# SPACE SCIENCE:

# Space Junk - Protecting Space for Future Generations

**Submitted By:**

Anugrah Nambiar, Akash Ranjan, Madiraju Bharadwaj, Nandakishor P

**ABSTRACT**

Apart from the looming climate change and global warming, the world is facing a disaster in its space infrastructure: the filling of the space orbit by debris. This research paper dives deep into the science of space junk and analyses the various methods used for its clearance. Further, it concludes by suggesting the Orbital-use fees method as the best method among them. The Orbital-use fees can be straight-up fees or tradeable permits, and they could also

be orbit-specific. Each government would have to charge the same amount per unit of collision risk for each satellite that enters orbit.

**INTRODUCTION**

The space is getting smaller and smaller. The modern world, where no artificial objects orbiting the Earth are secured, faces various challenges. We have devastated the universe since humans explored it. Thousands of dead satellites orbit our Earth, as do debris from all rockets we have launched over the years. Aged satellites and space debris clog low earth orbit, while new satellite launches increase the likelihood of collisions. A collision between a nuclear-powered spacecraft and space debris can result in nuclear contamination of the Earth or the space environment and can have catastrophic consequences**.** Hence, this necessitates the establishment of new policies to ensure the safety of spacecraft and to increase awareness about the hazards to the long-term usage of space. The Space Surveillance Network has been set up to tackle the same issue. It detects space debris and junk that can cause collisions with the space orbit.

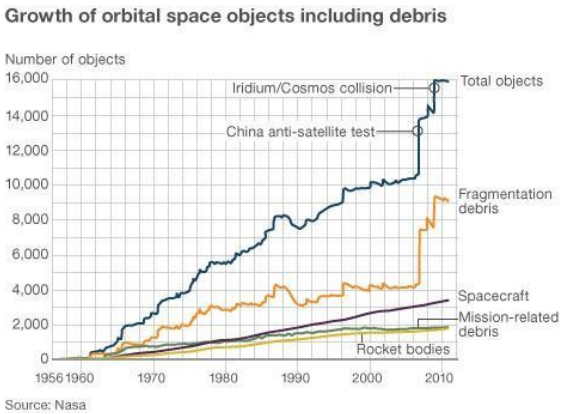
This paper is divided into sections to address all the relevant concerns regarding space junk. First, we summarise the space junk crisis and outline its adverse effects on humans and space exploration. Second, we identify and explore existing models/solutions to counter space junk issues. Third, we analyse these methods and choose the most appropriate ones. We conclude with a summary of the main findings and identify some future research directions.

**What is space junk?**

Space junk, commonly known as space debris, is an artificial object that orbits the Earth but is not helpful in space. They are non-functional with no reasonable expectation of being able to resume their intended functions. They could be the various particles that have been put into Earth's orbit by artificial objects. They usually orbit the Earth and can be dangerous if they collide with moving satellites or spacecraft. Nuts, bolts, impact debris, slag, rocket motors, paint flakes, satellite dust and coolants are some of them that pollute the Earth's orbit. These substances orbit the Earth and pose a grave threat to satellites. They can also erode parts of spacecraft and satellites and increase fragmentation. Since they overlap spacecraft paths, the probability of collision with a spacecraft increases as more items are abandoned in orbit. The Earth's orbit is divided into two parts: high and low. These orbits are all polluted by space debris, and flight engineers are entrusted with tracking them in order to avoid further collisions.

**How does Space junk come into existence?**

Several satellites and space probes are launched yearly, but not everything returns. Thousands of non-functional ones end up in the orbit of the Earth, contributing to what is called - Space Junk. All space debris is the product of objects launched from Earth and remains in orbit until they re-enter the atmosphere. Humans have been adding technical materials to the space environment for sixty years. These spacecraft have transformed virtually every aspect of our lives — from agriculture, environmental management and weather prediction to the internet and banking. However, when their official mission ends, their status changes from an asset to a liability. They become ‘space junk’.Operational satellites can also become space debris. Satellites run out of manoeuvring fuel, batteries wear out, solar panels degrade – causing an orbital debris feedback loop, in which the problem is exacerbated when solar panels are sandblasted by micrometeoroids and tiny debris. Some debris is created naturally from the impacts of micrometeoroids – dust-sized fragments of asteroids and comets. Some objects in lower orbits of hundreds of kilometres or less can return relatively quickly. They often re-enter the atmosphere a few years later, mostly burning out and preventing them from reaching Earth. Debris and satellites left in the high altitudes of 36,000 kilometres, where communications and meteorological satellites are often placed in geosynchronous orbit, can orbit the Earth for hundreds or even thousands of years. Some space junk results from collisions or anti-satellite tests in orbit. When two satellites collide, they can smash apart into thousands of new pieces, creating lots of new debris. This is rare, but several countries, including the USA, China and India, have used missiles to practice blowing up their own satellites. This creates thousands of new pieces of dangerous debris.




