.[31] A set of mitigation guidelines has been developed by the Inter-Agency Space Debris Coordination Committee (IADC), reflecting the fundamental mitigation elements of a series of existing practices, standards, codes and handbooks developed by a number of national and international organizations. The following guidelines should be considered for the mission planning, design, manufacture and operational (launch, mission and disposal) phases of spacecraft and launch vehicle orbital stages:

Guideline 1: Limit debris released during normal operations,

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[30] *United Nations Office for Outer Space Affairs. (2018). Resolution adopted by the General Assembly on 5 December 2018: International cooperation in the peaceful uses of outer space (A/RES/73/6).*

[31] *Aygul.Duysenhanova. (n.d.). Space debris. https://www.unoosa.org/oosa/en/ourwork/topics/space-debris/index.html*

Space systems should be designed not to release debris during normal operations. If this is not feasible, the effect of any release of debris on the outer space environment should be minimized.

During the early decades of the space age, launch vehicle and spacecraft designers permitted the intentional release of numerous mission-related objects into Earth orbit, including, among other things, sensor covers, separation mechanisms and deployment articles. Dedicated design efforts, prompted by the recognition of the threat posed by such objects, have proved effective in reducing this source of space debris.

Guideline 2: Minimize the potential for break-ups during operational phases,

Spacecraft and launch vehicle orbital stages should be designed to avoid failure modes which may lead to accidental break-ups. In cases where a condition leading to such a failure is detected, disposal and passivation measures should be planned and executed to avoid break-ups.

Historically, some break-ups have been caused by space system malfunctions, such as catastrophic failures of propulsion and power systems. By incorporating potential break-up scenarios in failure mode analysis, the probability of these catastrophic events can be reduced.

Guideline 3: Limit the probability of accidental collision in orbit,

In developing the design and mission profile of spacecraft and launch vehicle stages, the probability of accidental collision with known objects during the system's launch phase and orbital lifetime should be estimated and limited. If available orbital data indicate a potential collision, adjustment of the launch time or an on-orbit avoidance manoeuvre should be considered.

Some accidental collisions have already been identified. Numerous studies indicate that, as the number and mass of space debris increase, the primary source of new space debris is likely to be from collisions. Collision avoidance procedures have already been adopted by some member States and international organizations.

Guideline 4: Avoid intentional destruction and other harmful activities,

Recognizing that an increased risk of collision could pose a threat to space operations, the intentional destruction of any on-orbit spacecraft and launch vehicle orbital stages or other harmful activities that generate long-lived debris should be avoided. When intentional break-ups are necessary, they should be conducted at sufficiently low altitudes to limit the orbital lifetime of resulting fragments.

Guideline 5: Minimize potential for post-mission break-ups resulting from stored energy,

In order to limit the risk to other spacecraft and launch vehicle orbital stages from accidental break-ups, all on-board sources of stored energy should be depleted or made safe when they are no longer required for mission operations or post-mission disposal.

By far the largest percentage of the cataloged space debris population originated from the fragmentation of spacecraft and launch vehicle orbital stages. The majority of those break-ups were unintentional, many arising from the abandonment of spacecraft and launch vehicle orbital stages with significant amounts of stored energy. The most effective mitigation measures have been the passivation of spacecraft and launch vehicle orbital stages at the end of their mission. Passivation requires the removal of all forms of stored energy, including residual propellants and compressed fluids and the discharge of electrical storage devices.

Guideline 6: Limit the long-term presence of spacecraft and launch vehicle orbital stages in the low-Earth orbit (LEO) region after the end of their mission,

Spacecraft and launch vehicle orbital stages that have terminated their operational phases in orbits that pass through the LEO region should be removed from orbit in a controlled fashion. If this is not possible, they should be disposed of in orbits that avoid their long-term presence in the LEO region.

When making determinations regarding potential solutions for removing objects from LEO, due consideration should be given to ensuring that debris that survives to reach the surface of the Earth does not pose an undue risk to people or property, including through environmental pollution caused by hazardous substances.

