

# How Dangerous is Space Debris?

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**ABSTRACT:** Space junk is a problem that requires expert intervention. Last year, the European Space Agency reported that scientists altered the path of an important satellite to prevent a collision with an unknown orbiting object. Space junk - known as orbital debris to scientists who specialize in space matters - travels at speeds of more than 17,500 mph. According to the US National Aeronautic Space Administration, space junk colliding with a satellite or an astronaut-occupied space craft could be catastrophic. The destruction of a working satellite owned by a foreign nation worth millions of dollars might cause national defense or diplomatic problems. Attempts to remove space junk are challenging because there is no clear pattern of how debris is orbiting around our planet - with zero gravity, scientists cannot keep track of each piece of space junk. Furthermore, it is very costly to clean up space. This paper will explain how much orbital debris is in space, how it got there and whether trends are improving or deteriorating. In addition, this research paper will evaluate what solutions can be practically implemented by the international community to reduce space junk and minimize the risks to property and people.

**KEYWORDS:** Space Junk, Destruction, Space Debris, Satellite Collision, Orbital Debris Remediation, ISS

## Introduction

Orbital debris is NASA's preferred terminology for space junk, which it defines as "all man-made objects in orbit about the Earth which no longer serve a useful purpose" (NASA 2018). Space is vast but getting more crowded every year. According to the Index of Objects Launched into Outer Space maintained by the United Nations Office for Outer Space Affairs (UNOOSA 2014), there are 4,635 satellites currently orbiting the planet. Of these 2,600 are no longer functioning, which is an increase of 8.91% compared to 2016. The ratio of non-functioning satellites to functioning is 1.27. How many new man-made orbiting vehicles are sent to space each year? In 2017, UNOOSA (2014) recorded launches of 357 objects.

## Where does Space Junk come from?

Orbital debris originates from mission-related operations, accidents (which includes human error such as losing equipment on missions) or intentional creation (Hall 2014, 2). Some examples of mission-related space junk are abandoned spacecraft, capsules and parts that were intentionally released during the separation of spacecraft and protective shields/incidental hardware typically discarded into orbit as well (NASA 2018).

Accidents - there have been multiple incidents over the last 30 years which caused explosions between spacecraft due to orbital collisions. The NASA Scientific and Technical Information (STI) Program Office has kept track of every satellite breakup since 1962 and the list of satellites and space payloads that have fragmented in the last 56 years runs 14 pages - however, impacts from just 11 missions out of 4500 launches account for 32% of all rocket body fragmentations (Johnson 2008).

The best-known explosions and collisions involving spacecraft were the intentional destruction of a weather satellite by China in 2007 and the accidental smash-up between an active American Iridium satellite and a retired Russian Cosmos satellite which occurred on February 10, 2009. The incident, which occurred at an altitude of 770 km (470 miles) above Earth, created over 1600 orbital debris fragments (Wang 2010, 1).

"Nothing to this extent" has ever happened before, said Nicholas L. Johnson, chief scientist for orbital debris at the National Aeronautics and Space Administration (Broad 2009).

The weather satellite incident occurred when China conducted an anti-satellite test by intentionally blowing up its own Fengyun-1C weather satellite on January 11, 2007 by using military weapons (David 2007). Space aeronautics experts said the satellite's destruction was the most prolific and severe fragmentation in the course of five decades of space operations. The resulting collision littered Earth's orbit with hundreds of pieces of shrapnel (David 2007). By the end of the year

however, the reaction about China's test was more pointed and strongly worded, as authorities in space, military and diplomacy wondered if the world power intended on expanding aggressive weapons systems into space. The successful destruction raised international concerns about creating more space debris if other nations followed suit. Longer-term, the test raised questions about China's capability and intention to attack U.S. satellites (Kan 2007, 1).

