Dealing with the Issue of Space Debris

Bride Benson
Computer Science and Business Systems
Rajagiri School of Engineering and Technology (Autonomous), Kochi-682 039.

Abstract

Space explorations have always been at the cost of a deteriorating space environment. Today, there are millions of tiny pieces of debris orbiting the earth at high velocities, which can cause serious damage to future and ongoing missions in case of a collision. Furthermore, it could set off the production of more debris until the earth's orbit becomes unstable. This article deals with finding innovative and sustainable solutions to this issue so that we can continue our explorations without compromising the quality of space for our future generations.

Keywords

Space junk; Kessler syndrome; Sustainability; Debris; Collisions

1. Introduction

The skies have always been a source of man's curiosity and wonder and have instilled in us this inherent drive to explore and unravel more about the mysteries of the vast universe that we are a part of. Therefore, the advent of Space age has marked an important milestone in human history. But ever since the deployment of the first satellite into space back in 1957, there has been an ever-increasing number of debris left over from past space missions, which are no longer useful. Based on the statistic models released by the European Space Agency (ESA), there are about 35,000 objects being tracked and monitored and many millions of objects that are too small to be tracked; less than 10cm in size [1]. These objects range from machinery of dead satellites, rocket bodies, remnants of explosions and breakups to much smaller components like lens cap, bolts, paint flecks etc. Since these components travel at exceptionally high velocities at well over 22,300mph, they prove to be extremely disastrous for ongoing and future space missions in the case of a collision [2]. Recent missions like the multi-satellite constellation- Starlink satellites by SpaceX, which aims to provide high speed internet access globally [3] and kinetic anti-satellites by different countries to incapacitate their own satellites, though useful, risk the possibility of realizing the scenario described in Kessler syndrome, which says that the overpopulation of certain earth orbits especially the low earth orbit (LEO), may lead to self-sustained cascading collisions that result in an exponential increase in the amount of space debris leaving the orbit unstable for further use [4]. Many collision maneuvers are performed by satellites including the ISS and Cryosat every year to avoid impacts and this number is only set to increase if we do not act fast enough [5].

The current situation has left us with no choice but to come up with innovative and effective solutions to counter this issue. Studies have shown that the faster it is addressed, the more effective it will be, in terms of cost and outcome as compared to a few years later when the situation will have become more out of hand. Even though there is no shortage of ideas, the process of filtering through them and choosing the best ones is a tedious task as many of them may be far-fetched or too costly to be of any practical use [6]. It is imperative to keep in mind the fact that if it's wielded by the wrong hands, the ideas developed can also be doubled up and used as anti-satellite weapons if need be and is therefore one that must be carefully treaded upon [7].

2. Approach

While objects in lower earth orbits can re-enter the atmosphere in a few years and burn up, the ones in higher orbits, such as the geostationary orbits, which are at altitudes of 36,000km, continue to orbit the earth for thousands of years. Therefore, it is important to put proper mechanisms in place to de-clutter these orbits and make space for newer ones. The ideas so far proposed and developed include nets, harpoons, lasers, tethers, sails and specialized vehicles. These mainly aim at nudging the objects to either re-enter the earth's atmosphere or pushing them into not so important, less congested orbits called graveyard orbits via onboard propulsions, laser nudging, or other methods.

Onboard propulsions are achieved by using additional reserved fuel or by retaining just enough fuel before the end of the satellite's life to generate thrust for deorbit; used in Lithium-ion Battery Deorbiter. Once the satellite's altitude is lowered to about 500 km, the atmospheric drag acting on it will aid its break down. But the disadvantage of end-of-life deorbiting is that the alumina and soot particles created during its burn down as a result of the friction caused by the earth's atmosphere can damage the ozone layer that protects us from harmful ultraviolet radiations from the sun. If the space junk is big enough, it will reach the earth's surface without completely burning up and pollute land and oceans.

Another strategy used is passivation of satellites and launch vehicles (LVs) at the end of its mission. It refers to the process of removing the internal stored energy present in its propulsion systems, pressure vessels, etc. to prevent the risk of accidental blow up, which may result in fragmentation and more debris. However, passivation reduces the possibility of reusing the satellites or LVs. Though hard passivation can be done completely, it is practically feasible to achieve soft passivation, which in turn represents partial removal of stored energy from the satellite parts, thus enabling them to be reused.

3. Methodology

1) Laser Orbital Debris Removal makes use of giant ground-based lasers which are focused and pulsed to slow down the targets and revert them to the atmosphere. The main challenges faced include the high cost involved, difficulty in tracking the object and look-ahead, which refers to accurately pointing the laser at the spot where the target will be and the time the light takes to get there [8].
2) Sails and balloons made of extremely thin material are inflated and attached to the debris to increase its aerodynamic drag so that it enters the atmosphere faster and burns up. This idea is used by Gossamer Orbit Lowering Device (GOLD) for removal of junk from Low Earth Orbit (LEO). It is developed by the Global Aerospace Corporation [9].