Guideline 7: Limit the long-term interference of spacecraft and launch vehicle orbital stages with the geosynchronous Earth orbit (GEO) region after the end of their mission,

Spacecraft and launch vehicle orbital stages that have terminated their operational phases in orbits that pass through the GEO region should be left in orbits that avoid their long-term interference with the GEO region. For space objects in or near the GEO region, the potential for future collisions can be reduced by leaving objects at the end of their mission in an orbit above the GEO region such that they will not interfere with, or return to, the GEO region.[32]

C. Major International Treaties

Space exploration has been integral to human achievement in exploring unspoiled frontiers. However, with advances in technology and increased space activity, an increasingly urgent problem arises, namely the impact of space debris. Space junk, consisting of the remains of defunct satellites, fragments of spacecraft, and other components, poses a serious threat to the space environment and continued future exploration. The challenge of space debris mitigation is not only limited to technical aspects, but also involves complex dimensions of international law. Therefore, a deep understanding of legal responsibility and burden-sharing in safeguarding the space environment is extremely significant in creating a sustainable future of space exploration. With so many stakeholders involved in space exploration, effective coordination and regulation are essential to avoid an escalation of the space debris problem. National space agencies and international organizations play a huge role in designing and implementing space debris mitigation measures. Through cooperation between countries and international coordination, measures such as monitoring and tracking space debris, developing recovery technologies, and

[32] *United Nations Office for Outer Space Affairs. (2010). National legislation relevant to the peaceful exploration and use of outer space (ST/SPACE/49).*

managing the life cycle of space objects can be carried out more efficiently. Thus, international treaties are the columns of regulations to mitigate space debris.[33]

1. The Outer Space Treaty 1967

The Outer Space Treaty was considered by the Legal Subcommittee in 1966 and agreement was reached in the General Assembly in the same year. The Treaty was largely based on the Declaration of Legal Principles Governing the Activities of States in the Exploration and Use of Outer Space, which had been adopted by the General Assembly in its resolution 1962 (XVIII) in 1963, but added a few new provisions. The Treaty was opened for signature by the three depository Governments (the Russian Federation, the United Kingdom and the United States of America) in January 1967, and it entered into force in October 1967. The Outer Space Treaty provides the basic framework on international space law, including the following principles:

The exploration and use of outer space shall be carried out for the benefit and in the interests of all countries and shall be the province of all mankind;

Outer space shall be free for exploration and use by all States;

Outer space is not subject to national appropriation by claim of sovereignty, by means of use or occupation, or by any other means;

States shall not place nuclear weapons or other weapons of mass destruction in orbit or on celestial bodies or station them in outer space in any other manner;

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[33] *Siregar, E. R. E., Prabandari, A. P., & Siregar, N. (2024). International law review of space debris mitigation efforts.*

The Moon and other celestial bodies shall be used exclusively for peaceful purposes;
Astronauts shall be regarded as the envoys of mankind;

States shall be responsible for national space activities whether carried out by governmental or non-governmental entities;

States shall be liable for damage caused by their space objects;

States shall avoid harmful contamination of space and celestial bodies.[34]

Particularly the last three matters are related to space debris and this treaty, which is signed by most of the States, proves that the collaboration of the member States of the UNOOSA is decisive to achieve a space without debris.

2. Zero Debris Charter

At the Ministerial Conference of 2022, ESA was encouraged by its Member States to implement "a Zero Debris approach for its missions; and to encourage partners and other actors to maintain similar paths, thereby collectively putting Europe at the forefront of sustainability on Earth and in space, while preserving the competitiveness of its industry". The Zero Debris approach is ESA's ambitious revision of its internal space debris mitigation requirements that builds on more than a decade of ESA-wide collaborative work and will drive the development of technologies required to become debris-neutral by 2030.[35]

The Zero Debris Charter, in addition, is a community-driven and community-building document and initiative for the global space community. Facilitated by ESA's 'Protection of Space Assets' Accelerator and created and written by 40 space actors, the Charter contains both high-level guiding principles and specific, jointly defined targets to get to Zero Debris by 2030.

[34] *Robert.Wickramatunga. (n.d.). The Outer Space Treaty. https://www.unoosa.org/oosa/en/ourwork/spacelaw/treaties/introouterspacetreaty.html*
[35] *The Zero Debris Charter. (n.d.). https://www.esa.int/Space_Safety/Clean_Space/The_Zero_Debris_Charter*

NASA estimates that at least 500,000 pieces of debris 1 cm or greater circle our planet; ESA estimates more than 1 million.[36] As the number of spacecraft which are launched into orbit or beyond grows, so too does the amount of debris. Uncontrolled debris is sharp and fast-moving, and if pieces of debris smash into each other, their numbers can multiply drastically.

In addition to ESA, 9 of the agency's 22 full member states — Austria, Belgium, Estonia, Germany, Poland, Portugal, Romania, Sweden, and the United Kingdom — have signed the charter. ESA associate member Lithuania is also a signatory, as are Cyprus and Slovakia, who have signed cooperation agreements with the agency. Other than that, more than 100 organisations have signed the agreement to show their support to the treaty.[37]

3. The Paris Peace Forum's "Net Zero Space" Initiative

The Net Zero Space initiative is a multi-stakeholder platform that aims to achieve sustainable use of outer space by 2030 by taking concrete steps to mitigate the production of new orbital debris and remediate existing ones. In Particular, it intends to raise awareness among policy makers and the general public to better protect the Earth's orbital environment and to promote interoperable norms in this regard. To do so, it is developing both a political and public advocacy effort, as well as conducting substantive work to develop actionable policy proposals to better secure Earth's orbital environment.