**Why is space debris a problem?**

Even the tiniest space debris is a hazard: particles the size of dust grains, even paint chips, can scour hard-to-protect components like optics and solar panels, shortening operational lifetimes and creating even more tiny flecks of debris. The impact caused by a 1-kilogram object travelling at a speed of 7.0 km/s releases the same amount of energy as the detonation of a 6-kilogram of TNT.

The low earth orbit (LEO) debris field is currently unstable. Simulations show that the debris field will gradually develop without further launches. Without constant launch rates and mitigation efforts, the amount of debris in orbit is increasing. Anti-satellite weapon tests that generated fragments exponentially were conducted in China in 2007. In 2009, it contributed significantly to the increase in space debris. The rising number of space debris increases the potential danger to all space vehicles, especially those with humans aboard, like the International Space Station (ISS). The International Space Station is equipped with a tracker to monitor collision risk.Space junk can impact operational spacecraft, yielding even more debris of all sizes, further increasing the impact risk. This is known as "the Kessler syndrome," named for NASA scientist Donald J. Kessler, who hypothesised spacecraft and orbital debris could reach a density such that each impact generates more debris and a greater likelihood of colliding with other objects. Many space shuttle windows have been replaced because of damage caused by paint flecks. The density of the junk may become so great that it could hinder our ability to use weather satellites and monitor weather changes. Space junk has the daily potential to alter satellites' operations and movement. This translates into real-world costs, as satellite operators field alerts about potential collisions. Space junk is also problematic for astronauts. Particle impacts induce erosive damage, akin to sandblasting. A significantly smaller proportion of the debris pieces are larger, measuring more than 10 cm (3.9 in). The sole defence against larger debris is to steer the spaceship to avoid a collision. If the spacecraft collides with heavier debris, many of the following fragments will be in the 1 kilogramme (2.2 lb) mass range, and these items will pose an additional collision risk. Space debris not only endangers human life but poses a threat to other satellites and spacecraft in orbit and has the potential to create trash in space, increasing the chance of collision and thereby interfering with the regular operation of space objects of critical value to the Earth. Weather and satellite data from space are critical to science, communication, aviation, and astronomy. The biggest contributor to the current space debris problem is explosions in orbit, caused by left-over energy – fuel and batteries – onboard spacecraft and rockets. Despite measures being in place for years to prevent this, we see no decline in the number of such events.  Practically, collisions are rare—the last two satellites to collide and break apart happened in 2009 and 2021.

One such incident occurred when Debris from Russian Proton rockets launched from Kazakhstan's Baikonur cosmodrome littered the Altai area of eastern Siberia. This includes trash from old gasoline tanks containing very toxic fuel waste and unsymmetrical dimethylhydrazine (UDMH), a carcinogen that is detrimental to plants and animals. While efforts are made to restrict fallout from launches within a specific area, total containment is exceedingly difficult to achieve.

**How much junk is there?**

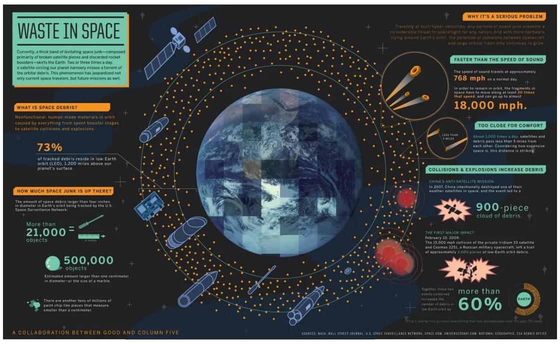
The number of debris objects, their combined mass, and the total area they take up has been steadily increasing since the beginning of the space age. This is further fuelled by a large number of in-orbit break-ups of spacecraft and rocket stages.The Earth's orbit is divided into two; high and low earth orbits. These orbits are all polluted by space debris, and flight engineers are tasked with tracking them to avoid further collisions. NASA's most recent estimation of space debris as of 22nd March 2011 is 22000. NASA estimates the population of debris between one and 10 centimetres as about 500,000 objects. The latest models from the European Space Agency estimate that figure is closer to 900,00 objects in space. An estimated 20,000 objects—including satellites and space debris—are crowding low-Earth orbit. It's the latest tragedy of the commons; the researchers said: Each operator launches more and more satellites until their private collision risk equals the value of the orbiting satellite.

