

FORUM:	Environment Commission
ISSUE:	Measures to Reduce Space Debris and Environmental Risks from Expanding Satellite Constellations in Low Earth Orbit
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Introduction

Over the past two decades, the rapid development of satellites has transformed Earth's orbits from domains dominated by government agencies to a place full of commercial activity (Jolly and Undseth). Space debris is defined as defunct human-made objects in space that are no longer serving as a useful function. Particularly those in Earth's orbit. These objects range from tiny fragments, such as solidified liquids expelled from spacecraft, unburned particles from solid rocket motors, and the vast amount of fragmentation debris produced when spacecraft break apart (SEAC | Space Economy Academy). Thus, the rapid dominance of commercial satellites contributes to the risk of the further creation of space debris. This space debris not only poses a danger to other spacecraft and astronauts, but it possesses more significant environmental risk.

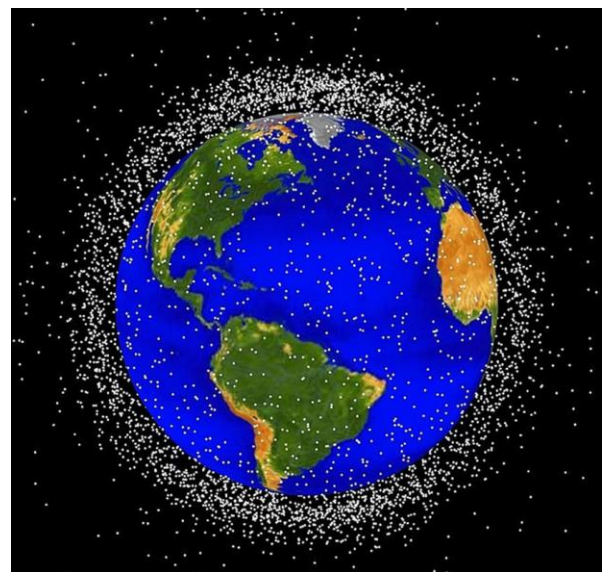


Figure 1 Low earth orbit becoming crowded with space debris

Background

As shown in Figure 2, the surge of annual satellite launches from 2013 to 2023 underscores the pivotal role of space infrastructure in modern society (Jolly and Undseth). For example, satellites now

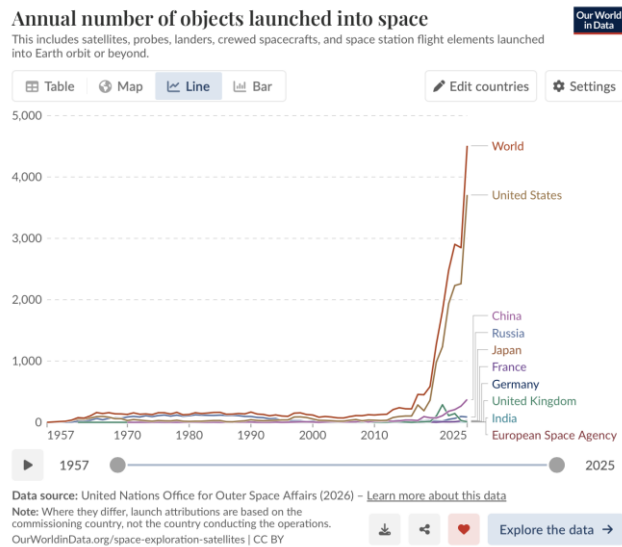


Figure 2 Annual number of objects launched into space

1 million objects (Jolly and Undseth). This uncertainty emphasizes the concerns related to the satellite constellation in the Low Earth Orbit (LEO).

Problems Raised

Increasing space debris and collision risk

As mentioned, satellites often become debris when they fail, are abandoned, collide, or fragment. ESA estimates that several fragmentation events in 2024 created more than 3,000 tracked objects in Earth's orbit (ESA). This creates a potentially self-reinforcing cycle where more satellites are deployed, leading to more congestion, providing more collision opportunities, creating more space debris, and even more collision opportunities in the future. This is also well known as Kessler syndrome, in which collisions generate enough debris to trigger further collisions and potentially make certain orbital regions increasingly difficult or impossible to use. Thus, the increase in space debris becomes environmentally significant, as LEO is a finite shared environment where pollution cannot simply be cleaned up in the same way as pollution on Earth.

Atmospheric pollution from satellite launch and re-entry

The rapid expansion of LEO satellite constellations also creates an environmental concern regarding atmospheric launch and re-entry. A 2025 study modelling future launch scenarios found that rocket emissions could have ongoing and significant effects on the ozone layer (Revell et al.). Chlorine and black carbon emitted from rocket propellants while launching can cause ozone depletion and atmospheric warming. Also, as LEO constellations are designed to re-enter the atmosphere, two major re-



entry pollutants are emitted: NO_x (nitrogen oxides) and Al₂O₃ alumina. No_x is generated by the shockwave and extreme heating of re-entering spacecraft, with 95% of NO_x emissions from 2019 launch and re-entry activity originating from re-entry (Revell et al.). Meanwhile, the ablation of satellites introduces alumina particles that could cause radiative heating and perturbations to stratospheric winds and ozone (Revell et al.). Thus, deorbiting is not a solution for extensive satellites but rather a cause of atmospheric consequences that impact our climate, possibly contributing to global warming.