The initiative currently has 64 members from across the value chain and beyond the industry, and from 24 different countries from all over the world.

Ever since its launch in 2021, the coalition has grown exponentially and has been conducting a series of activities which all share the same objective: to raise awareness beyond the industry of the need to deal with the problem of orbital debris, while finding concrete, viable and practical solutions before the situation becomes irrecoverable.

4. The Artemis Accords

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[36] *European Space Agency. (2023). Protecting Earth: The role of ESA in safeguarding our planet.*
[37] *Twelve countries sign the Zero Debris Charter. (n.d.). https://www.esa.int/Space_Safety/Space_Debris/Twelve_countries_sign_the_Zero_Debris_Charter*

NASA, in coordination with the U.S. Department of State and seven other initial signatory nations, established the Artemis Accords in 2020. With many countries and private companies conducting missions and operations around the Moon, the Artemis Accords provide a common set of principles to enhance the governance of the civil exploration and use of outer space. The Artemis Accords reinforce the commitment by signatory nations to the Outer Space Treaty, the Registration Convention, the Rescue and Return Agreement, as well as best practices and norms of responsible behavior for civil space exploration and use.[38] The Accords got signed by 48 countries globally. The Artemis Accords primarily focus on guiding the peaceful and cooperative exploration and utilization of space, particularly relating to the Moon and other celestial bodies. While they do not specifically focus on space debris, some provisions indirectly address related concerns. The Accords emphasize the importance of sustainable practices, including the safe disposal of spacecraft to prevent harm to the space environment. They stress cooperation to avoid harmful interference, which includes considerations for minimizing risks related to debris. By promoting transparency and the registration of space objects, the Accords indirectly contribute to tracking and managing objects in orbit, which is a key aspect of addressing space debris.[39]

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[38] NASA. (2024, November 13). Artemis Accords - NASA. https://www.nasa.gov/artemis-accords/

[39] https://www.nasa.gov/wp-content/uploads/2022/11/Artemis-Accords-signed-13Oct2020.pdf?emrc=673a556f73860

XI. National and Private Sector Initiatives

Dealing with space debris and their associated works is fast rising amongst the priorities of national-based as well as private initiatives. Efforts by governments and space agencies (like NASA, ESA, ISRO) around the world are helping to create policies specifically aimed at mitigating debris; these include measures such as guidelines to deorbit obsolete satellites after their mission has ended, and new systems for tracking orbital objects. A push to develop technological solutions for this global issue can only be embodied by initiatives like the ESA's ClearSpace-1 mission[40], which intends on physically clearing debris from the earth's orbit. Meanwhile in the private sector, firms like Astroscale and Northrop Grumman are developing active debris removal technologies — ones that are expected to use magnetic capture in combination with robotic arms. Finally, SpaceX has pledged to build satellites that deorbit in a

[40] *ClearSpace-1. (n.d.). https://www.esa.int/Space_Safety/ClearSpace-1#:~:text=ClearSpace-1%20The%20first%20mission%20to%20remove%20a%20piece,does%20not%20add%20to%20the%20space%20debris%20problem.*

shorter time frame so as to prevent long-term congestion. This is triggering global agreement on procedures, such as laws and platforms spearheaded by international efforts.

A. National Policies on Space Debris

As the unprecedented expansion of all types of space activities brings major environmental challenges in terms of orbital congestion, national space debris policies have become key elements to provide solutions and sustainable outer-space environments. The Orbital Debris Mitigation Standard Practices is a leading guideline from the United States, which requires satellite operators to reduce debris after its mission. Likewise, the European Space Agency (ESA) and individual countries like Germany and France are governed by international standards as well as those on behalf of nations from UNESCO or the United Nations' Committee on the Peaceful Uses of Outer Space (COPUOS).

