What would a sustainable space environment look like?

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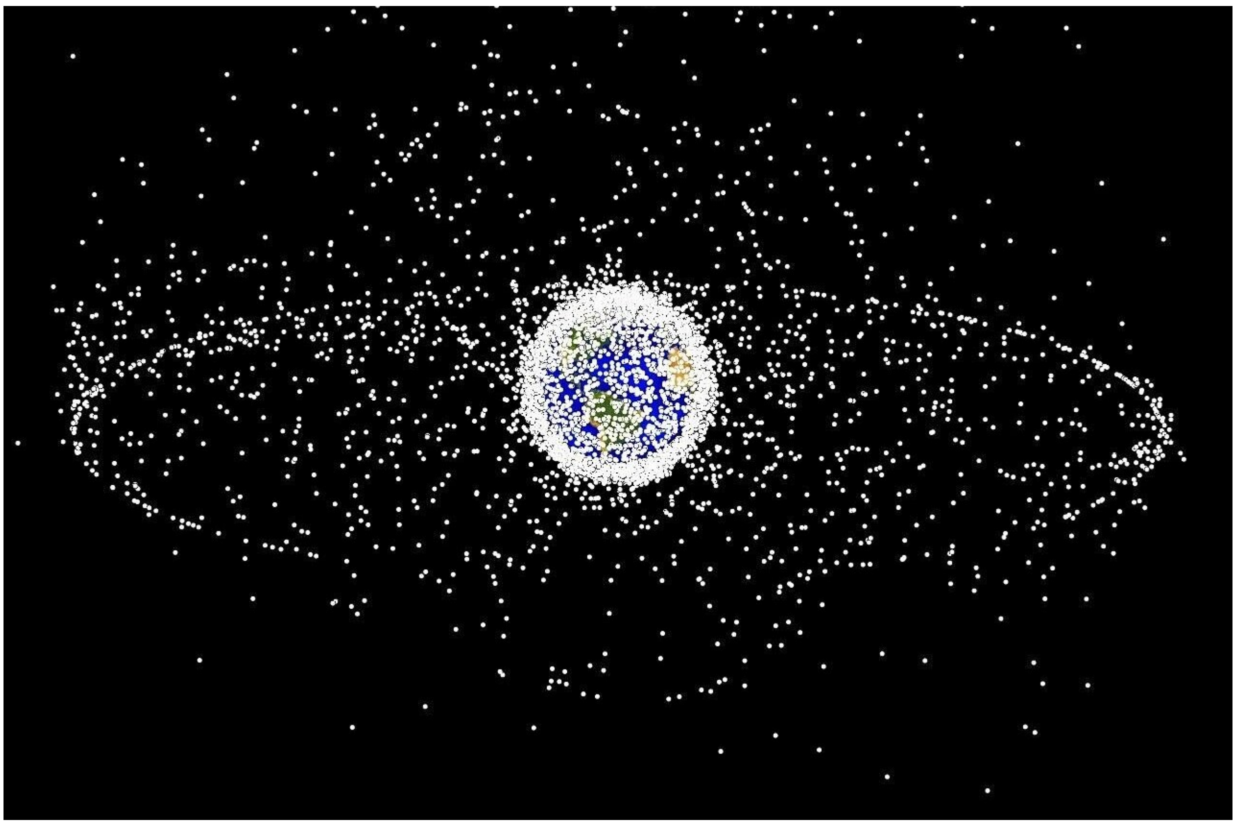

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October 4, 2022, will be an auspicious day as humanity celebrates the 65th anniversary of the beginning of the Space Age. It all began in 1957 with the launch of the Soviet satellite Sputnik-1, the first artificial satellite ever sent to orbit. Since that time, about 8,900 satellites have been launched from more than 40 countries worldwide. This has led to growing concerns about space debris and the hazard it represents to future constellations, spacecraft, and even habitats in low Earth orbit (LEO).