International Actions

United Nations: Space Debris Mitigation Guidelines-2007

The first major international response was the UN Space Debris Mitigation Guidelines, which were developed through the Committee on the Peaceful Uses of Outer Space (COPUOS) and endorsed by the UN General Assembly in Resolution 62/217 in 2007 (United Nations Office for Outer Space Affairs 2007). The seven guidelines address limiting debris release, preventing spacecraft breakups, reducing accidental collision probability, avoiding intentional destruction of spacecraft, preventing post-mission breakups, limiting long-term presence of spacecraft, and rocket strategies in LEO (United Nations Office for Outer Space Affairs 2007). These guidelines have established an international principle that satellites should be designed and operated with their entire orbital lifetime with consideration. However, these guidelines are not legally binding under international law.

COPUOS: Guidelines for the Long-Term Sustainability of Outer Space Activities-2019

In 2019, the UN COPUOS adopted 21 guidelines for the Long-term Sustainability of Outer Space Activities. The UN General Assembly welcomed them in Resolution 74/82 (United Nations Office for Outer Space Affairs 2019). The guidelines encourage states and satellite operators to strengthen national regulations, share accurate orbital and debris monitoring data constantly, conduct collision assessments before deployment, address uncontrolled re-entry risks, and cooperate internationally on space sustainability (United Nations Office for Outer Space Affairs 2019). This framework has addressed the problems created by rapidly increasing satellite numbers: more satellites create more data and conjunctions that need greater international information sharing. Thus, it created a broad sustainability framework, but it has not created a comprehensive, globally binding space-traffic-management framework, lacking feasibility and practicality.



Key Players

UN COPUOS (United Nations Committee on the Peaceful Uses of Outer Space) and UNOOSA (United Nations Office for Outer Space Affairs)

The UN, through COPUOS and UNOOSA, promotes the long-term sustainability of outer space by establishing international guidelines on debris mitigation, collision avoidance, orbital information-sharing, and responsible space activities. However, their guideline's implication is voluntary rather than legally binding, limiting the UN's ability to directly control rapidly expanding satellite constellations. The UN has nevertheless increasingly involved the private sector in sustainability efforts, including collecting industry case studies on collision avoidance, orbital-data sharing, debris mitigation, and disposal.

Private satellite operators (SpaceX/Starlink, Amazon, Eutelsat/OneWeb, etc.)

Private operators are the major drivers of the constellation expansion as they seek to provide global connectivity, commercial services, and technological development. However, their expansion has constantly contributed to the increasing number of spacecrafts in LEO, and the associated risks of orbital congestion and environmental issues have increased. At the same



Figure 3 SpaceX's 60 New Starlink Satellites

time, operators have started adopting mitigation techniques such as collision avoidance, orbital tracking, controlled disposal, etc. UNOOSA's industry case studies, for example, document private sector participation in orbital data sharing, conjunction assessment, debris mitigation (Bhakare). Their position therefore involves a fundamental trade-off: continued constellation expansion significantly improves technological aspects, but in the meantime, more environmental concerns will be raised.

Possible Solutions

Establish binding international end-of-life and debris standards

As current UN guidelines stay largely voluntary, transforming these guidelines into common international minimum standards could enhance the practicality and feasibility. For example, requiring satellites to have a verified disposal plan before launch, reducing the maximum post-mission orbital lifetime from the traditional 25 years to 5 years or less, and requiring a high probability of successful disposal and interfaces that allow failed satellites to be removed. ESA already uses a 5-year disposal



requirement and a >90% successful disposal probability, which could provide a model for international standards (European Space Agency).

Introducing mandatory lifecycle environmental assessments for mega-constellations

Before approving a large constellation, requiring assessments of its entire environmental lifecycle, such as scrutinizing launch, operation, orbital congestion, disposal, and atmospheric re-entry, ensures Furthermore, mandating the operators to report environmental data and potentially pay environmental fees or provide financial guarantees for mitigation could serve as an incentive for them to contribute to sustainable satellite constellations. Overall, making satellite operators, who are a major part of the issue, responsible for the full environmental cost of their constellations, while establishing internationally consistent rules so companies cannot avoid stricter standards simply by operating under a different national jurisdiction could ensure that the private sector complies with the effort to reach sustainable expansion of satellites.

Glossary

Low Earth Orbit (LEO)

The region of Earth's orbit extending from approximately 160 to 2,000 km above Earth's surface, where most large satellite constellations operate.

Space debris

Human-made objects or fragments in space that no longer serve a useful purpose, including defunct satellites, rocket stages, and fragments produced by collisions or breakups.

Satellite constellation

A group of satellites operating together in orbit to provide services such as telecommunications, navigation, or global internet connectivity.

Kessler Syndrome

A theoretical chain reaction in which collisions between objects in orbit generate debris, increasing the likelihood of further collisions and potentially making an orbital region increasingly difficult to use.

Orbital congestion

The increasing concentration of satellites and debris within heavily used orbital regions, which raises the probability of collisions and complicates satellite operations.



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