In addition to these global efforts, Asian countries have also taken significant steps and developed notable policies in the field of space debris mitigation. Japan and India both have adopted a more expansive view of debris mitigation and taken concrete steps to implement them in national space policies. China's growing stake in space exploration has led plans to regulate its satellite deployments. These efforts are complemented by collaborative measures such as joint research and international agreements. National policies collectively aim to balance space innovation with long-term orbital safety. One of the best examples is the United States's national space policy. Orbital debris mitigation has been included in every U.S. National Space Policy since 1988 (1988, 1989, 1996, 2006, 2010, and 2020).
The latest National Space Policy released in December 2020 continued the tradition to focus on limiting the generation of new debris:

> •“Preserve the Space Environment. To preserve the space environment for
> responsible, peaceful, and safe use, and with a focus on minimizing space debris
> the United States shall…
>
> • Limit the creation of new debris, consistent with mission requirements and

cost effectiveness, during the procurement and operation of spacecraft, launch services, and conduct of tests and experiments in space by following and periodically updating the United States Government Orbital Debris Mitigation Standard Practices…

• Pursue research and development of technologies and techniques to characterize and to mitigate risks from orbital debris, reduce hazards, and increase understanding of the current and future debris environment;

• Evaluate and pursue, in coordination with allies and partners, active debris removal as a potential long-term approach to ensure the safety of flight in key orbital regimes…"[41]

B. Private Sector Solutions

As humanity ventures deeper into the realm of space exploration and commercialization, the threat posed by space debris has escalated, demanding urgent attention and innovative solutions. The year 2024 witnessed a series of pivotal developments and initiatives, highlighting the critical challenge of orbital debris, which presents a significant risk to operational satellites, the International Space Station (ISS), and future space missions. Ranging from minute paint flecks to spent rocket stages, the orbit around Earth has become increasingly cluttered, creating a perilous environment in space. This is where the private companies step in.[42]

1. SpaceX

[41] *The White House. (2022). National orbital debris implementation plan.*
[42] *What's the environmental impact of space debris and how can we solve it? (2024, September 10). World Economic Forum. https://www.weforum.org/stories/2022/07/environmental-impact-space-debris-how-to-solve-it/*

SpaceX has more than 6,600 Starlink satellites in low-Earth orbit, more than half of all active spacecraft. SpaceX monitors the satellites' positions and shares data with other spacecraft operators and launch providers to ensure that the deorbit operation does not place the older Starlink craft in anything's path as they fall to a safe, fiery demise in Earth's atmosphere.

"All satellites maintain their maneuverability and collision avoidance capabilities during the descent," SpaceX's statement reads. "Additionally, these deorbiting satellites take maneuver responsibility for any high-risk conjunctions consistent with space safety and sustainability best practices."

Starlink satellites are designed to make autonomous decisions themselves to maneuver out of the way of other spacecraft based on data provided by the U.S. Space Force and the commercial space awareness firm LeoLabs. Between June 1, 2023, and Nov. 30, 2023, Starlink satellites had to maneuver 24,410 times to avoid collisions, which amounts to around six maneuvers per satellite. While high, that number is falling — but some experts are still worried.[43]

2. **LeoLabs**

Ask anyone in the space business and they'll tell you that orbital debris is a serious problem that will only get worse, but dealing with it is as much an opportunity as it is a problem. LeoLabs is building a global network of radar arrays that can track smaller debris than we can today, and with better precision — and the first of its new installations is about to start operations in New Zealand.

There are some 12,000 known debris objects in low Earth orbit, many of which are tracked by the U.S. Air Force and partners. But they only track debris down to 10 centimeters

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[43] *Viktor. (2024, February 13). SpaceX commits to space sustainability, shares proactive measures for Starlink satellite deorbiting. starlinkinsider.com. https://starlinkinsider.com/spacex-commits-to-space-sustainability-shares-proactive-measures-for-starlink-satellite-deorbiting/*

across — meaning in reality there may be hundreds of thousands of objects up there, just as potentially destructive to a satellite but totally unknown. it can detect and track objects down to 2 centimeters across. They're small, yes, but moving at thousands of miles per hour.

It is estimated that the ability to see objects of that size in orbit could increase the number tracked to a quarter of a million. And with other radars able to track about a thousand objects per hour, they couldn't possibly do the job even if they could draw a bead on them.[44]

3. Astroscale

Founded in 2013, Astroscale is the global leader in on-orbit servicing, dedicated to the safe and sustainable development of space. The company delivers a variety of innovative and scalable on-orbit servicing solutions, including life extension, in-situ space situational awareness, end-of-life, and active debris removal. These solutions empower satellite operators to reduce risks, increase returns, and achieve mission success while fostering a sustainable space environment. Astroscale is also defining the economics of on-orbit servicing and collaborating with government and commercial stakeholders to develop norms, regulations, and incentives that promote the sustainable growth of space.