A third source of orbital debris resulted from human error, such as when astronauts accidentally lost control of tools while working outside of their spacecraft. In 1965, during America's first Extravehicular Activity (EVA), a thermal glove floated out of the Gemini IV capsule (Hall 2014, 3). Then a year later, American Mike Collins accidentally let go of a Hasselblad camera while working outside the Gemini X capsule. As he was he was entering the capsule, a micrometeoroid and orbital debris experiment he had retrieved from the spacecraft's exterior also floated away. In 2008, a grease gun leaked inside the tool bag while Heidemarie Stefanyshyn-Piper was working outside the International Space Station. When she was trying to clean up the spill, the tools in her bag slipped away. The bag had various other tools which remained in orbit for eight months but burned up when they entered the atmosphere (Hall 2014, 3).

Before spacecraft collisions created  $\frac{1}{3}$  of all space junk, the principal source of orbital debris was from the explosions resulting from the old launch vehicle upper stages (fuel tanks), which were left in orbit with active energy sources, e.g., residual propellants and high-pressure fluids inside the tanks. Explosions in the disconnected stages typically occurred between a few months and a few years after the launch into space (Hall 2014, 4) and were caused by the sun's strong heat increasing pressure inside the propellant tanks long enough to cause explosions. Just as machine parts on Earth can become more fragile by high temperature fluctuations between heat and cold, the fuel tanks weaken due to temperature extremes in space much greater than Earth's. This weakens the wall separating the hypergolic propellants, allowing them to mix and then to ignite (NASA 2018).

The ejected upper stage explosion problem can be avoided by running the rocket engines long enough to deplete the fuel or by venting excess fuel into space. Many mission operators have begun using those procedures to empty the launch upper stages of explosive materials (European Space Agency 2005).

### **The Mission of the International Space Station and Orbital Debris**

Despite not getting the same amount of news media as it garnered 20 years ago, the International Space Station (ISS) is still fully operational, currently on Mission 56 with 6 astronauts from the US, Russia and Germany. The six astronauts have been performing tasks from a long mission list that have many purposes - testing equipment, training, scientific experiments and fulfilling commercial projects paid for by governments and private companies. In October, 2018, two spacewalks were on the agenda for the ISS crew.

One question frequently asked by amateurs and professionals alike, "Does space debris pose a risk to the ISS itself and to astronauts?" The answer is No, because NASA scientists track the largest pieces of the 500,000 space debris fragments that exist - if the odds of an orbiting piece of junk hitting an astronaut are greater than 10,000:1, NASA actually moves the ISS or the astronauts out of the way (NASA 2013). The probability is higher for objects smaller-than-baseball size which currently cannot be tracked with available sensors. However, space junk projected to orbit close to the ISS, causing the astronauts to move the vehicle occurs infrequently, about once a year on average (NASA 2018).

USSPACECOM - part of the US Air Force -is the group tasked with the responsibility for preventing collisions with space junk. The monitoring activity is conducted by SPACECOM staff at 25 radar and optical sensors located around the world. Most debris (about 84 percent) is out approximately 800 kilometers - roughly twice the normal altitude of the space shuttle which orbits at about 300 kilometers (Tozer 2012). Only a small amount of space junk exists where the ISS orbits. (Tozer 2012).

Ironically, the American astronaut who spent a year in space, Mark Kelly, wrote in his 2017 autobiography that he was almost hit by orbital space debris. "At the time, you think, if we get hit, we

will be vaporized,” he said. “There’s no two ways about it; it would be like a nuclear explosion. But it’s not something worth dwelling on” (O’Callaghan 2017).

### **Other factors to consider concerning collisions in Space**

While it’s true that there are thousands of space objects directly above Earth in an 800-kilometer band, space is so vast that it’s helpful to pause for a moment and reflect... in the area directly above the entire continental U.S., there are typically only three or four items orbiting above 3.1 million square miles. Therefore, the likelihood of collisions between satellites, spacecraft and orbiting objects is very small (NASA 2018).

In fact, in 2013 it was reported that the probability of a collision between an orbiting asset and space debris larger than 1 cm (0.4in.) will be once every 1.5-2 years, according to the Head of the Russian Hall/ History of Space Debris 8 Figure 5 [NASA] Space Agency. This compares with a 2010 estimate giving the likelihood of once every 5 years (Sorokin 2013).