**SPACE JUNK IN NUMBERS :**

2,000 active satellites in Earth's orbit
3,000 dead satellites in Earth's orbit
34,000 pieces of space junk larger than 10 centimetres
128 million pieces of space junk larger than 1 millimetre
One in 10,000: risk of collision that will require debris avoidance manoeuvres
25 debris avoidance manoeuvres by the ISS since 1999

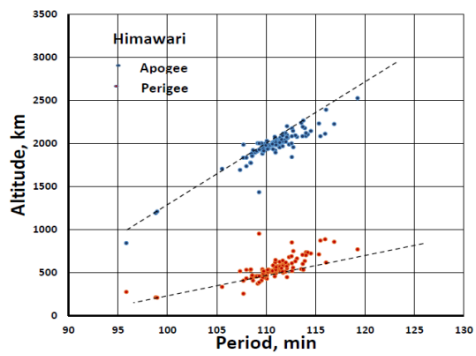
Not only have we left a lot of space junk in Earth's orbit, there are objects elsewhere too, such as on the lunar surface. Some of the things abandoned on the Moon include 3 Moon buggies from Apollo 15, 16 and 17, 54 uncrewed probes that have crashed or landed on the Moon, 190,000 kilograms of material left by humans on the Moon ! Some other surprising objects left on the Moon and nearby orbital space include

a) a golden olive branch
b) three golf balls
c) a falcon feather
d) a photograph of the astronaut's family.




**ANALYSIS:**

Given the tremendous risk posed by space debris, numerous precautions have been taken to ensure that it can be predicted and avoided. Numerous technological studies have been conducted to accomplish this, and unique detectors for tracking purposes have been devised. Optical and radar detectors such as lasers and transit telescopes are some of these devices. However, the usage of these devices is restricted because they can only trace things of a specific size. Another issue with tracking space debris is the stability of such small trash in orbit, which makes determining orbits for (re-acquisition) challenging. Tracking devices cannot track garbage less than 1 cm in size, complicating traceability. It is suspected that the smaller debris is abundant and has gone unnoticed. According to ESA Metroid, there are about 600,000 items larger than 1 cm in orbit. Another method to track debris is through measurements done in space. In this method, researchers use returned debris hardware, which acts as an information base regarding the orbit environment. Examples of such satellites used are the EURECA satellite which was recovered by STS-57 Endeavour. Moreover, debris can be tracked using Gabbard diagrams.

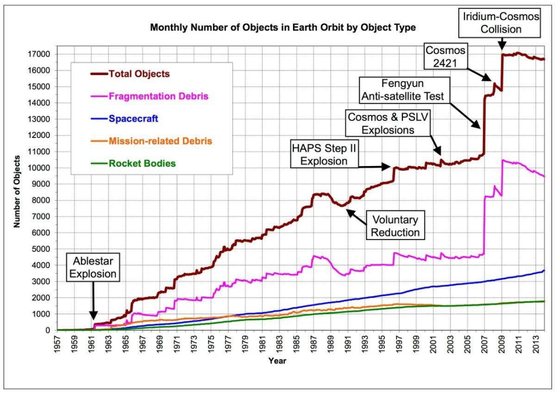



Gabbard diagram of Himawari Rocket fragments

Several space agencies and multilateral organisations have tackled this subject over the years. The consensus is always the same: the problem is unavoidable and becoming worse. It's also true that the level of concern is rising. There is now a vast jungle of debris above, ranging from ancient rocket stages that continue to loop about the Earth decades after they were launched to paint flakes that have lifted off once-shiny spacecraft and floated off into the horizon. Today, it is said there are more than 22,000 pieces of debris actively being tracked. These are just the big, easy-to-see items, however. Moving around unseen are an estimated 500,000 particles ranging in size between 1- 10cm across and perhaps tens of millions of other particles smaller than 1cm.  In 2017, commercial companies, military and civil departments and amateurs lofted more than 400 satellites into orbit, over 4 times the yearly average for 2000–2010. Numbers could rise even more sharply if companies such as Boeing, OneWeb and SpaceX follow through on plans to deploy hundreds to thousands of communications satellites into space in the next few years.

