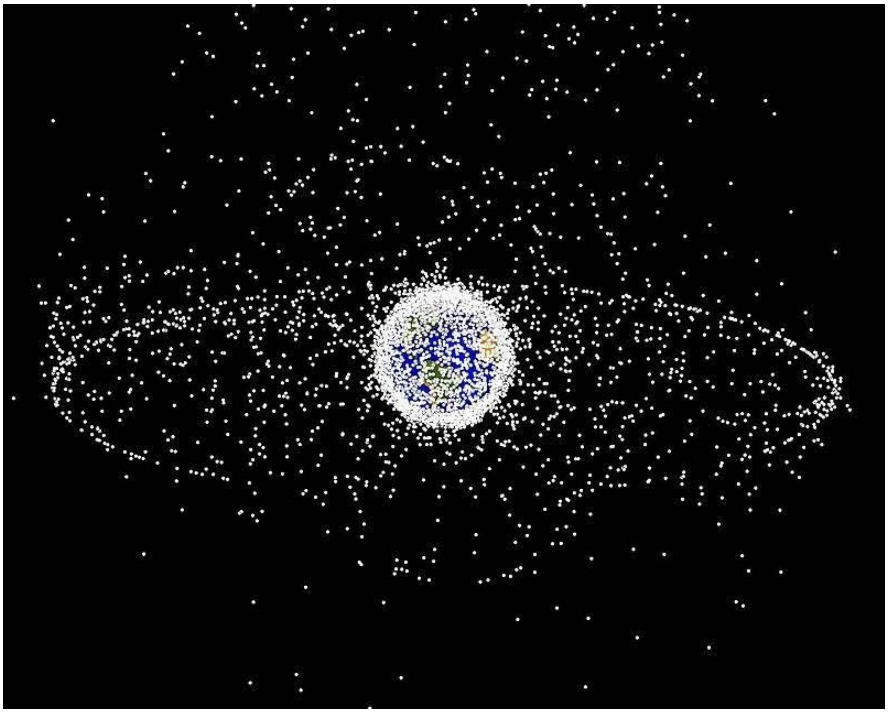
RECYCLING SPACE DEBRIS

INTRODUCTION

Space debris or Space junk is a term for human-made objects in space i.e principally in Earth orbit which no longer serve a useful function. This can include nonfunctional spacecraft, abandoned launch vehicle stages, mission-related debris and fragmentation debris. Examples of space debris include derelict satellites and spent rocket stages as well as the fragments from their disintegration, erosion and collisions, such as paint flecks, solidified liquids from spacecraft breakups, unburned particles from solid rocket motors, etc.

There are about 22,000 large objects orbiting the Earth, if you include all the equipment dropped by astronauts while floating in space and the debris from colliding satellites down to around 1cm in size, there are about one million bits of space junk in Earth's orbit . This large amount of space hardware has a total mass of more than 7500 tonnes.



A computer generated image representing space debris as could be seen from high Earth orbit.

The two main debris fields are the ring of objects in Geosynchronous Earth orbit (**GEO**) and the cloud of objects in Low Earth orbit(**LEO)**.

ORBITAL DEBRIS

The rising population of space debris increases the potential to all space vehicles ,but especially to the International Space Station,

SPACE debris encompasses both natural (meteoroid) and artificial (man made) particles. Meteoroids are in orbit about the sun, while ,ost artificial debris is in orbit about the Earth. Hence the latter is more commonly referred to as orbital debris.

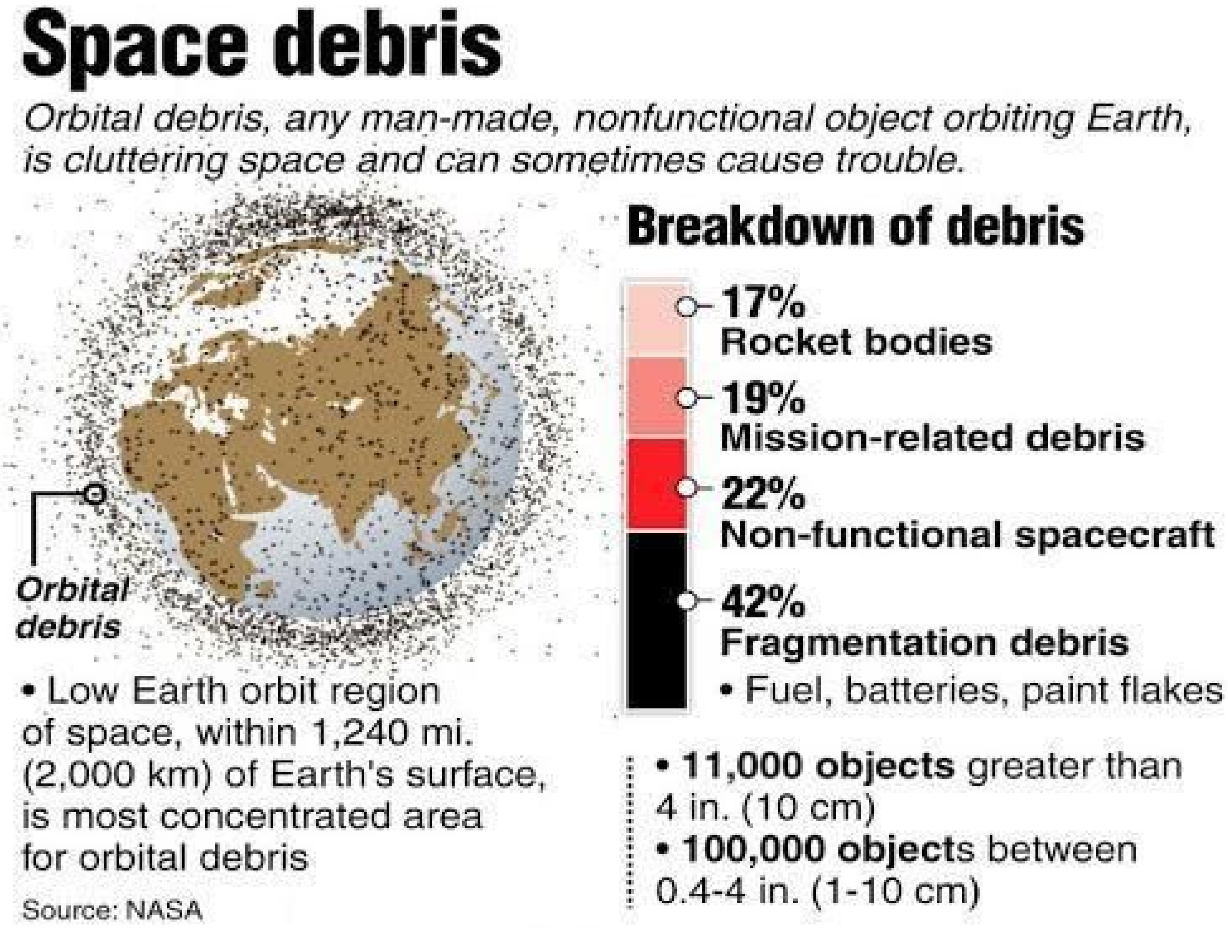
There are more than 20,000 pieces of debris larger than a softball orbiting the Earth. They travel at speeds up to 17,500 mph, fast enough for a relatively small piece of orbital debris to damage a satellite or a spacecraft. There are 500,000 pieces of debris the size of a marble or larger. There are many millions of pieces of debris that are so small they can't be tracked.

Even tiny paint flecks can damage a spacecraft when travelling at these velocities . In fact a number of space shuttle windows have been replaced because of damage caused by material that was analyzed as paint flecks .

The greatest risk to space missions comes from non-trackable debris was said Nicholas Johnson, NASA chief scientist for orbital debris.

With more satellites and rockets launching each year, collisions with space junk are becoming more likely. Losing a satellite could mean your TV reception is poor or the weather forecast is a bit less reliable. But it could also mean aeroplanes can't navigate properly and people aren't made aware of a tornado that's bearing down towards them.

A long-term solution is needed to clean up space.



RECYCLING SPACE DEBRIS

The graveyard orbit is effectively an abandoned junkyard with no caretaker. Flashes of bright light have been seen in there, and it's believed satellites are colliding or exploding from unused fuel or degraded batteries. This debris has the potential to fall back to GEO, threatening satellites there.

The law currently isn't on the side of a collective solution to space junk. Even if an out-of-control satellite is heading towards one that's functioning and worth billions of dollars, international agreements forbid action to remove it without the owner's permission, even if a space drone could intervene and take it to the graveyard orbit.

