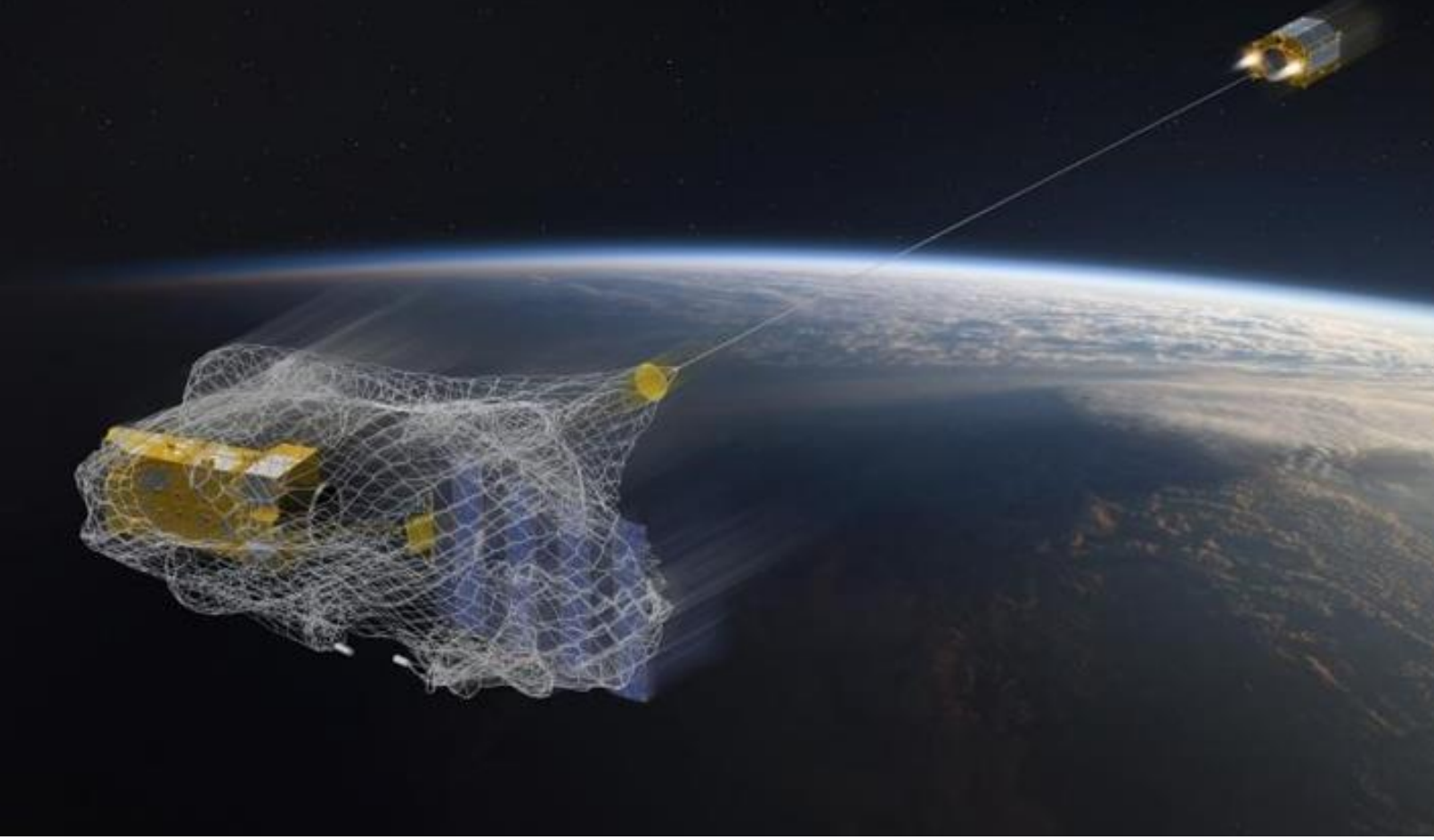