The number of objects in orbit is rising so rapidly that researchers are investigating new ways of attacking the problem. Researchers are currently assembling a big data set with the most up-to-date information on where everything is in orbit. Others are creating space trash taxonomies, figuring out how to measure qualities like the shape and size of an object so that satellite operators know how much to worry about what's coming their way. Several researchers are also identifying unique orbits that satellites may be relocated into when their missions are completed so that they burn up in the atmosphere fast, helping to clean up space. It has been found that just a few uncontrolled space crashes could generate enough debris to set off a runaway cascade of fragments, rendering near-Earth space unusable. Some scientists are tackling the problem of space junk by trying to understand where all the debris is to a high degree of precision. That would alleviate the need for many unnecessary manoeuvres that today are used to avoid potential collisions.

Satellite operators need to know what the object is to gauge the risk of an impending collision, yet tracking catalogues provide minimal information on many goods. In such circumstances, the military and other space trackers employ telescopes to gather information in the brief period preceding a potential collision. US Air Force, \are developing methods to rapidly decipher details of orbiting objects even when very little is known about them. By studying how an object reflects sunlight as it passes overhead, we can understand whether the object is operational or not. Once researchers know what an orbiting object is made of, they have a number of potential ways to reduce its threat. This includes proposals involving the use of magnets to sweep up space junk, or lasers to obliterate or deflect debris in orbit. However, given the enormous quantity of objects in orbit, such active efforts to clean up space junk seem unlikely to be practicable in the long run. As a result, some scientists believe that a passive approach to space debris mitigation is the best option. This takes use of the Sun's and Moon's gravitational influences, known as resonances, which can send satellites crashing to the ground




**The current method to clean up space junk:**

According to NASA, with half a million bits of space debris fouling Earth's orbit, there is a rising problem of cluttering up our access route to space. Several firms and entities have developed methods for removing decommissioned satellites and other space trash.

Through this method we would like to highlight the 7 recent proposals made to remove space debris .

1. **Using redundant satellites / System of Harpoon** :
   Engineers in the UK are developing a system to harpoon rogue or redundant satellites and pull them out of the sky. It is a response to the ever-growing problem of orbital junk - old pieces of hardware that continue to circle the Earth and now pose a collision threat to operational spacecraft. The harpoon would be fired at the hapless satellite from close range. A propulsion pack tethered to the projectile would then pull the junk downwards to burn up in the atmosphere.

2. **Raising Campaigns , building self-removal orbits** :
   Several governments, including the United States, Russia, France, and others, have taken initiatives to mitigate the growing hazard of space debris. These initiatives include scientific studies on eliminating human-made objects in orbit, campaigns to raise awareness

of the dangers presented by these space junks, steps to mitigate the risk of space debris, and building satellites capable of moving out of orbit after use, known as self-removal orbits.

3. **Using the power of electricity :**

The Japanese Aerospace Exploration Agency proposes to use an electrodynamic tether whose current would slow down the speed of satellites or space debris. Slowing the satellite's speed would make it gradually fall closer to Earth, where it will burn up. The tether will be able to change its position by the use of force that's generated by an electric current and the Earth's magnetic field. The tether will also get attached to a large piece of debris so the space trash can be guided down into a destructive reentry.

4. **Ideas from European countries** :

The most promising developments in the field of space cleanup have come from Europe. RemoveDEBRIS, an experimental project led by the University of Surrey, England, launched into orbit in 2018 and trialled a number of ways to capture space junk. The methods included nets, a harpoon, and attaching a ‘drag sail’ to redundant satellites to bring them out of orbit faster. The drag of the solar sail will push orbiting space debris down to lower orbits. The proposal is still under design and is expected to be completed by 2025. At the end of 2019, the European Space Agency (ESA) announced Clearspace-1, an ambitious 5-year plan led by Swiss startup ClearSpace. It will culminate in a 2025 mission to remove a 100 kg payload left behind by an ESA rocket in 2013.