Since its first successful launch in March 2021, Astroscale has proven rendezvous and proximity operations technologies in orbit during the ELSA-d and ADRAS-J missions, establishing the company as a leader in on-orbit servicing. Astroscale spacecraft have been selected for pioneering missions with JAXA, the U.S. Space Force, the ESA, the UK Space Agency, and Eutelsat OneWeb. As more satellite operators adopt on-orbit servicing to routinely inspect, relocate, remove, and extend the life of spacecraft, the potential of a circular space economy — and a future of no waste in space — is being unlocked. Headquartered in Japan, Astroscale has a global presence with subsidiaries in the United Kingdom, the United States, France, and Israel.[45]

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[44] *LeoLabs, Propelling the dynamic space era. (2024, August 6). LeoLabs | Propelling the dynamic space era Propelling the dynamic space era. LeoLabs | Propelling the Dynamic Space Era. https://leolabs.space/*

[45] *About Astroscale - Astroscale, Securing Space Sustainability. (2024, July 29). Astroscale. https://astroscale.com/about-astroscale/about/*

C. Debris Tracking and Monitoring Systems

It is estimated that there are more than 750.000 debris objects larger than 1 cm in Earth orbit, any of which can damage operational satellites. For many missions, the risk of losing a spacecraft through impact with space debris is the third highest, after the risks associated with launch and deployment into orbit. To avoid collisions with space debris, the orbits of objects in space must be known. This requires a system of sensors comprising, typically, radars, telescopes and laser-ranging stations, and a data centre to process the acquired observation data.

A Space Surveillance and Tracking (SST) system detects space debris, catalogues debris objects, and determines and predicts their orbits. Most simply, any SST system can be considered as a 'processing pipeline' to process observation data acquired by sensors – the telescopes, radars or laser-ranging stations mentioned above – and provide derived applications and services, typically comprising collision warnings. The central product of an SST system is an object catalogue, which must contain up-to-date orbit information for all objects over a certain size threshold. A SST system's existence is necessary for any space related missions or else the object which is sent to space can get damaged and this would result with the mission being unsuccessful in the end. Other than the efforts of ESA, NASA, APSCO (Asian-Pacific Space Cooperation Organization), private companies such as LeoLabs are also working to detect the debris around the orbit of the Earth to ensure the safety of the space missions.

X. Progress and Challenges of Orbital Debris Remediation

The problem of space debris is recognized by many countries and solutions are being produced, but there are many difficulties in effective debris removal methods. The main ones are economic, legal and political problems and disputes. Collecting space debris is a difficult process and requires large budgets. Since this problem is a problem of all of humanity, there is a great debate among countries about who will cover this cost. Some countries think that since 95% of the debris in orbit is produced by China, the United States of America and the Russian Federation, these countries should cover these costs. But the chances of convincing these countries to cover this expense seem slim. A May 2024 NASA report weighing the costs and benefits of debris remediation suggests active debris removal makes economic sense, with profits hundreds of times higher than the upfront cost.

Another difficulty is the laws. The six UN treaties governing human activities in space were all signed before 1980, and do not adequately address the legal challenges raised by debris remediation. International law does not offer a solid definition of debris, let alone an explicit roadmap to handle legal issues. The Outer Space Treaty (OST) clearly assigns ownership of spacecraft and debris to the state that registered them. Hence, a debris remediation mission would likely require the consent of the debris owner, assuming it can even be traced. The OST also enjoins space faring nations to conduct space activities with "due regard" to others' interests, but never defines the scope of the "due regard" accountability. This loophole in the law leaves space debris unattended.[46] The web of international treaties that shapes the use of space is arguably the biggest hurdle to addressing the threat of space debris. Even if we had the technology to remove space debris today, the international laws regulating space would make removal legally complex and expose the remover to liability. Countries have often relied on diplomatic negotiations to address incidents that should invoke space law, highlighting the present ineffectiveness of space law in such situations.[47]

The last and most complicated problem is political relations and conflicts. When you look at it, this problem concerns all countries, but rightfully so, countries that have not sent any spacecraft into space do not want to take on this responsibility, while countries that have done a lot of work, such as United States of America, RF and China, invite all countries to work to reduce their responsibilities. There have been serious discussions between the US and RF about

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[46] *Space Generation Advisory Council. (n.d.). Beyond mitigation: Progress and challenges of orbital debris remediation.*

[47] Review, C. L. (2024, January 23). *Preventing the next global crisis: addressing the urgent need for space debris removal — California Law review*. California Law Review. https://www.californialawreview.org/print/preventing-the-next-global-crisis-addressing-the-urgent-need-for-space-debris-removal

space for many years, and this situation includes difficulties such as Russia not allowing its own spacecraft to touch during a debris collection operation, and similarly, the US not allowing Russia to touch its own vehicles during an operation. Outside of non-binding UN-led initiatives, the world's three largest debris producers barely cooperate on debris. Mistrust between great powers has stood in the way of effective global space sustainability governance, and can make active debris removal an escalatory issue. A lack of diplomacy threatens to fragment the global space policy landscape with insufficient overlap and cooperation.[48]