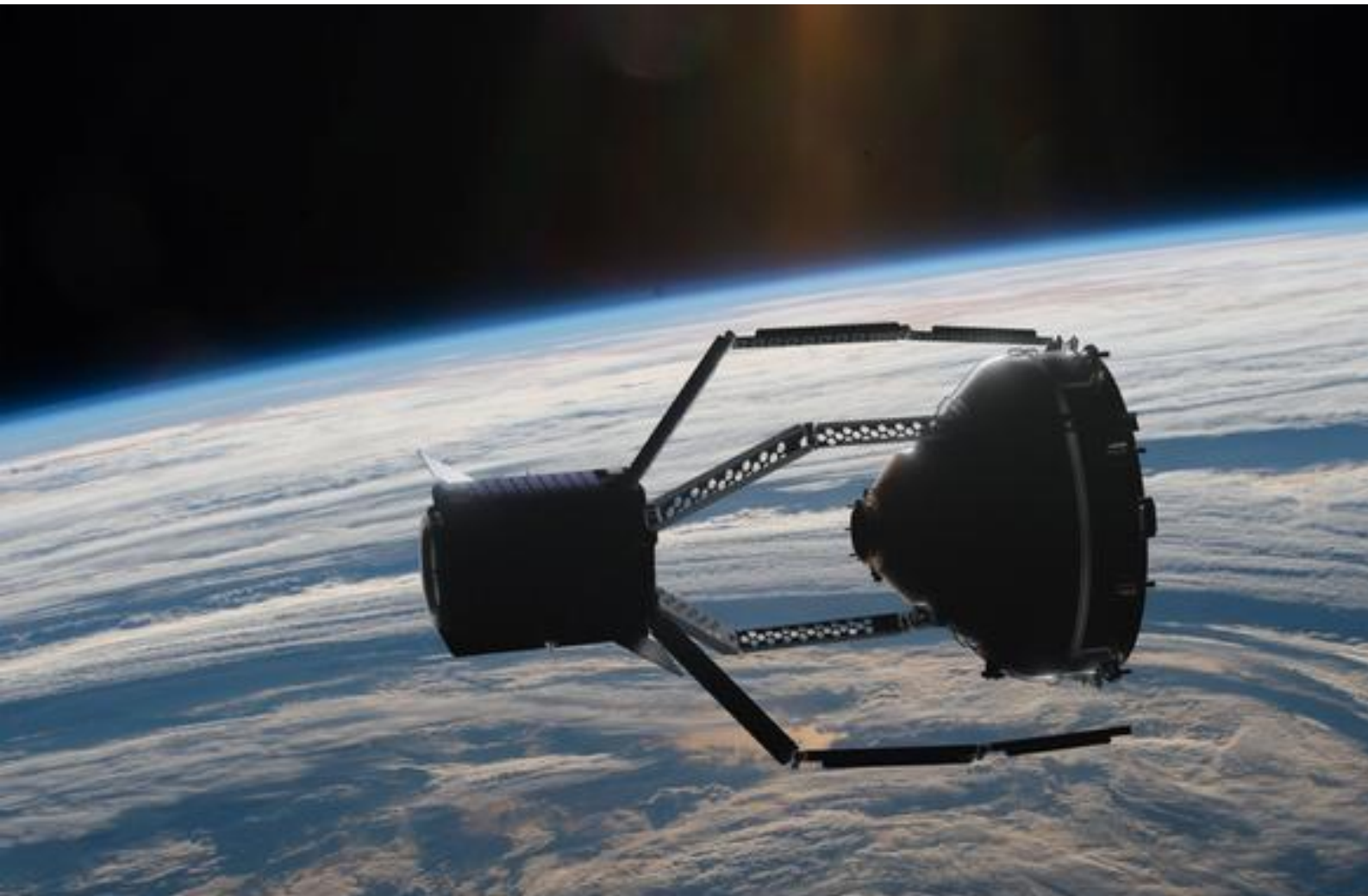