By repairing, repurposing or recycling satellites and space junk at a facility in Earth's orbit, this material could help build future spacecraft or exploration outposts, like a base on the moon. Using what's already floating around up there means there are no launch costs and using those resources will reduce space junk. It's the equivalent of building a home in the UK from local materials rather than importing bricks from Australia.

Recycling satellites could provide not just raw materials for more construction in space, but a revenue stream to fund it. Research showed that at an orbit 150km further out than GEO, Gateway Earth would have access to the whole of GEO. From there whole satellites could be taken by space drones into the floating recycling centre for a tune-up if needed.

Providing these services could bring in over USD$8 billion per year, but the space laws that would govern this work are outdated and need revising. Luckily, this is something the UN is already working on, and our members are working with them to overcome barriers.

If these satellites are no longer serviceable, the shell could be used for other purposes. Some of the recycled materials from space junk could be ground down and used to 3D print radiation shielding for Gateway Earth. Studies have shown the efficiency of solar panels from disused satellites only drops to about 24% after 15 years, so these could be gathered and used to power the station.

Some of the most advanced cameras ever built are in space. These could be refitted onto Gateway Earth or new satellites to scan space for asteroids that could collide with Earth. As the business of deploying and using satellites is set to grow at a phenomenal rate, having an outpost in orbit that can manage all of them will become vital.

Gateway Earth has plans to generate further revenue in future by acting as a space hotel, a satellite and spacecraft construction facility and a fuelling hub for spacecraft travelling between planets. We need a space equivalent for the plastics wake-up call that people heard from Blue Planet II. There is still time, but plans for cleaning up Earth's orbit need to be acted on now. Over the next 10 years, 150 new GEO satellites are planned which will increase the risk of collision significantly.

REVIEW OF LITERATURE

HISTORY

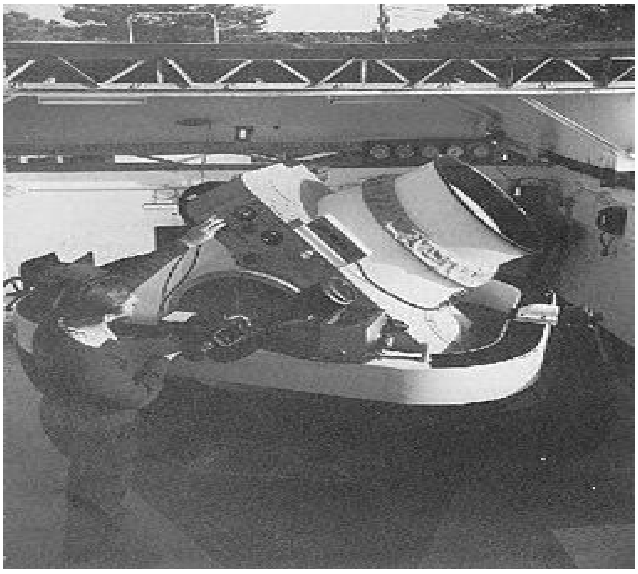
In the first half of the twentieth century, before man-made objects were launched into space, some scientists suggested that the space around the Earth might be littered with undetectably small chunks of natural debris that could hinder manned spaceflight.

The Soviet Union launched Sputnik 1, the first artificial satellite, into orbit on October 2, 1957.

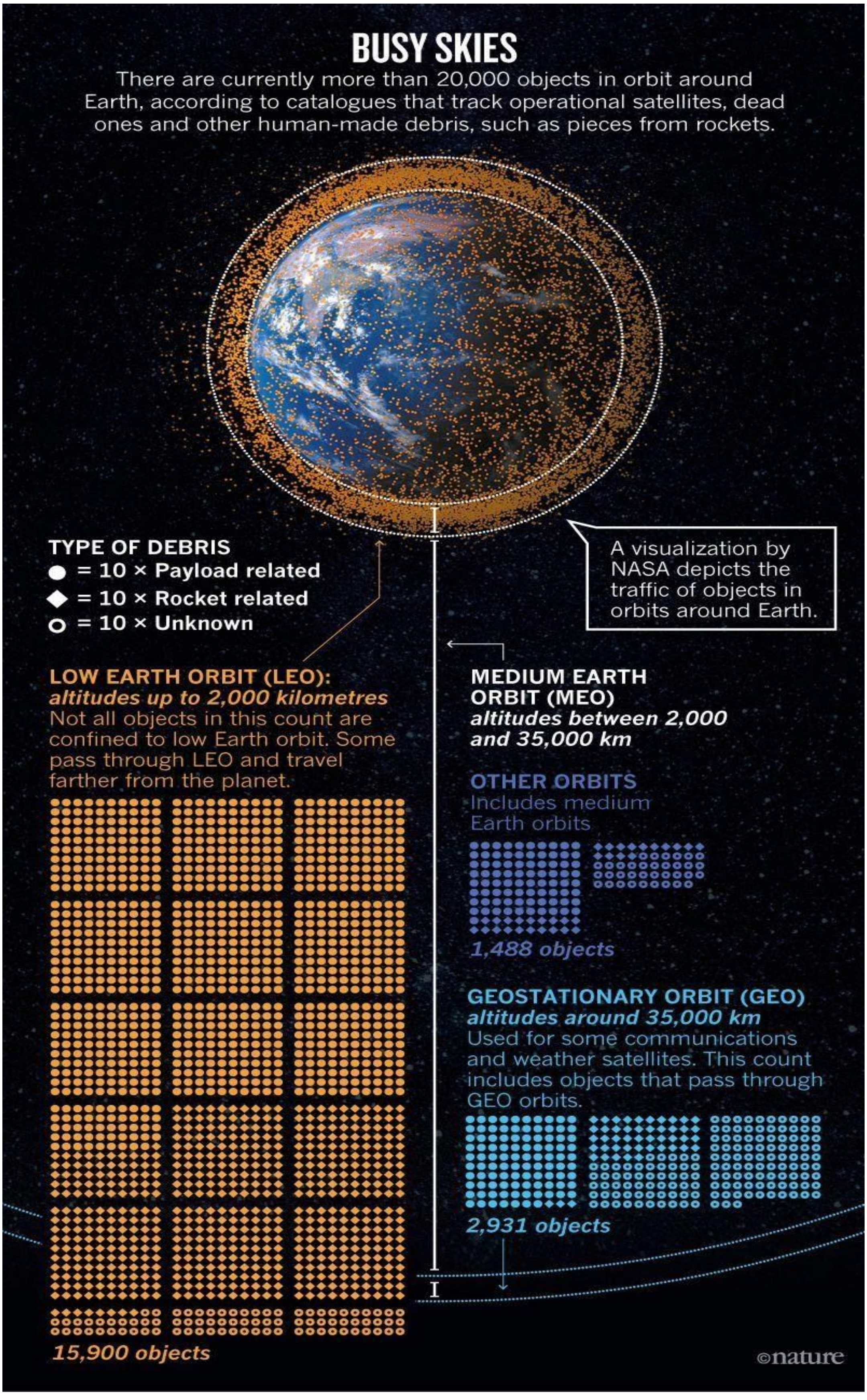
Sputnik 1 did not start the accumulation of space debris the world now faces. The core stage of its launch rocket remained in orbit only two months, and the satellite itself burned up on atmospheric re-entry a month later. However, the long-term problem began to grow soon afterward. Vanguard 1, the second satellite launched by the United States, was placed in orbit in March 1958 and stopped radio transmissions six years later; but the 1.47 kg (3.25 lb) satellite is still in medium-Earth orbit (MEO) and is expected to remain so for nearly 200 more years. Its elliptical orbit ranges from 654 km (406 mi) to 3,969 km (2,466 mi) above the Earth.[5] Two other Vanguard satellites, launched in 1959, are inactive but remain in similar orbits. Since they are no longer operational, they are categorized as space debris.

The North American Aerospace Defense Command (NORAD) began compiling a database (the Space Object Catalog) of all known rocket launches and objects reaching orbit: satellites, protective shields and upper- and lower-stage booster rockets.

In addition to approaches to debris reduction where time and natural gravitational/atmospheric effects help to clear space debris, or a variety of technological approaches that have been proposed (with most not implemented) to reduce space debris, a number of scholars have observed that institutional factors—political, legal, economic and cultural "rules of the game"—are the greatest impediment to the cleanup of near-Earth space. By 2014, there was little commercial incentive to reduce space debris, since the cost of dealing with it is not assigned to the entity producing it, but rather falls on all users of the space environment, and really on human society as a whole that benefits from space technologies and knowledge. A number of suggestions for improving institutions so as to increase the incentives to reduce space debris have been made. These include government mandates to create incentives, as well as companies coming to see economic benefit to reducing debris more aggressively than existing government standard practices. In 1979 NASA founded the Orbital Debris Program to research mitigation measures for space debris in Earth orbit.