A. Legal and Regulatory Gaps

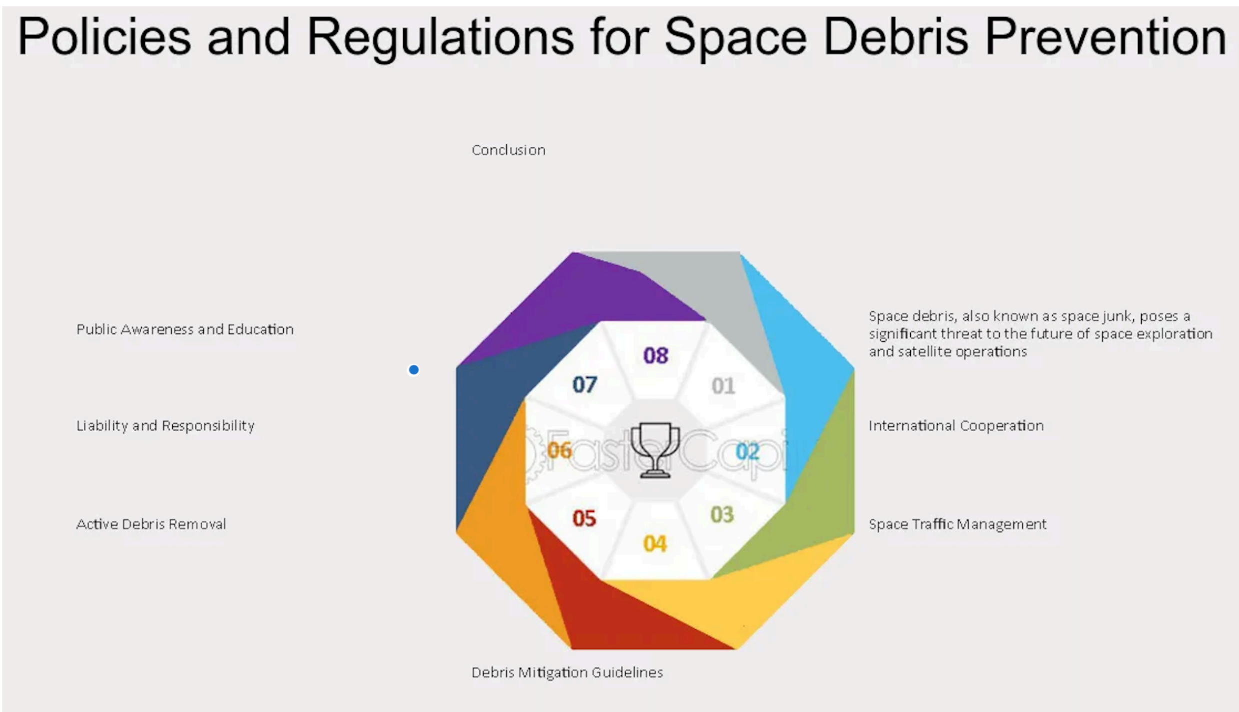
The Outer Space Treaty (OST), ratified in 1967, is the foundation of all international space regulation. It establishes space as the province of all humankind and promotes its peaceful use and exploration for the benefit and in the interests of all countries.[49] Since 1967, new vehicles have been sent continuously or the vehicles already in space have reached the end of their life and become new space debris. Space is filling with more satellites and commercial ventures, all threatened by orbital debris. It is time to clarify which agencies have authority to act.[50] The threat of space debris originally was not widely appreciated, and the response to the risks of space debris has only recently begun. Any attempts at addressing space debris have been further complicated by a variety of issues, each significant enough on its own to prevent meaningful progress. These issues include the tragedy of the commons, norms regarding the unregulated use of space, and distrust between space-faring nations over the militarization of space. Early indications show progress in creating international agreements that actively address

[48] *Space Generation Advisory Council. (n.d.). Beyond mitigation: Progress and challenges of orbital debris remediation.*

[49] Runnels, M. B. (2023). Protecting Earth and Space Industries from Orbital Debris: Implementing the Outer Space Treaty to Fill the Regulatory Vacuum in the FCC's Orbital Debris Guidelines. *American Business Law Journal*, *60*(1), 175–229. https://doi.org/10.1111/ablj.12221

[50] Lloyd, J. (2023, July 26). Why space debris flies through regulatory gaps. Issues in Science and Technology. https://issues.org/space-debris-fcc-harbert-balakrishnan/

the threat of space debris, despite the challenges faced. To address the expanding issue of space debris, it is essential to first identify the successes and failures of various efforts along the way and understand the underlying reasons behind them. The Outer Space Treaty of 1967 is the main column of all the other space laws and treaties. Unfortunately, the fact that the law is so dysfunctional in the ever-developing, changing and growing space debris causes very big problems. However, its provisions are too generic to deal with the complex problems of space debris with any certainty.