SPACE DEBRIS



How many objects are surrounding Earth?

Ever since the space race, the number of objects on Low Earth Orbit and Geostationary orbit has increased exponentially. Previously, this was considered a measurement of human achievement, now it might be considered a measurement of human stupidity. As is common with new technological advancements, we fail to consider first the consequences of innovation and pretend they don't exist until we cannot anymore. There are now more than 7000 artificial satellites in Earth's orbit with that number set to increase at an accelerating rate. The fact we were oblivious to is that, as trivial as it may sound, when several things are travelling at more than 30 times the speed of sound in opposite directions, collisions have consequences. To add insult to injury, most of the debris caused by collisions and fragmentation is so small that it is almost impossible to detect. ESA estimates that fragmentation events (the main source of space debris as of now) account for around 900,000 objects larger than 1cm in diameter in orbit. The US Space Surveillance Network only tracks around 28,000 objects in their database, with the vast majority of these being larger than 10cm in diameter, because anything smaller than that is way too hard to track. Despite these objects being so small, the damage they do is anything but that. A paint chip of just 1 gram will have 4 times the momentum of a bullet when travelling in space. To track these objects, you must either track them from the ground or from space. Tracking them from the ground is the most effective method for most purposes. To do this, radar detectors are used, and orbital mechanics calculations are made. Tracking from space is also possible, however it is more effective for performing avoidance maneuvers rather than for categorizing specific debris.

Past collisions

Many of the artificial instruments that are currently orbiting around our planet are capable to resist to impacts with small debris, even though it happens at high speeds. Yet, the biggest problem occurs when two objects of significant dimensions or satellites end up in a route of collison. At first space agencies and experts thought that a collision between bigger objects would have been rare because of the large distances between one another and of the different orbits each satellite had. However, on the 10th of February 2009, the biggest space collision occurred, were an inactive Russian satellite, named Kosmos 2251, that was mainly used for communications, collided with an operative American satellite which was also used for communications, known as Iridium 33. The incident occurred 800km above Siberia and more than 2000 pieces of debris were created from the collision, with a size of at least 4 inches in diameter. Many of these pieces of trash have remained in LEO orbiting at high velocity and creating a serious risk for other active satellites. The collison occurred at 430km from the international space station that at that time was fully operating with six astronauts. Fortunately, Nasa had anticipated the risk of a collision and the space station was unharmed.

Could the situation be even worse? The Kessler effect

The Kessler effect was initially thought by the astrophysics Don Kessler in 1978, from which it gets the name. The Nasa scientist describes this phenomenon as a selfsustaining cascading collision of space debris in lower earth orbit. He elaborated the idea that once a certain critical mass is reached, the total number of space debris orbiting the earth will keep on increasing, even if no additional artificial objects are launched into orbit. This is explained with the domino effect; collision gives rise to more debris, which leads to more collisions, in a chain reaction that could potentially never stop.

In fact, Kessler believed and theorized, that a belt of space junk could form around the earth, and that eventually could threat space activities, and especially it could make the use of satellites in specific orbital ranges impractical for many years. Kessler described in his paper "Collision Frequency of Artificial Satellite: The creation of a Debris Belt" that the only way to avoid this catastrophic scenario was to significantly reduce the number of non-operating spacecrafts left in orbit. Even though a large part of the debris eventually disintegrates and destroys itself by entering the upper atmosphere, many other survive. On average, each year more than 300 objects increase the orbital population, which corresponds to the low limit predicted by Kessler.

Future increases in orbital population

In the near future, some of the biggest satellite constellations are going to be launched and this may make the situation even worse. The three main ones are: Starlink (SpaceX), Kuiper (Amazon) and OneWeb.

SpaceX's first proposal was announced in January 2015. Then the number of satellites that are planned to be launched increased. Musk's objective is to build worldwide satellite internet network to help achieve his Mars colonization vision. The U.S. Federal Communications Commission (FCC) has granted SpaceX permission to fly 12,000 Starlink satellites. The company has now filed paperwork to launch up to 30,000 additional spacecraft bringing the total to 42,000.

To put that into perspective, only about 4,300 active artificial satellites currently orbit Earth, and only 11,670 have ever been launched in all of history, according to the European Space Agency.

Starlink's satellites operate at an altitude of around 340 miles (550 kilometers) — low enough to get pulled down to Earth by atmospheric drag in a few years so that they don't become space junk once they die.