5. **Role of SpaceX and Elon Musk :**

Starlink satellites operate lower than conventional satellites, are designed to de-orbit one to five years after their missions are completed, and link to the DoD’s debris tracking system to autonomously adjust their flight paths in response to threats. Another example of a company taking responsible, safe actions is

Iridium which replaced their entire constellation, de-orbiting all their old satellites and replacing them with newer ones while keeping comms going.

6. **External removal Methods :**

   Several companies, including SpaceX and Amazon, are planning vast new groups of satellites, called mega-constellations, that will beam the internet down to Earth. If successful, there could be an additional 50,000 satellites in orbit. Mega-constellation satellites occupy orbits between 400 and 1200km and in order to be economically viable, are typically as small and low-cost as they can be, whilst still able to deliver their services. Application areas range from low latency services for banking to delivering internet access to remote areas, as well as services to aircraft, ships and potentially military users.

So far, proposed solutions have been primarily technological or managerial. Apart from these methods. We have proposed a new solution to the Space Junk problem labelled as

" **ORBITAL-USE FEES** "

**Proposed method**

A better approach to the space debris problem is implementing an orbital-use fee—a tax on orbiting satellites. Orbital-use fees could be straight-up fees or tradeable permits, and they could also be orbit-specific since satellites in different orbits produce varying collision risks. Most importantly, each satellite's fee would be calculated to reflect the cost to the industry of putting another satellite into orbit, including projected current and future costs of additional collision risk and space debris production—costs operators do not factor currently into their launches. Orbital-Use fees are not the same as launch fees, Launch fees by themselves can't induce operators to deorbit their satellites when necessary, and it's not the launch but the orbiting satellite that causes the damage. Orbital Use fees implementation will make sure that the priority here is that satellite operators are having the mentality to pay the cost of the collision risk imposed on other operators. These fees would increase over time, to account for the rising value of cleaner orbits. In the researchers' model, the optimal fee would rise at a rate of 14 per cent per year, reaching roughly $235,000 per satellite-year by 2040. As quoted by Burgess, who is also an assistant professor in environmental studies and an affiliated faculty member in economics at CU Boulder, “Space is a common resource, but companies aren’t accounting for the cost their satellites impose on other operators when they decide whether or not to launch.The researchers discovered that for an orbital-use fee strategy to succeed, all countries launching satellites would need to participate—roughly a dozen that launch satellites on their own launch vehicles and more than 30 that own satellites.  Furthermore, each government would have to charge the same amount per unit of collision risk for each satellite that enters orbit, albeit revenue might be collected separately. Countries already employ similar tactics in carbon prices and fishery management.

Researchers found that with orbital-use fees, the long-run value of the satellite industry would increase from around $600 billion under the business-as-usual scenario to around $3 trillion. The increase in value comes from reducing collisions and collision-related costs, such as launching replacement satellites. When comparing orbital-use fees to business as usual, it was found out that orbital use fees forced operators to directly weigh the expected lifetime value of their satellites against the cost to industry of putting another satellite into orbit and creating additional risk. This should lead to reduction in the number of satellites launched to Orbit.

## CONCLUSION

Space debris has increasingly caused concern in most countries, such as the United States, European and Asian countries, among others. They have the propensity to erode body parts of spacecraft and satellites when they collide and create more debris in orbit, which would increase the chances of other collisions.

These objects are usually artificial materials discarded in orbit or dead satellites. Areas that require high alert are the LEO and GEO, which have many satellites and stationed targets, respectively. Flight engineers and space agencies have stationed various tracking devices like optical and radar detectors, among others, used to track space debris. These devices are, however, limited to the debris of sizes 1cm and above, leaving several tiny debris unchecked.  Space debris is increasingly filling the Earth's orbit, with predictions putting it at four times its present value by 2050. To avoid rampant collisions much should be done to mitigate its growth and remove the existing debris. Amongst the various methods that are proposed to help mitigate the growth of debris and remove them from orbit, none of these approaches addresses the underlying incentive problem: satellite operators do not account for costs they impose on each other via collision risk. Orbital-Use fees have proved to be more efficient and feasible. An internationally harmonised orbital-use fee can correct these incentives and substantially increase the value of the space industry. However, much effort still continues to be placed on space safety.

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