Baker-Nunn Camera were widely used to study space debris.


BUSY SKIES
There are currently more than 20,000 objects in orbit around Earth, according to catalogues that track operational satellites, dead ones and other human-made debris, such as pieces from rockets.
TYPE OF DEBRIS
= 10 × Payload related
= 10 × Rocket related
= 10 × Unknown
A visualization by NASA depicts the traffic of objects in orbits around Earth.
LOW EARTH ORBIT (LEO):
altitudes up to 2,000 kilometres
Not all objects in this count are confined to low Earth orbit. Some pass through LEO and travel farther from the planet.
15,900 objects
MEDIUM EARTH ORBIT (MEO)
altitudes between 2,000 and 35,000 km
OTHER ORBITS
Includes medium Earth orbits
1,488 objects
GEOSTATIONARY ORBIT (GEO)
altitudes around 35,000 km
Used for some communications and weather satellites. This count includes objects that pass through GEO orbits.
2,931 objects
©nature

GROWTH OF DEBRIS

Space debris has been increasing rapidly since the start of the Space Age, which began in 1957 .Only in the last 15 years has the international community recognized this increase as a growing threat to satellites. During that time, space-faring countries have developed a set of guidelines intended to limit the production of debris.
According to the most recent numbers released by the Space Debris Office at the European Space Operations Center (ESOC), about **5450** launches have taken place since *Sputnik 1* was launched into space - excluding failed launches.

On top of all that, it is estimated that more than **500** break-ups, explosions, or collisions haven taken place in the past sixty years. Over time, this has led to the current situation in Low Earth Orbit (LEO), which is littered with space debris.

These objects pose a significant threat to operational satellites, spacecraft, and space stations. At present, roughly **22,300** of these objects are regularly tracked and cataloged by the U.S. Department of Defense's Space Surveillance Network (SSN).

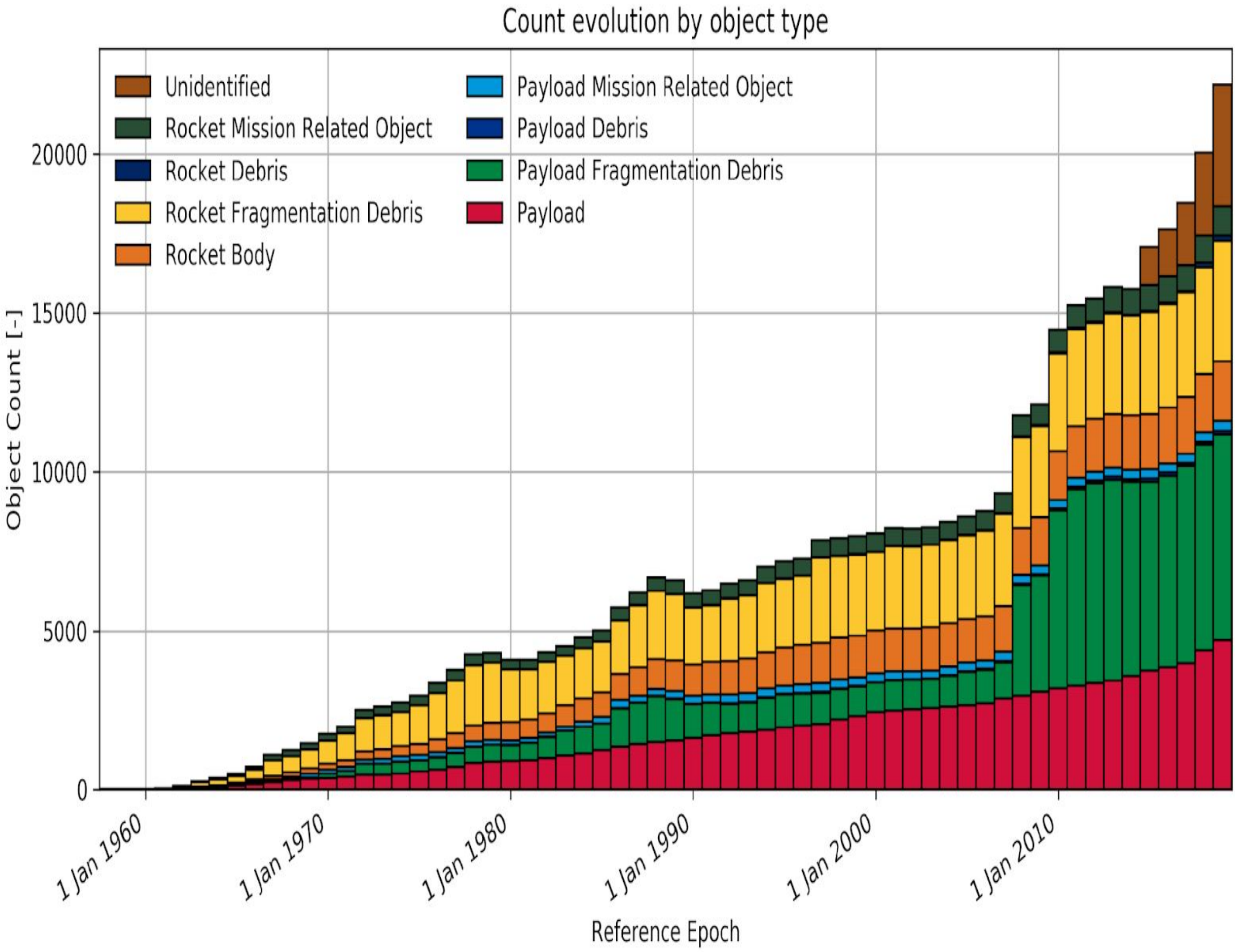
However, these are just the objects that are large enough to be tracked by ground-based radar. All told, there are an estimated **34,000** objects in orbit that measure about **10 cm (4 in)** in diameter, another **900,000** objects that measure between **1 cm (0.39 in)** and **10 cm**, and a whopping **128 million** objects that measure between **1 mm** and **1 cm**.

While these last objects might sound underwhelming, even the tiniest objects can pose a severe collision hazard. This is due to the velocity of objects in orbit, which can get as high as **7** or **8 km per second (4.3 to 5 mps)**, which works out to about **12875 km/h (8,000 mph)**.

At these speeds, even small flecks of matter can cause serious damage to satellites, spacecraft or space stations. However, the biggest danger in having so much debris in orbit is the way it can become increasingly worse over time all on its own.

- As of 2009, 19,000 debris over 5 cm (2 in) were tracked.

- As of July 2013, estimates of more than 170 million debris smaller than 1 cm (0.4 in), about 670,000 debris 1–10 cm, and approximately 29,000 larger pieces of debris are in orbit.
- As of July 2016, nearly 18,000 artificial objects are orbiting above Earth, including 1,419 operational satellites.
- As of October 2019, nearly 20,000 artificial objects in orbit above the Earth, including 2,218 operational satellites.



SIZE

There are estimated to be over 128 million pieces of debris smaller than 1 cm (0.39 in) as of January 2019. There are approximately 900,000 pieces from one to ten cm. The current count of large debris (defined as 10 cm across or larger) is 34,000.The technical measurement cutoff is c. 3 mm (0.12 in). Over 98 percent of the 1,900 tons of debris in low Earth orbit as of 2002 was accounted for by about 1,500 objects, each over 100 kg (220 lb). Total mass is mostly constant despite addition of many smaller objects, since they reenter the atmosphere sooner. There were 9,000 pieces of orbiting junk identified in 2008, with an estimated mass of 5,500 t (12,100,000 lb).