3) Compact satellites called CubeSats are being used for the purpose. It is equipped with a chaser and robotic arms which can cling and tether onto the targets and then deorbit together [10]. ClearSpace-1 developed at the Federal Institute of Technology is one such initiative.
4) Sticky boom developed by Altius Space Machines initially to be used as a docking mechanism for launch vehicles can also be used to attach to any target object due to the difference in electrostatic charges induced on the object it comes in contact with. It uses the principle of electro adhesion. It can then be maneuvered back to the atmosphere.
5) DARPA's Phoenix program takes a different approach to the traditional development process of geosynchronous earth orbit (GEO) satellites, which are expensive and profligate. They use independent modules called Satlets which can combine in different combinations to achieve different results. These are cost effective, reusable and easy to put together.
6) NASA has come up with the Active Debris Removal Vehicle (ADRV) which can help remove debris from LEO by approaching the object, assessing its motion, and determining an initial capture trajectory. It then matches its rotation rates and executes a capture maneuver. The object is deorbited after that. It is so compact that eight such vehicles can fit in a single payload.
7) Many organizations like SSN by the US military's joint space operations center (JSpOC) have come up with debris detecting mechanisms which offer collision warnings 72 hours in advance to satellite operators for close approaches based on highly accurate predictions made from astronomical observations and deep learning algorithms. These are vital for performing timely maneuvers that can save the on-going mission from destruction and creation of more debris [11].
8) Implementation of Orbit tax has also been discussed, which is an internationally coordinated orbital fee to be paid annually by the government for each satellite put into orbit. This will encourage more responsible use of orbit and removal of the satellite from the orbit at the end of its mission [12].

Conclusions

Space debris poses significant threats to the sustainability of space environment. Though many promising solutions have been proposed, the best way is always to encourage responsible behavior among all the stakeholders in space exploration. This includes reducing the number of unnecessary launches, making even the smallest of changes in the design of a mission, which will help prevent the release of unnecessary parts of machinery into space. For example, the protective lid of a camera or other equipment could be hinged so that it does not float away in space to add on to the already increasing amount of space debris. The tracking of debris is another serious concern, which needs to be addressed wisely. Many erratic and ignorant decisions have been taken by the authorities and have resulted in serious issues affecting the biosphere globally. Therefore, it is necessary to work together to be responsible and keep coming up with sustainable, yet innovative ideas that will help reach newer heights without curbing the dreams of future generations.

References

1. Colombo, C., Letizia, F., Trisolini, M. and Lewis, H., 2018. Risk and Mitigation. Frontiers of Space Risk: Natural Cosmic Hazards & Societal Challenges, p.105.
2. Putzar, R., Schaefer, F. and Lambert, M., 2008. Vulnerability of spacecraft harnesses to hypervelocity impacts. International Journal of Impact Engineering, 35(12), pp.1728-1734.
3. Sánchez, A.H., Soares, T. and Wolahan, A., 2017, January. Reliability aspects of mega-constellation satellites and their impact on the space debris environment. In 2017 Annual Reliability and Maintainability Symposium (RAMS) (pp. 1-5). IEEE.
4. Kessler, D.J. and Cour-Palais, B.G., 1978. Collision frequency of artificial satellites: The creation of a debris belt. Journal of Geophysical Research: Space Physics, 83(A6), pp.2637-2646.
5. Witze, A., 2018. The quest to conquer the space junk problem. Nature, 561(7721), pp.24-26.

6. Hakima, H. and Emami, M.R., 2018. Assessment of active methods for removal of LEO debris. Acta Astronautica, 144, pp.225-243.
7. Su, J., 2013. The environmental dimension of space arms control. Space Policy, 29(1), pp.58-66.
8. Thiry, N., Vasile, M. and Monchieri, E., 2016, March. Mission and system design for the manipulation of phos with space-borne lasers. In 2016 IEEE Aerospace Conference (pp. 1-13). IEEE.
9. Lappas, V., Pellegrino, S., Guenat, H., Straubel, M., Steyn, H., Kostopoulos, V., Sarris, E., Takinalp, O., Wokes, S. and Bonnema, A., 2011, September. DEORBITSAIL: De-orbiting of satellites using solar sails. In 2011 2nd International Conference on Space Technology (pp. 1-3). IEEE.
10. Sharma, A. and Sinha, N.K., 2022, March. Dynamics of Tethered Space-Robot Swarm for Active Debris Removal. In 2022 IEEE Aerospace Conference (AERO) (pp. 1-8). IEEE.
11. Gordon, S., 2021. International Environmental Law Principles: A New Solution for the Space Debris Problem?. McGill University (Canada).
12. Kesharwani, U. and Chaturvedi, A., 2020. Orbit tax–mitigating space debris or aggravating economic disparity?. Völkerrechtsblog.