### **The Feasibility of Practically Reducing Space Debris**

Reducing orbital debris is incredibly difficult. Therefore, the most important action that space experts and policy makers currently recommend is to prevent the unnecessary creation of additional orbital debris. This can be done through prudent vehicle design and operations ((UNOOSA 2014).

The International Academy of Astronautics or IAA is a significant, global organization of scientists and space experts from many countries who meet regularly to discuss the importance of space debris as a policy issue. The subject-matter experts of the IAA published their fifth update Situation Report on Space Debris in August 2017 (Bonnal and McKnight 2017). In the executive summary, the IAA reported that if an orbiting satellite impacts with small bits of debris - even as small as 5 mm - the result will be grave, e.g. the collision would likely disrupt or terminate a satellite’s operations (Bonnal and McKnight 2017, 5).

The serious warnings expressed in this conclusion are offset by the positive findings of the IAA that there has been a reduction of the space debris created from the two extraordinary satellite destruction events (2007 and 2009) cited earlier in this paper. According to the IAF report, a large amount of debris from the satellite explosions were frictionally burned when reaching the Earth’s atmosphere after gradually sinking due to the scientific principle of atmospheric drag (in the science of Physics), which is a deterioration in the strength of an orbit because of an object hitting gas molecules in space. Small bits of space junk sink as the orbit gets weaker... then they burn. This is a positive trend “for keeping the short-term collision hazard under control at the lower altitudes (i.e., less than 650 km)” (Bonnal and McKnight 2017, 7).

The final message contained in the report’s Executive Summary is sobering. The IAA believes that a catastrophic event may occur which was first forecasted by a scientist named Kessler, who postulated that it’s possible that an accumulated domino effect may occur if orbital debris collide and explode in chain reaction one after the other. The Academy states it’s not scientifically clear what exact circumstances will cause this catastrophe to occur or how fast the domino effect will happen. (Bonnal and McKnight 2017, 7).

The IAA report reins in the enthusiasm that debris mitigation alone can prevent the onset of the possible cascading breakup events (Page 8). This does not mean that debris mitigation guidelines and practices should be revoked, if anything, this implies that debris mitigation efforts should be consistently implemented in compliance with existing guidelines. This has spurred the community to study how Active Debris Removal (ADR) can be engineered and executed to reduce the mass of debris in orbit that might be involved in future catastrophic collisions. Related analyses have examined other ways to reduce the probability of massive derelicts from colliding on orbit by nudging them out of harm’s way before they can collide. Unfortunately, these debris remediation options have technical, operational, and policy challenges that are amplified by the ambiguity in collision dynamics in the short-term (i.e., hours to days) and long-term (i.e., years to decades) periods.

### A promising orbital debris retrieval experiment

An advancement in active debris removal happened this year. Scientists from the University of Surrey, UK devised the first experiment designed to capture orbital debris using a sophisticated net and harpoon. The experiment was developed by Surrey Satellite Technology (SSTL), which is part of the RemoveDebris consortium together with the University of Surrey, the aerospace company Airbus and other European companies. The experiment involved deploying a sophisticated cabinet with multiple compartments - called the CubeSat but it looks more like a refrigerator - engineered with sensors, cameras, robots and other advanced instrumentation. It was sent to space in April, 2018 on a Space X rocket launched from Cape Canaveral, Florida and the destination was the International Space Station (ISS). On September 16, 2018, two astronauts on the ISS positioned the cube into space by utilizing a robotic arm. A target was released from the cube and the giant harpoon-style net was projected from a capsule and snagged the target in the net. The entire experiment was captured on video and can be viewed on the Space.com website (Pultarova 2018).

The leaders of the European RemoveDebris mission declared the experiment a success. "It went very well," said RemoveDebris mission principal investigator Guglielmo Aglietti, director of the Surrey Space Centre at the University of Surrey. "The net deployed nicely, and so did the structure attach to the CubeSat. We are now downloading the data, which will take a few weeks, since we only can do that when we have contact with the satellite. But so far, everything looks great" (Pultarova 2018).

Ingo Retat, who fashioned the net in cooperation with the aerospace company Airbus, worked with teams of scientists on the net technology for 6 years, experimenting with many different iterations before they had sufficient confidence to test the net in space (Pultarova 2018).

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