This has led to many proposed solutions for cleaning up "space junk," as well as satellite designs that would allow them to deorbit and burn up. Alas, there are still questions about whether a planet surrounded by mega-constellations is sustainable over the long term. A recent study by James A. Blake, a research fellow with the University of Warwick, examined the evolution of the debris environment in LEO and assessed if future space operations can be conducted sustainably.

For his Ph.D. project, Blake focused on the imaging and tracking of space debris in geosynchronous Earth orbits (GEOs) around 36,000 km (22,370 mi) above the equator. In this region of space, satellites follow the rotation of the Earth and have the same orbital period as the Earth, making it highly sought-after for telecommunications. However, space in this region is very limited, which could lead to serious problems of overcrowding and debris.

In particular, Blake's main body of work was a survey of faint geosynchronous debris carried out using the Isaac Newton Telescope at the Roque de los Muchachos Observatory on the island of La Palma. His work was summarized in a study titled "DebrisWatch I: A survey of faint geosynchronous debris," which appeared in January 2021 in the journal Advances in Space Research. As he indicated in this study, the population of debris in GEO is not well-constrained but represents a growing problem.

A historic problem

According to the ESA's Space Debris Office (SDO), as of March 3, 2022, about 12,720 satellites have been launched to Earth orbit since Sputnik-1. Of these, an estimated 7,810 remain in orbit, of which about 5,200 are still operational. All told, about 29,860 debris objects in LEO are regularly tracked by Earth-based observation networks and are maintained in their catalog.

Previously, it was thought that the population of debris in GEO would be fairly negligible because of the strict spacing regulations that are meant to ensure satellites don't collide. However, the recent apparent destruction of communications satellites—AMC-9, owned by Luxembourg-based telecom SES S.A., and Lockheed Martin's Telkom-1—has provided clear evidence that a debris field exists in GEO. This presents new implications for future constellations in GEO.

As Blake told Universe Today via email, charting the evolution of space debris is essential to the future of debris mitigation:

"Sputnik 1 was the first of thousands of satellites to be launched into Earth orbit over the past six decades, and that number continues to grow rapidly. Some have re-entered the Earth's atmosphere, while others are orbiting in an abandoned and uncontrolled state, posing a threat to the active satellites we rely on.

"Over time, the orbital debris population has grown due to accidental explosions and collisions, alongside intentional anti-satellite tests. The vast majority of debris produced by these events remains invisible to us, too small to be detected by our current generation of surveillance networks, yet still holding the potential to severely damage spacecraft."

According to Blake, there's a lesson to be learned from humanity's exploitation of the near-Earth environment. In keeping with the interconnected nature of space exploration and life on Earth, this same lesson applies equally to humanity's activities on the ground. In short, humanity needs to act sustainably so that future generations can enjoy and benefit from the freedoms we've enjoyed since the dawn of the Space Age. To do this, says Blake, collision avoidance is a must:

"Effective collision avoidance requires timely and accurate information. As satellite and debris catalogs grow ever larger, surveillance networks are being tasked with monitoring more and more objects to provide sufficient warning to operators, who can then opt to maneuver their craft out of harm's way."

Monitoring and mitigating

The current strategy for preventing an uncontrollable debris environment in orbit involves a two-pronged approach: tracking and "passivating." The task of tracking satellites and debris is handled by several space agencies and government offices worldwide. For instance, the Joint Space Operation Center at Vanderburg Air Force Base in California (JSpOC) uses the Space Surveillance Networks (SSNs), a combination of optical and radar sensors, to monitor satellites and debris in orbit.

The NASA Orbital Debris Program Office (ODPO), located at the Johnson Space Center, measures the orbital debris environment while developing measures to control debris growth. The Office of Safety and Mission Assurance (OSMA), located at NASA HQ in Washington D.C., is responsible for developing, implementing, and overseeing agency-wide policies and procedures to ensure safety, reliability, and space environment sustainability.

There's also the ESA's Space Debris Office (SDO)—located at the European Space Operations Center (ESOC) in Darmstadt, Germany—which is responsible for measuring and modeling the orbital debris environment and developing protection and mitigation strategies.