Orbital debris source	Size range	How observed	Primary instrument (United States)	Estimated number on-orbit (2006AD)
Payloads and rocket bodies past end-of-life	> 5 cm	Tracked and cataloged	SSN radars	3600
Mission-related	< 1 m	Tracked and cataloged	SSN radars	1270
Fragments of on-orbit explosions and collisions	< 1 m	Tracked and cataloged, < 10 cm observed statistically	SSN radars, Haystack & HAX radars	> 1,000,000
Sodium potassium coolant droplets	~ 1 mm to 5 cm	Observed statistically	Haystack & HAX radars	~55,000
Solid rocket motor char, slag, and dust	~ 100 μm to 5 cm	Observed statistically	Returned surfaces*, ground-based tests	unknown
Ejecta and paint flakes (degradation products)	< 1 mm	Observed statistically	Returned surfaces*	unknown
Meteoroids	< 1 cm	Observed statistically	Returned surfaces*, ground-based optical and radar measurements	unknown

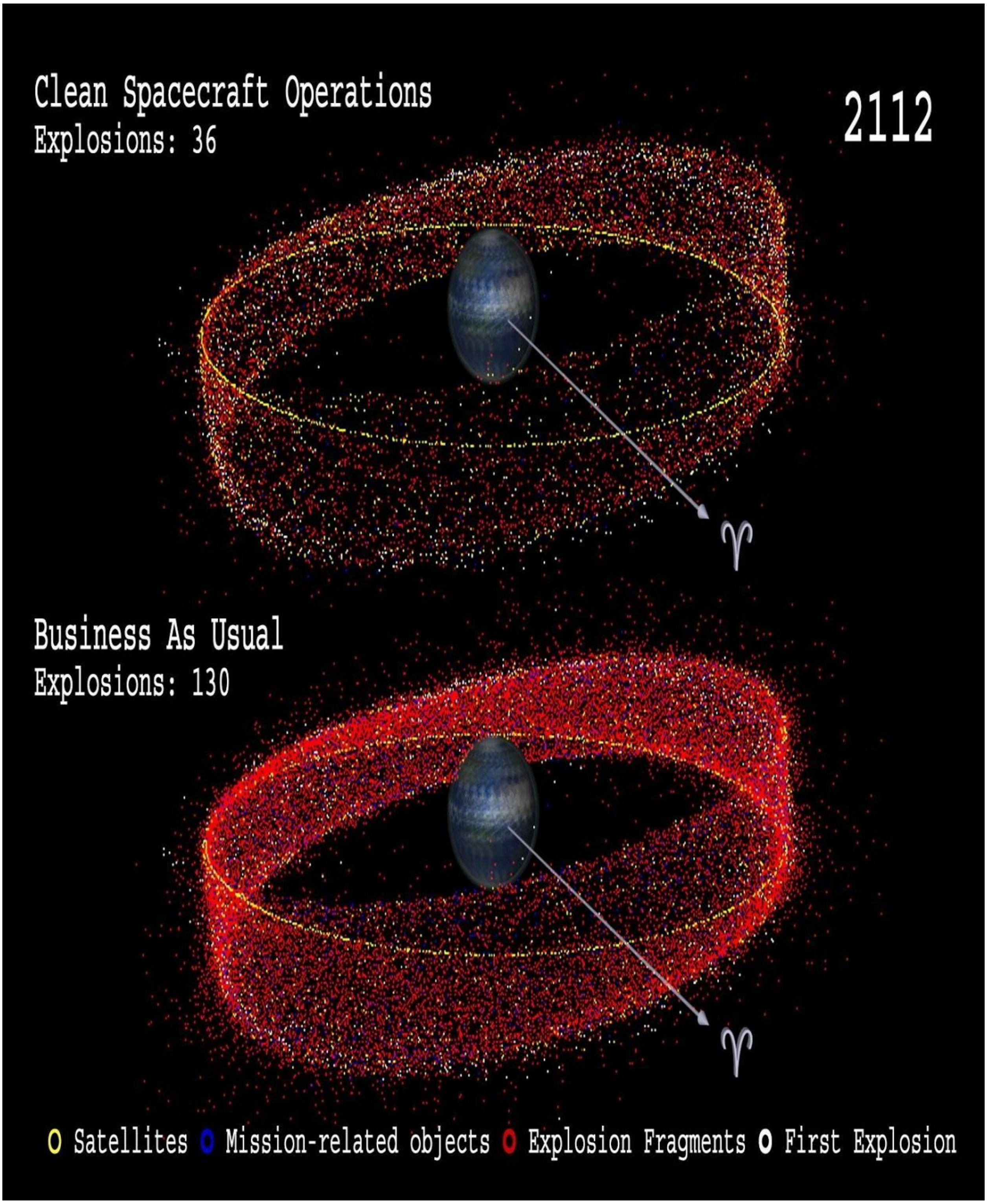
* Space shuttle, ISS module, HST solar panels, Eureka & LDEF surfaces

The Causes of Space Debris

A major contributor to orbital debris has been object breakup. As of August 2007, there have been 194 breakups and 51 events in which debris was shed from an object. Since that data compilation, many more are believed to have occurred. Breakups can be caused by explosions and collisions. Explosions can result from residual propellant, overheated batteries, collisions, or in some cases, deliberate destruction of the satellite. The cause of approximately 22% of observed breakups is unknown.

Two events in recent years have greatly increased the amount of debris on orbit. In 2009, the active U.S. Iridium 33 satellite collided with the defunct Russian Kosmos 2251 satellite, creating about 2,000 tracked objects. In 2007, the Chinese deliberately destroyed their own FY-1C satellite in a test of an antisatellite weapon, creating more than 3,000 tracked objects. (The tracked objects represent only a small fraction of the debris objects created by that event.)

Approximately 70,000 objects about 2 cm in size have been observed in the 850 to 1,000-km altitude band above Earth. NASA has hypothesized that these objects are frozen bits of nuclear reactor coolant leaking from several Russian RORSATs (Radar Ocean Reconnaissance Satellite).


Clean Spacecraft Operations
Explosions: 36
2112
Business As Usual
Explosions: 130
Satellites
Mission-related objects
Explosion Fragments
First Explosion

EARTH ORBITALS

There are two main orbits that satellites exist in. Low Earth Orbit (LEO) is about 200 km to 1,000 km above the Earth and is where the International Space Station orbits the planet every 90 minutes, along with thousands of other satellites. At 36,000 km, the forces acting on satellites cause them to stay in the same place within their orbit. This is called Geostationary Earth Orbit (GEO). Satellites here are stationary above a single point on Earth, making them useful for weather forecasting and communications.

LEO is very crowded, and there is a risk of collisions here which could create a shower of debris so wide it collides with other satellites, creating more and more debris in a chain reaction. Eventually the entire orbit could become so full of debris it's unusable. A lot of debris already litters LEO, but technology is being developed and tested to remove it.

It is theorized that a sufficiently large collision of spacecraft could potentially lead to a cascade effect, or even make some particular low Earth orbits effectively unusable for long term use by orbiting satellites, a phenomenon known as the Kessler syndrome.The theoretical effect is projected to be a theoretical runaway chain reaction of collisions that could occur, exponentially increasing the number and density of space debris in low-Earth orbit, and has been hypothesized to ensue beyond some critical density.

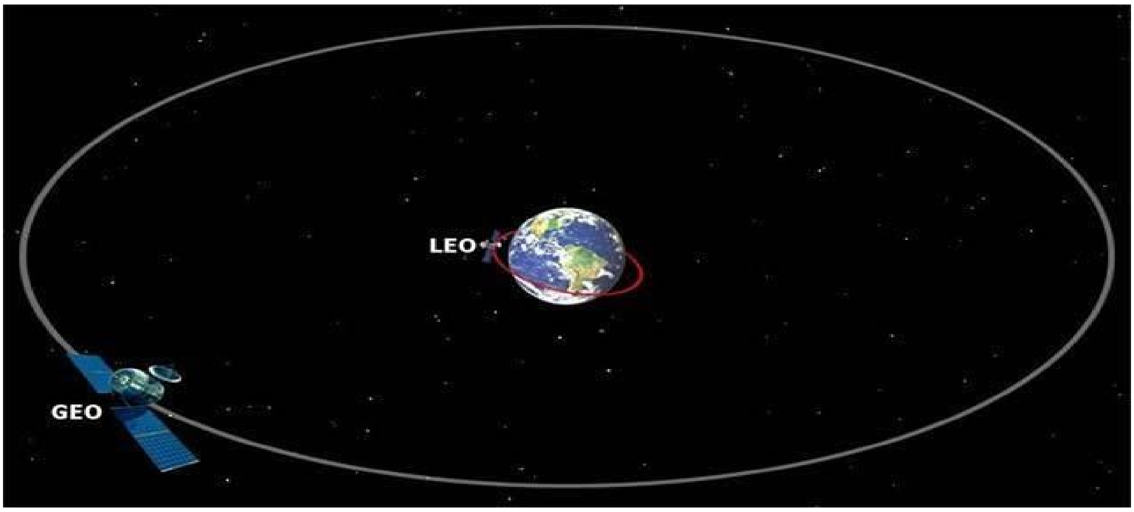
Crewed space missions are mostly at 400 km (250 mi) altitude and below, where air drag helps clear zones of fragments. The upper atmosphere is not a fixed density at any particular orbital altitude; it varies as a result of atmospheric tides and expands or contracts over longer time periods as a result of space weather.

In GEO, when a satellite comes towards the end of its life, the owners will attempt to put it in a higher "graveyard" orbit where it's left to drift about 300 km to 400 km away from an internationally agreed protection zone. But only about 80% of all satellites that reach the end of their life in GEO actually make it to the graveyard orbit. The other 20% need dealing with as a matter of urgency – and that's where a recycling facility in space could help.