Policies and Regulations for Space Debris Prevention - Space Debris: Space Debris Threat: Preventing Future Asteroid Events

All things considered, the international nature of space debris therefore necessitates that an international solution must be based on a 'level playing field'.[51]

B. Financial and Technological Barriers

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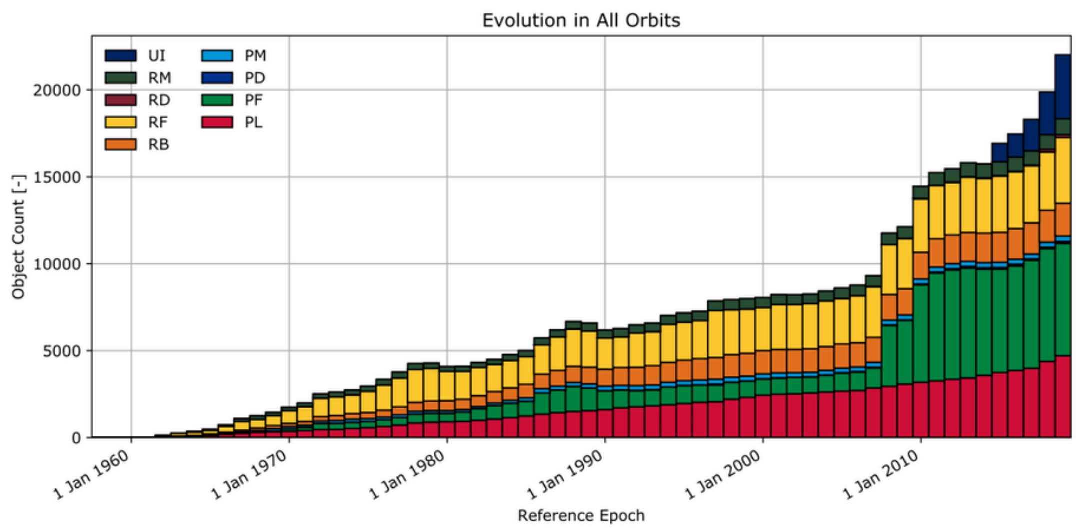
[51] *Space debris: The legal issues - Royal Aeronautical Society*. (n.d.-b). Royal Aeronautical Society. https://www.aerosociety.com/news/space-debris-the-legal-issues/

Since space is a challenging area to explore, research costs are exceptionally high, making financial constraints the biggest obstacle to these studies.. For satellites in geostationary orbit, the OECD reports that such costs amount to an estimated 5–10% of the total mission costs, which could be hundreds of millions of dollars. In low Earth orbits, the relative costs per mission could be even higher than 5–10%. Space debris protection and mitigation measures are already costly to satellite operators, but the main risks and costs lie in the future, if the generation of debris spins out of control and renders certain orbits unusable for human activities. However, the cost of inaction would be far greater. Enough debris in orbit could ultimately lead to the ‘Kessler syndrome’ in which collisions cascade, leading to more and more self-generating collisions, and what the OECD defines as “an ecological tipping point that may render certain orbits unusable.”



(a) Evolution of number of objects.

The socio-economic impacts of the Kessler syndrome would be severe.[52] All satellites and space stations are exposed to space debris, but the risk of collision differs greatly. The entire global value of economic activity at risk is estimated to be USD 191 billion with the bulk of the value concentrated in orbits at 500-600 km altitude. The orbits with the highest exposure to debris (at around 850 km altitude and 70-80 degrees inclination) are mainly occupied by publicly funded

[52] *The cost of space debris*. (n.d.). https://www.esa.int/Space_Safety/Space_Debris/The_cost_of_space_debris#:~:text=Space%20debris%20is%20expensive%2C%20and%20will%20become%20even%20more%20so&text=For%20satellites%20in%20geostationary%20orbit,higher%20than%205%E2%80%9310%25.

satellites, vital for scientific research, climate monitoring, weather forecasting and national security. Practically all the risk (97%) is associated with defunct objects, with two-thirds (65%) coming from spent rocket bodies.[53] At the same time, the inadequacy of space law affects the economic dimension of space debris because it is unclear who will undertake the responsibility and cost of collecting this debris.