However, also Amazon wants to build a constellation of 3,236 satellites (Kuiper), orbiting at an altitude of 590 to 630 kilometers (370 to 390 miles). Amazon has not launched any satellites already but the FCC's approval means that Amazon must launch at least half of the constellation by 2026 if it wants to use its operating license.

In addition, OneWeb is also building a satellite internet service, but unlike Starlink, the company plans to provide services to businesses rather than customers. The company launched the first six satellites in February 2019 and as of September 2021, OneWeb has launched 322 satellites.

How the ISS prevents damages and collisions

Well, before how, ask if! Actually, the ISS does not even try to avoid the collision with every small space debris or tiny object that can finish in its orbit. One measure of safety is shielding, using Kevlar, a synthetic material that can help to reduce damages from small objects, up to a size of 1.5 cm. This is fundamental since the collision with very small objects cannot even be detected. For bigger objects, there is a contingency plane and a strictly procedure. Nasa has a specific unified combatant command, USSTRATCOM. They do some estimates of the trajectory the object will follow, 'drawing a so called 'pizza box': it measures about 4 x 50 x 50 kilometers, with the ISS centered in it.Then they do some visions: if the chance of hitting is greater than 0,001% it is a yellow flag. If it is greater than 0,01%, it is a red flag.

They will send those results to another department, TOPO, that analyses if the threat is significant or not. Now it enters some consultation between mission control center in Houston and Moscow. Next step they take in consideration eventually if a DAM (debris avoidance maneuver) should be done or not. It is done by executing a small burn in the prograde or retrograde direction, to increase or decrease the velocity of the ISS.

Sometimes DAM is not executed since there is really no trust in the projections, or it may be possible to enter in the orbit of other objects. DAM is performed more or less 1.5 times a year.If a DAM is actually not executed, would be possible that we have another safety measure: the crew moves into the Russian Soyuz or U.S. commercial crew spacecraft that are used to transport humans to and from the station. In this way if an important collision happens and the life-supporting loses pressure or some important component had a critical damage, they would be able to leave the station.

Finding solutions: the ESA Clean Space program

In order to solve problems related to the space debris, in 2012 the European Space Agency came up with the Clean Space Initiative. CS is an entirely new program that devotes attention to environmental impacts of space agencies activities both on Earth and in space.

CS program is divided in 3 branches: Eco design, Space Debris Mitigation and Active Debris Removal.

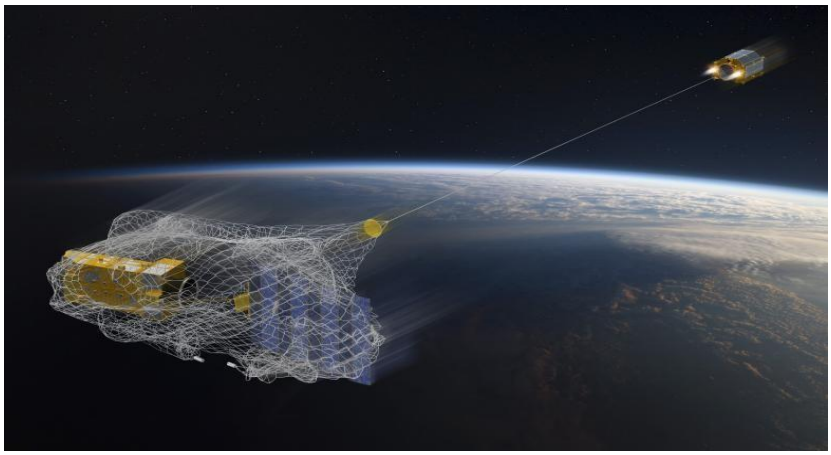
1. Eco design consists in the development of tools to evaluate the environmental impact of programmes and in identifying more sustainable technologies that can be used in a mission. The main tool developed at the first stage is the Life Cycle Assessment, which is a framework used to evaluate environmental impact of industrial activities. After using LCA, ESA engineers try to identify alternative processes or technologies that can reduce impacts. During this design stage, it is fundamental to create components that are "designed to demise", which means that they can burn up in the atmosphere during re entry.