Many communications satellites are in geostationary orbits (GEO), clustering over specific targets and sharing the same orbital path. Although velocities are low between GEO objects, when a satellite becomes derelict (such as Telstar 401) it assumes a geosynchronous orbit; its orbital inclination increases about .8° and its speed increases about 100 miles per hour (160 km/h) per year. Impact velocity peaks at about 1.5 km/s (0.93 mi/s). Orbital perturbations cause longitude drift of the inoperable spacecraft and precession of the orbital plane. Close approaches (within 50 meters) are estimated at one per year. The collision debris pose less short-term risk than from an LEO collision, but the satellite would likely become inoperable. Large objects, such as solar-power satellites, are especially vulnerable to collisions.

Although the ITU now requires proof a satellite can be moved out of its orbital slot at the end of its lifespan, studies suggest this is insufficient. Since GEO orbit is too distant to accurately measure objects under 1 m (3 ft 3 in), the nature of the problem is not well known. Satellites could be moved to empty spots in GEO, requiring less maneuvring and making it easier to predict future motion. Satellites or boosters in other orbits, especially stranded in geostationary transfer orbit, are an additional concern due to their typically high crossing velocity.

Despite efforts to reduce risk, spacecraft collisions have occurred.



A HAZARD TO HUMAN

Although most debris burns up in the atmosphere, larger debris objects can reach the ground intact. According to NASA, an average of one cataloged piece of debris has fallen back to Earth each day for the past 50 years. Despite their size, there has been no significant property damage from the debris.

Notable examples of space junk falling to Earth and impacting human life include:

I. 1969: five sailors on a Japanese ship were injured by space debris.
II. 1997: an Oklahoma woman, Lottie Williams, was injured when she was hit in the shoulder by a 10 cm × 13 cm (3.9 in × 5.1 in) piece of blackened, woven metallic material confirmed as part of the propellant tank of a Delta II rocket which launched a U.S. Air Force satellite the year before.
III. 2001: a Star 48 Payload Assist Module (PAM-D) rocket upper stage re-entered the atmosphere after a "catastrophic orbital decay" crashing in the Saudi Arabian desert. It was identified as the upper-stage rocket for NAVSTAR 32, a GPS satellite launched in 1993.
IV. 2003: Columbia disaster, large parts of the spacecraft reached the ground and entire equipment systems remained intact. More than 83,000 pieces, along with the remains of the six astronauts, were recovered in an area from three to 10 miles around Hemphill in Sabine County, Texas. More pieces were found in a line from west Texas to east Louisiana, with the westernmost piece found in Littlefield, TX and the easternmost found southwest of Mora, Louisiana. Debris was found in Texas, Arkansas and Louisiana. In a rare case of property damage, a foot-long metal bracket smashed through the roof of a dentist office.NASA warned the public to avoid contact with the debris because of the possible presence of hazardous chemicals. 15 years after the failure, people were still sending in pieces with the most recent, as of February 2018, found in the spring of 2017.

V.2007: airborne debris from a Russian spy satellite was seen by the pilot of a LAN Airlines Airbus A340 carrying 270 passengers whilst flying over the Pacific Ocean between Santiago and Auckland. The debris was reported within 9.3 kilometres (5 nmi) of the aircraft.

Researchers have estimated that about 80 tons of space debris re-enters Earth's atmosphere each year, but again, most of that debris will burn up in the atmosphere or fall to Earth without anyone noticing. Unfortunately, just because something burns up doesn't mean that it disappears. The intense heat caused by friction may break down these pieces of debris and melt them, but the compositional chemicals are still being released into the atmosphere. Some composite metals and polymers actually consume ozone when they push back through the atmosphere and burn up, experiencing chemical reactions that produce nitric oxide, which can deplete ozone.

Fortunately, our planet is quite large, and space is absolutely massive, so even with that many pieces of debris crashing back into Earth's atmosphere every year, the impact that it currently has on the environment in negligible. The activities of mankind on the planet have a far more negative effect on the ozone and climate change than a few thousand small impacts of small pieces of space junk.

Some people fear that a satellite may fall from the sky and land on their house, but frankly, the odds of anything falling from space and striking a person are astronomical. In the six decades since we began launching things into space, there has only been ONE recorded incident of a person being struck by falling debris.

- In future there's a possibility that the space debris can accumulate a vast portion of the orbits causing the orbits to block every activity.

THE KESSLER SYNDROME

The Kessler Syndrome is a theory proposed by NASA scientist Donald J. Kessler in 1978, used to describe a self-sustaining cascading collision of space debris in LEO. It's the idea that two colliding objects in space generate more debris that then collides with other objects, creating even more shrapnel and litter until the entirety of LEO is an impassable array of super swift stuff. At that point, any entering satellite would face unprecedented risks of headfirst bombardment.

Matter in orbit travels at ridiculously high speeds, like… 22,000km/h, just as an example. If this matter were to travel in the same plane and direction indefinitely, it would be impossible for any matter to collide, like cars going straight on a highway at the same speed, never endeavoring to switch lanes or get off on an exit.

But in space, uncontrolled objects do not follow a straight path. Instead, each piece of debris is subject to drift and decay. The variation in Earth's gravitation field causes drift, or the gradual movement of an object to a different orbital plane. The friction of an object with Earth's atmosphere causes decay, or the slow decrease in an object's altitude.

Kessler's Syndrome refers to a cascading effect of colliding debris creating additional debris and additional collisions.

The Kessler Syndrome is bad news because impacts between objects of sizable mass can cause significant damage to 'useful' objects that are present in LEO. Not only that, but the resulting debris cascade could also make it extremely difficult to launch satellites in the LEO in a way that they wouldn't be hit by flying debris. Finally, the long-term viability of new satellites in the LEO would become decidedly low.

SOURCES OF DEBRIS

A. Big bangs in Earth orbit

The majority of space debris occurred because of explosions in higher orbits. Mission designers carry extra fuel on board in case it is unexpectedly needed. This extra fuel is stored in pressurized tanks once the rocket stage is discarded. When leaks occur sudden explosive release of pressure takes place due to each explosion thousands of small debris objects and about hundred tones of fragments are generated which are still in the orbit. This debris collides with other objects leading to creation of even more small space debris.

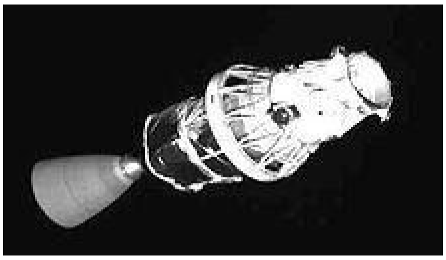
B. Lost Equipment

Debris is also caused during space-walks. For example Sunita Williams of STS-116 lost a camera during extra-vehicular activity(EVA) . Lost equipments include garbage bag, gloves, tool kits etc. Lost equipment is one of the key sources of growing debris in space. We have to minimize this to as small as possible during the space walks.

C. Boosters

Lower stages, like the solid rocket boosters of the Space Shuttle, or like the Saturn IB stage of the Apollo program era, do not reach orbital velocities and do not add to the mass load in orbit. Upper stages, like the Inertial upper stage, start and end their productive lives in orbit.

Boosters remain a serious debris problem and one of the major known impact events was due to an Ariane booster .



Booster

D. Debris from and as a weapon

One major source of debris in the past was the testing of anti-satellite weapons carried out by both the U.S. and Soviet Union in the 1960s and '70s. The NORAD element files only contained data for Soviet tests, and it was not until much later that debris from U.S. tests was identified. By the time the problem with debris was understood, widespread ASAT testing had ended. The U.S.'s only active weapon, Program 437, was shut down in 1975 .

FINDINGS

One way to potentially reduce these hazards, and the costs and risks of launching new satellites, would be to build and launch an on-orbit recycling system. Notionally, the system would have the ability to vaporize small existing space debris; recycle and recover manufacturing materials from existing satellites; and even perform in-space manufacturing of structural elements for new satellites.

- **Bringing the Sun into Focus**

In its basic form, the recycler would include a large parabolic reflector, perhaps 50 to 100 feet in diameter; a spherical crucible made of material with an extremely high melting point; a set of compartments in which different types of salvaged materials could be stored; and several robotic

Space Junk Recycler (Northrop Grumman Artist Concept) arms for capturing "dead" satellites or other space debris.

The recycler's reflector would concentrate solar energy into a small spherical space, creating an intense source of heat. The heat could be used either to simply vaporize existing small debris, or to heat larger pieces of space debris in the recycler's crucible. The crucible could be rotated through the thermal flux like a rotisserie grill to heat the debris to a desired and uniform temperature.