Space poses many challenges for humans and vehicles, and we must use technology to overcome the dangers that these challenges will cause, and develop new technologies. However, making a new invention can sometimes take decades or even centuries, which has become another main obstacle to the collection of space debris.Thus, the development of compact, robust and autonomous systems for deorbiting of spacecraft in low-Earth orbit (EIO) and the re-orbiting of spacecraft in geostationary orbit (GEO) is necessary.[54] Since the dangers that space debris can cause have been identified, many new technologies have been used to try to eliminate this problem. In 2011, ESA carried out end-of mission operations for its European Remote Sensing (ERS-2) satellite, which had been operational for over 16 years. During these operations, the remaining orbital lifetime was significantly reduced from more than 2 centuries to well below 15 years, and all residual fuel was consumed. ERS-2 re-entered the atmosphere on 21 February 2024. This effectively reduced the risks of collision and accidental break-up by orders of magnitude. In 2013, ESA's astronomy satellites Planck and Herschel, which were located at the second Lagrange point, were injected into orbits around the Sun after their missions were completed, in order to avoid creating a collision threat or reentry hazard. In 2015, large orbit-change manoeuvres were implemented for ESA's Integral spacecraft and one of the satellites in its Cluster-2 mission. These manoeuvres ensured that Integral and all four of the Cluster spacecraft will re-enter Earth's atmosphere during the next decade in a safe way, and avoid long-term interference with the protected low-Earth and Geostationary orbits. And the last attempt, in 2023, ESA successfully performed the first assisted reentry of its Aeolus mission. Aeolus was designed according to debris mitigation requirements of an earlier time and was not

[53] *The Economics of Space Sustainability*. (2024, June 28). OECD. https://www.oecd.org/en/publications/the-economics-of-space-sustainability_b2257346-en.html

[54] *Zero Debris Technologies*. (n.d.). https://www.esa.int/Space_Safety/Clean_Space/Zero_Debris_Technologies

designed to be controlled as it re-entered Earth's atmosphere. But ESA operators went a step beyond to carry out the first assisted reentry of its kind and target the reentering satellite towards the ocean, further reducing the very small chance that fragments could cause harm should any reach Earth's surface.[55] These are just the inventions and experiments made by the European Space Agency; many other groups have undertaken similar initiatives.

XI. Points that a Resolution Should Cover

- How can existing international treaties, such as the Outer Space Treaty, be updated to address the modern challenges of space debris?
- How can international cooperation be strengthened to ensure equitable contributions from developed and emerging space-faring nations?
- What specific technologies (e.g., laser-based removal, robotic systems, or drag sails) should be prioritized for debris mitigation and active removal?
- How can international partnerships facilitate the sharing of technology and expertise to make debris removal accessible for all nations?
- Should nations or private entities be incentivized to develop and deploy innovative debris-removal technologies?
- How should liability for damage caused by space debris be allocated among nations, private entities, and other stakeholders?
- What legal definitions and frameworks are necessary to address ownership and responsibility for space debris?
- Should binding international agreements mandate compliance with debris mitigation guidelines, and how can enforcement mechanisms be implemented?
- How can the costs of active debris removal be shared equitably among stakeholders?

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[55] *Mitigating space debris generation*. (n.d.). https://www.esa.int/Space_Safety/Space_Debris/Mitigating_space_debris_generation

- Should economic incentives be provided to private companies that develop sustainable space practices?
- How can debris tracking and monitoring capabilities be improved, and who should oversee these systems?
- How can the environmental impact of space debris on Earth's atmosphere and outer space ecosystems be minimized?
- What responsibilities should private space operators bear in mitigating space debris?
- How can the private sector be held accountable for ensuring long-term sustainability in their space operations?
- Should partnerships between governments and private entities be formalized to address debris-related challenges?
- How should the potential militarization of space and anti-satellite tests be addressed to prevent the creation of additional debris?
- How can the international community prepare for potential scenarios involving cascading debris collisions (e.g., Kessler Syndrome)?

XII. Suggestions for Further Research

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- *https://www.weforum.org/stories/2022/07/environmental-impact-space-debris-how-to-solve-it/*

- *https://www.esa.int/Space_Safety/ClearSpace-1#:~:text=ClearSpace-1%20The%20first%20mission%20to%20remove%20a%20piece,does%20not%20add%20to%20the%20space%20debris%20problem*.
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- https://www.esa.int/Space_Safety/Space_Debris/The_current_state_of_space_debris
- https://www.esa.int/Space_Safety/Space_Debris/ESA_and_UNOOSA_illustrate_space_debris_problem

- *https://www.nasa.gov/centers-and-facilities/white-sands/micrometeoroids-and-orbital-debris-mmod/*
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