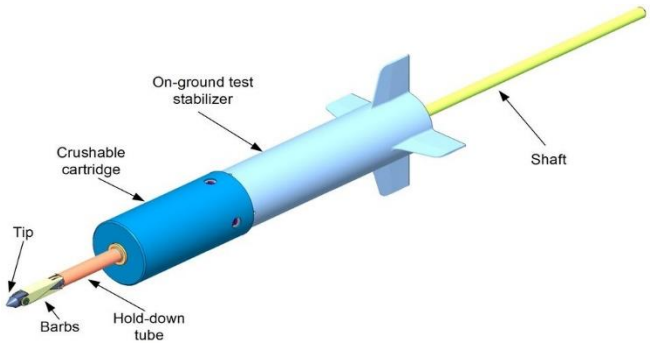
2. Space debris mitigation is related to the study of technologies for managing the end of life of space assets in order to reduce the production of debris objects.

3. Active debris removal. Since the population of debris objects will increase during years it is necessary to remove some of them each year. ESA is creating devices in order to remove objects, in LEO and GEO, that have an high mass and high probability to collide. The main stages of objects removal are firs capturing and then re entry or deorbiting. Re entry will consist in the burning of objects in the atmosphere.

Right now, the most promising mechanisms, that have already successfully completed some tests, are:

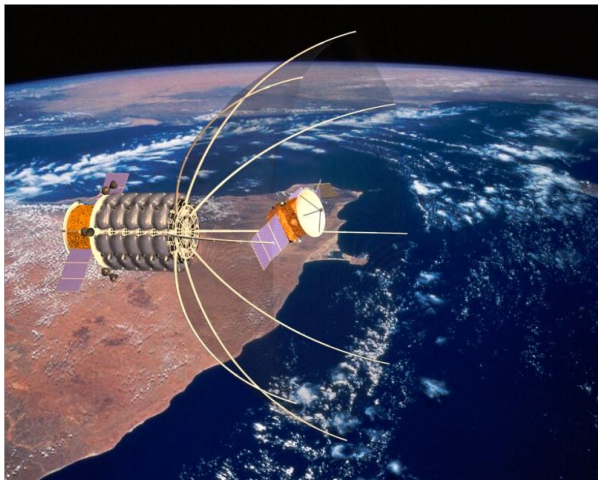
Throw Net: it is formed by a mechanism that ejects a net through a canister using cold gas and springs. The net opens and wrap around the targeted debris object. Then, a tether that connects the net to the canister would be tensioned and the targeted object will be pulled by the canister module and the re entry will start.

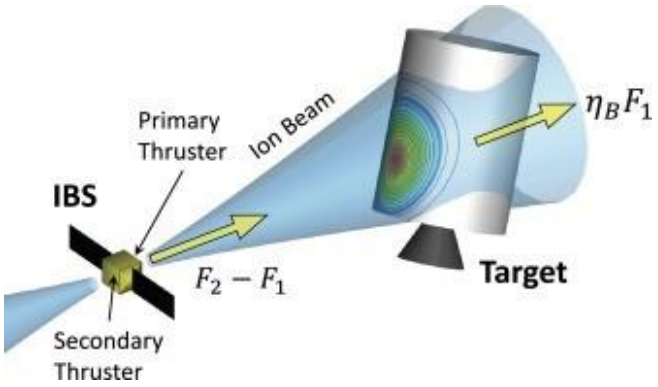




Harpoon: it is a technology similar to throw net. An harpoon is pushed to the target and penetrates it. After the docking stage, the target is pulled away and deorbited.

Clamping Mechanism: clamping mechanism is the most fascinating object removal technology, since it embrace the target with robotic arms and than it pushes the target toward Earth atmosphere. ESA has planned to launch a clamping mechanism called “Clear Space 1” in 2025, in order to catch VESPA.





Ion Beam Shepherd: it is a contact less technology that expels charged particles at high velocity to move and deorbit a spacecraft thanks to electromagnetic forces impressed on the target.

Drag Sail: it is a large aluminium coated membrane that attaches to an unused satellite and acts like a sail creating drag for de orbiting faster.