Using this approach, explains Eller, we could selectively melt and capture material of type A, heat the crucible more to melt and capture material of type B and so on.

Materials melted and captured at each stage of the recycling process could be stored in separate compartments in the form of ingots, or perhaps piped in real time to another part of the recycler as source material for in-space manufacturing operations. Any unneeded leftovers from the recycling process could be compressed into small pieces and vaporized by the solar concentrator.

There could also be self-sustaining aspect to this recycler, adds Eller. If the mirrored surface of the solar concentrator became contaminated, the recycler could vaporize a piece of scrap aluminum in such a way that material is deposited as a new thin and highly reflective layer on the mirror, effectively recoating it was said by him .

Scavenging the Graveyard

An ideal source of dead satellites for the recycler would be so-called "graveyard" orbits several hundred kilometers above geosynchronous (22,500 miles) altitude. Satellites are typically safe-d (batteries drained, propellant tanks emptied) and placed in a graveyard orbit at the end of their operational lives to reduce the chance of colliding with an operational spacecraft.

According to Eller, a recycler could either be placed in a relatively fixed location in orbit where dead satellites could be brought for recycling, or the entire facility could maneuver from satellite to satellite in a graveyard orbit. In theory, an in-space 3-D manufacturing facility could be attached to the other end of the recycler. As old satellites are ingested (think PacMan) and converted to raw materials, new satellite structures would be produced and pushed out the other end for in-space assembly.

Smarter, Lighter, Cheaper Space recycler captures “dead” satellite (Northrop Grumman artist concept)

The ability to perform on-orbit recycling and manufacturing could also enable a new generation of simpler, lighter and potentially more capable satellite systems. Free from the impact of gravitational forces during launch, satellites could be assembled in space using simpler designs and materials with far less mass and structural strength. As a result, they might look very different from traditional spacecraft buses, which are essentially boxes with one or more solar array appendages.

If we built a satellite in space, it could be a single panel of any desired length explains Eller. One side could be an array of RF [radio frequency] elements and electronics, like a single large circuit board. You could produce additional panels to serve as solar arrays, or perhaps attach solar cells to the back of the original panel.

After building this “panelsat” in orbit, you could plug in a module launched from Earth containing all of the electronic components that are currently too difficult to produce in space.

Working the Vision

In the end, admits Eller, space recycling is a vision that should be driven by economics. It makes perfect sense to recycle existing satellites because they are made of the materials most often needed to make new satellites. That’s why we should develop this or similar concepts as a nation. If we can figure out a way to convert dead satellites from a waste product into an economic benefit, recycling in space will happen.

- **DARPA (PHOENIX PROGRAM)**

The United States Department of Defense is looking for ways to repurpose space junk thousands of miles above Earth back into valuable satellite parts, or even completely new spacecraft.

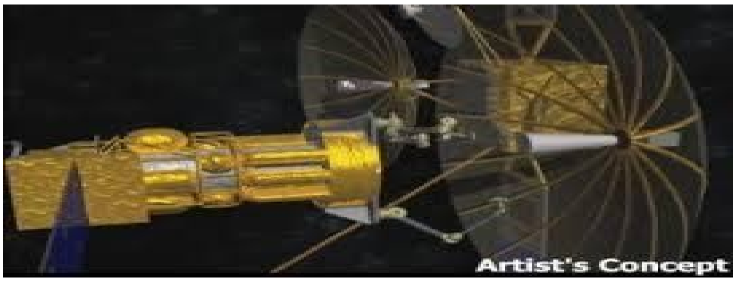
The military's Defense Advanced Research Projects Agency (DARPA) has started a program called Phoenix, which seeks to recycle still-functioning pieces of defunct satellites and incorporate them into new space systems on the cheap.

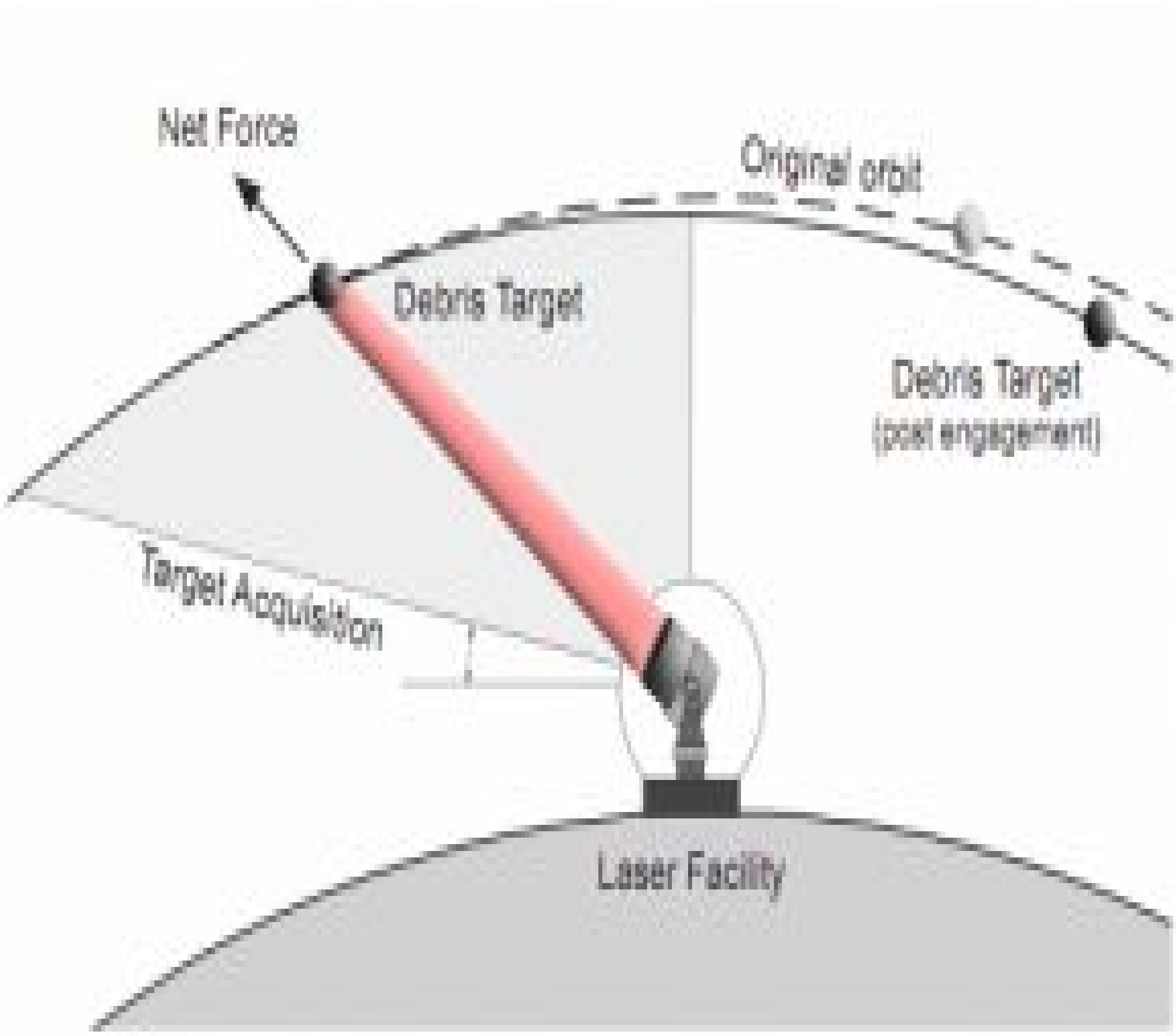
The Phoenix program aims to use a robot mechanic-like vehicle to snag still-working antennas from the many retired and dead satellites in geosynchronous orbit — about 22,000 miles (35,406 kilometers) above Earth — and attach them to smaller "satlets," or nanosatellites, launched from Earth.

If this program is successful, space debris becomes space resource, was said by DARPA director Regina Dugan said in a statement.

The Phoenix program envisions launching a "tender" vehicle, the mechanic-like satellite servicing system, into geosynchronous orbit. The tender would be equipped with grasping mechanical arms and remote vision systems. The satlets would then be launched separately as extra payloads hitching rides into space aboard other satellites.

The tender vehicle would cruise over to a satlet, pluck it out of its housing and ferry it to the appropriate defunct satellite. The tender would then switch the antenna over from the retired satellite to the satlet, creating a "new," and relatively cheap, satellite using previously useless space junk.