It also coordinates activities and research efforts with the ESA's constituent agencies, which form the European Network of Competences on Space Debris (SD NoC).

At the international level, there's the Inter-Agency Space Debris Coordination Committee (IADC), a forum that includes thirteen national space agencies (including NASA, Roscosmos, the ESA, and the Indian and Chinese space agencies). This body developed guidelines in 2001 that have been revised multiple times (the most recent occurring in 2020) and have since been adopted by the United Nations Committee on the Peaceful Uses of Outer Space (UNCOPUOS).

On the other end of things, there's the famous "25-year rule," where operators are encouraged to dispose of satellites within 25 years of mission completion via atmospheric re-entry. Low-altitude satellites may already be naturally capable of doing this. In contrast, potentially non-compliant satellites can be outfitted with thrusters, drag sails, and other instruments to accelerate the deorbiting process. As Blake explained:

"Operators are encouraged to 'passivate' spacecraft at the end of their mission, by depleting or saving any remnant sources of internal energy onboard the satellite or rocket body, thus reducing the chances of explosion. Adherence to the '25-year rule' for deorbiting spacecraft in low Earth orbit is still concerningly low, and a boost to cooperation on an international scale will be paramount to tackling the debris problem."

A problem of policy

In the end, Blake indicates that one of the greatest hurdles to achieving sustainability in space is policy. For the past few decades, the IADC guidelines adopted by UNCOUPOUS have formed the basis for standard mitigation practices on the international stage. Unfortunately, these guidelines are voluntary (i.e., not legally binding), and some space-faring nations have chosen not to include them in their national regulatory frameworks.

In addition, adherence to the "25-years rule" remains very low in LEO, and the process of re-entry is not a viable option for objects in the high-altitude GSO region. As a result, operators will typically attempt to raise decommissioned satellites into so-called "graveyard" orbits well beyond GSO—or what is known as a supersynchronous orbit (SSO). This has the effect of clearing the operational zone in orbit for use by future satellites, but the debris can still pose a threat to spacecraft destined for the Moon or deep-space.

What is needed, says Blake, is a policy of active debris removal (ADR) that works in tandem with stricter adherence to regulations for debris mitigation:

"Ultimately, we'll want to conduct regular removal missions to actively dispose of dead spacecraft and debris, though a number of technological hurdles are yet to be cleared. As evidenced by the recent Russian ASAT test back in November 2021, there is also a need for internationally recognized, legally binding regulations, to sanction against reckless behavior."

In addition, NASA, the ESA, the China National Space Agency (CNSA), and other space agencies are currently testing ADR systems. Concepts include Earth-based directed-energy arrays (lasers), spacecraft equipped with plasma beams, harpoons and nets, and magnetic space tugs. In recent years, says Blake, there have also been efforts to formulate a "space sustainability rating" that would incentivize operators to adhere to safe practices and debris mitigation. However, several questions remain unanswered.

For instance, with access to space becoming more widespread, how does a regulatory framework compare University-led CubeSat experiments to commercial constellations of satellites (a la Starlink)? Also, how will lawmakers attribute liability in the event of a collision involving uncontrolled debris? And what mechanisms will be in place to ensure a level playing field between emerging space agencies and those with a decades-long presence in space?

The debate around these questions and attempts to find solutions are actively unfolding around us right now. It has also led to the rise of non-profit organizations like the Space Court Foundation (SCF) the Space Generation Advisory Council (SGAC). There are also the time-honored efforts to formulate and crystallize policy by the Institute of Air & Space Law (IASL) at McGill University and the United Nations Office for Outer Space Affairs (UNOOSA).

As our presence in space continues to grow, we can expect some spirited debate, resolutions, and impressive innovations in the coming years. As always, the driving force behind these developments will be a basic matter of necessity. Humanity's future in space depends upon accessibility and safety, something that cannot happen with huge debris fields in orbit.

More information: James A. Blake, Looking out for a sustainable space. arXiv:2202.06994v1 [astro-ph.EP], doi.org/10.48550/arXiv.2202.06994

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