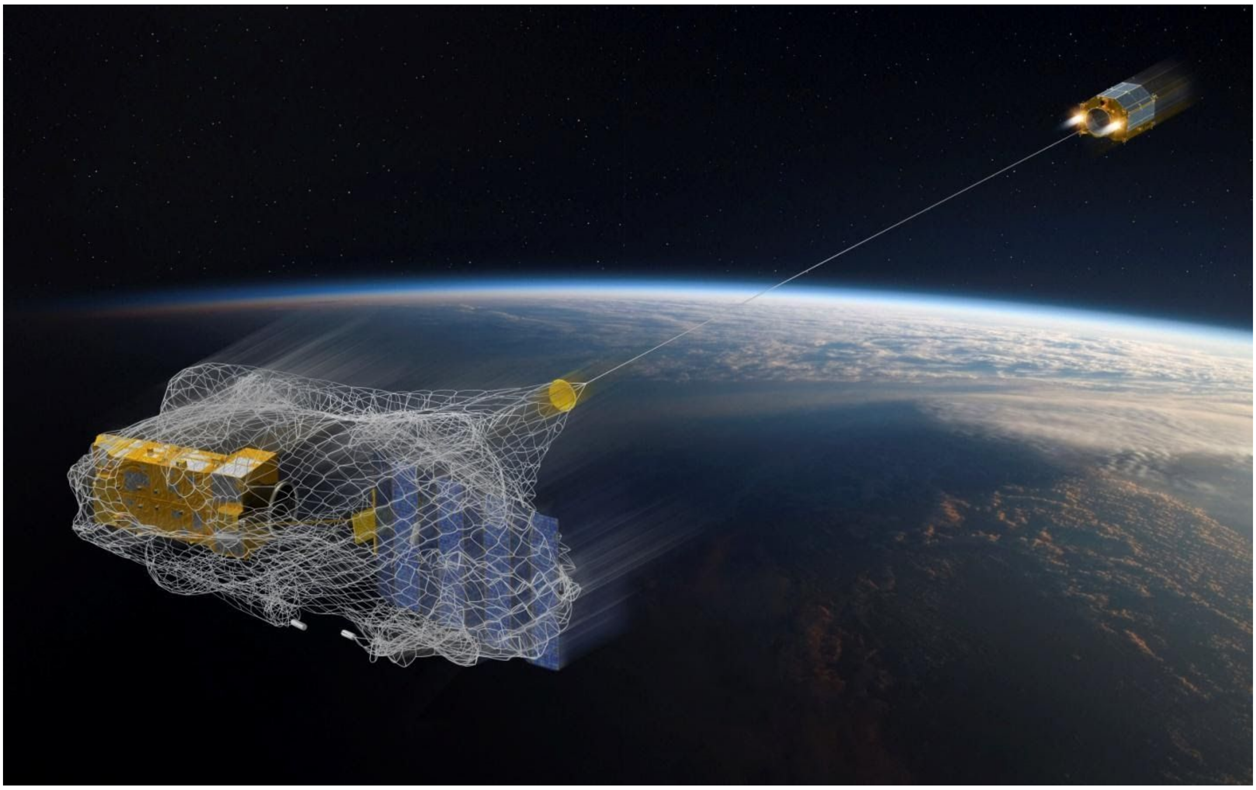


REMOVE DEBRIS PROGRAM

The RemoveDebris experiment, a program launch by the University of Surrey in the U.K., is making steady progress towards a simple design that may just work: a fleet of space whaler craft. By using both nets and harpoons to capture space debris, Remove Debris slows the speed of the objects until they drop out of orbit: a simple, yet effective approach to reducing large chunks of debris.

The project is also experimenting with Radio Frequency Identification Devices (RFID) systems that will be used by “chaser ships” to mark debris for removal. After tagging, a space junk harvester will be deployed to harpoon and return the debris to Earth.

The RemoveDebris team has worked to test their system on Earth, and last month, the first test was carried out in space. Space.com hosted the following video from the project showing the test of their net system, which caught a piece of space debris without causing it to break up.



- **THE CLEARSPACE-1**

The ClearSpace-1 mission will target the Vespa (Vega Secondary Payload Adapter) upper stage left in an approximately 800 km by 660 km altitude orbit after the second flight of ESA's Vega launcher back in 2013. With a mass of 100 kg, the Vespa is close in size to a small satellite, while its relatively simple shape and sturdy construction make it a suitable first goal, before progressing to larger, more challenging captures by follow-up missions – eventually including multi-object capture.

The ClearSpace-1 'chaser' will be launched into a lower 500-km orbit for commissioning and critical tests before being raised to the target orbit for rendezvous and capture using a quartet of robotic arms under ESA supervision. The combined chaser plus Vespa will then be deorbited to burn up in the atmosphere.

ClearSpace-1 will be the first space mission to remove an item of debris from orbit, planned for launch in 2025. The mission is being procured as a service contract with a startup-led commercial consortium, to help establish a new market for in-orbit servicing, as well as debris removal.

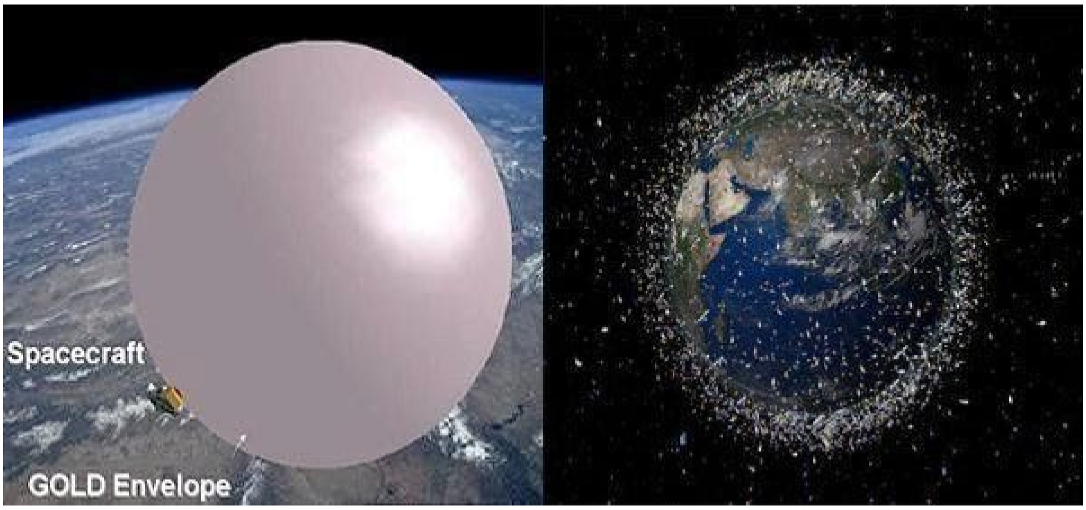
NASA and ESA studies show that the only way to stabilise the orbital environment is to actively remove large debris items. Accordingly we will be continuing our development of essential guidance, navigation and control technologies and rendezvous and capture methods through a new project called Active Debris Removal/ In-Orbit Servicing – ADRIOS.

The results will be applied to ClearSpace-1. This new mission, implemented by an ESA project team, will allow us to demonstrate these technologies, achieving a world first in the process.


©2013 ESA-CNES-ARIANESPACE / Optique vidéo du CSG - P BAUDON

- **SPACE BALLOONS**

The Gossamer Orbit Lowering Device, or GOLD system, uses an ultra-thin balloon (thinner than a plastic sandwich bag), which is inflated with gas to the size of a football field and then attached to large pieces of space debris. The GOLD balloon will increase the drag of objects enough so that the space junk will enter the earth's atmosphere and burn up. If the system works, it could speed up the re-entry of some objects from a couple hundred years to just a few months.

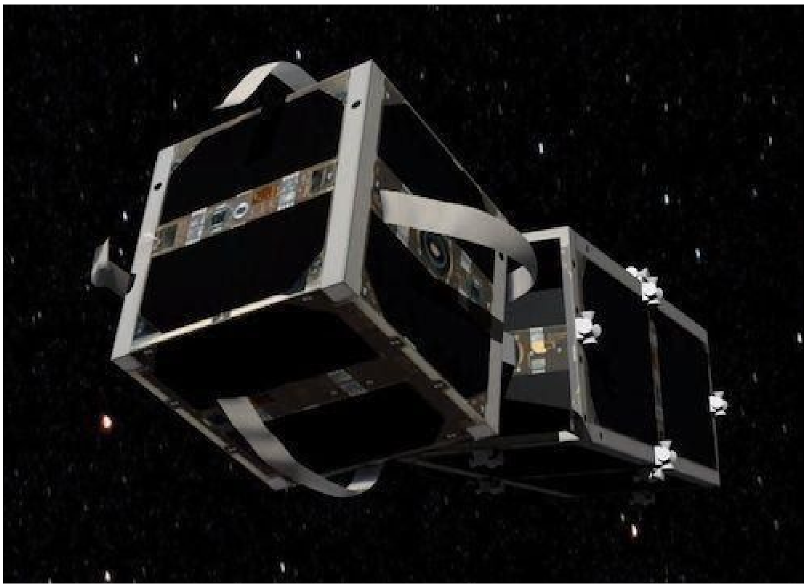


- **GIANT LASERS**

Using high-powered pulsed lasers based on Earth to create plasma jets on space debris could cause them to slow down slightly and to then re-enter and either burn up in the atmosphere or fall into the oceans. The method is called Laser Orbital Debris Removal (LODR) and it wouldn't require new technology to be developed - it would use laser technology that has been around for 15 years. It would be relatively cheap, and readily available.The biggest hitch, other than adding more litter to the oceans, is the estimated $1 million per object price tag.

- **SELF DESTRUCTING JAINTORS**

Swiss researchers at the Federal Institute of Technology have devised a small satellite, called CleanSpace One, which could find and then grab onto space junk with jellyfish-like tentacles. The device would then plummet back towards Earth, where both the satellite and the space debris would be destroyed during the heat and friction of re-entry.

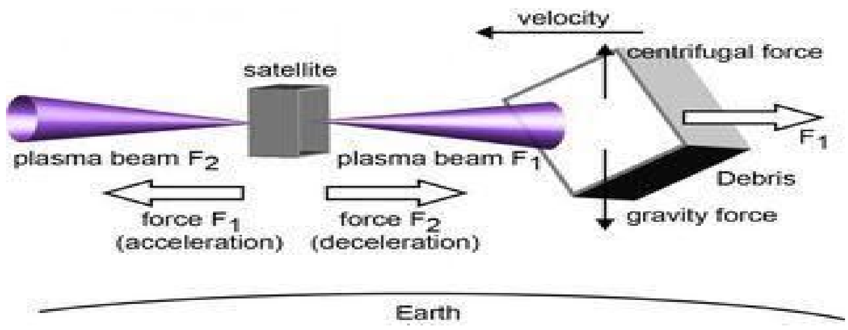


- **STICKY BLOOM**

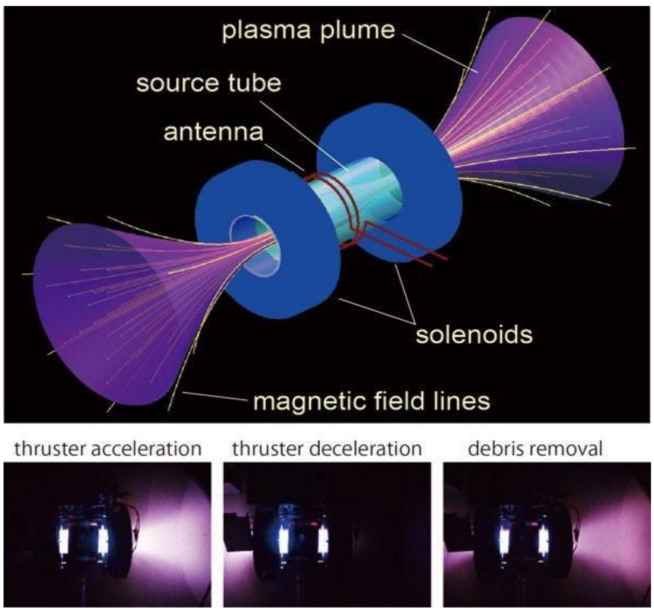
Altius Space Machines is currently developing a robotic arm system it calls a "sticky boom", which can extend up to 100 meters, and uses electroadhesion to induce electrostatic charges onto any material (metal, plastics, glass, even asteroids) it comes into contact with, and then clamp onto the object because of the difference in charges. The sticky boom can attach to any space object, even if it was not designed to be grappled by a robotic arm. The sticky boom could be used to latch onto space debris for disposal.

Spacecraft with Plasma Beams to Force Space Junk to Burn Up

The Japanese-Australian team is developing a system that solves these problems with a unique bi-directional plasma beam arrangement. The two beams can counteract each other, with one keeping the shepherd satellite in position, and the other directing the junk toward Earth. A single power source powers the two beams, and the satellite aims the beams as required.



Lab tests have clearly demonstrated that a helicon plasma thruster can remove space debris with a single propulsion system. The lab experiments, magnetic fields and gas injections control the plasma plumes from the single plasma thruster. Laboratory tests measured the force applied to the simulated space junk. The system applied the exact amount of counterforce to the satellite to keep it in position. The system operates in three different modes: satellite acceleration, satellite deceleration, and debris removal.



METHODOLOGY

Every space debris specialist will agree that it is crucial to determine which orbital region is the most sensitive and what are the most dangerous items of debris. Their threat is usually accounted for in terms of collision/explosion probabilities (polluting potential), potential damage to active spacecraft and risk of causing casualties on the ground. The literature shows increasing consideration for ‘indexes’ for space debris. These indicators measure the level of threat according to several characteristics.

Take any debris as an example; when a collision occurs, the result is a cloud of debris in which the amount of smaller elements depends on the mass of the object. Hence, there is an increase in the debris density (flux) around the impact point. The polluted area may contain active satellites that contribute to a lot of different applications on Earth or in space: in other words assets that are creating economic value thanks to the information they provide to users. Economic theory has recently seen a surge of interest in the value of information as a way to quantify non-monetary value. Moreover, it is also helpful in quantifying heterogeneous economic variables.

By combining all values it is possible to build a comparative valueless index:

$$\text{Value} = \alpha Sj + \beta Cj + \gamma \pi j$$

$\{\alpha, \beta, \gamma\}$ are determined following a singular value decomposition method and applied to all satellites in the data set.

After this process and considering the post-collisional dispersion of a cloud within 10 years, it is possible to measure the impact of a single piece of debris. The ‘Steve Index’, SI, is a combination of the expected number of debris I_P.M, the total mass of other debris I^deb ; and the total value of active assets I^sat ; in the cloud range.

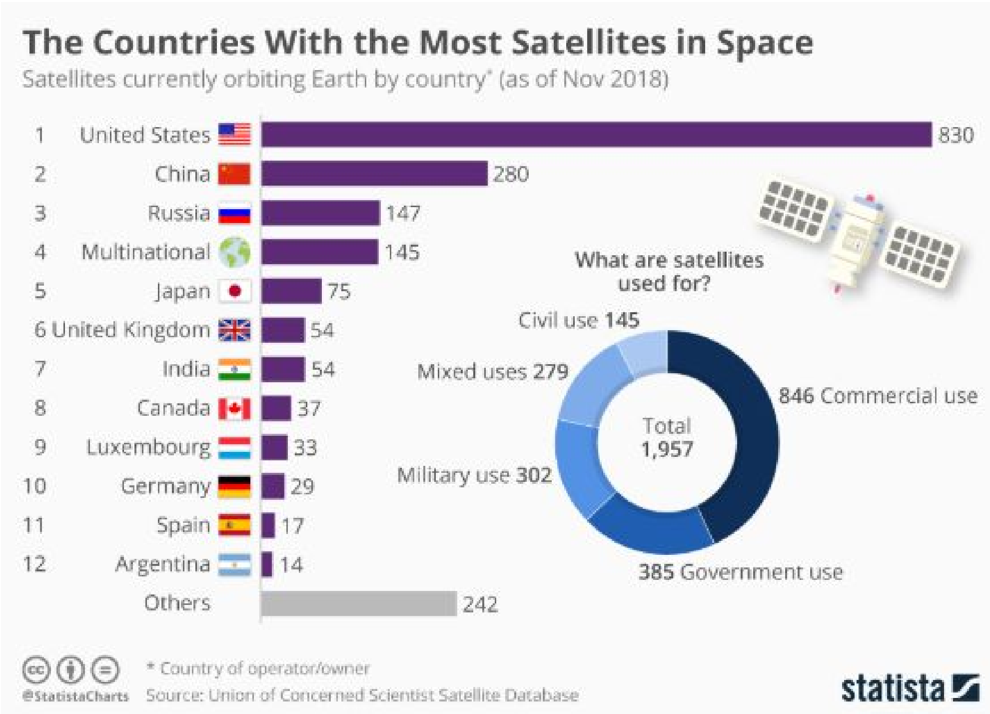
$$SI = \left(\frac{I^{deb}}{\bar{I}^{deb}} + x \times \frac{I^{sat}}{\bar{I}^{sat}}\right) \times \frac{I_{P.M}}{\bar{I}_{P.M}}$$

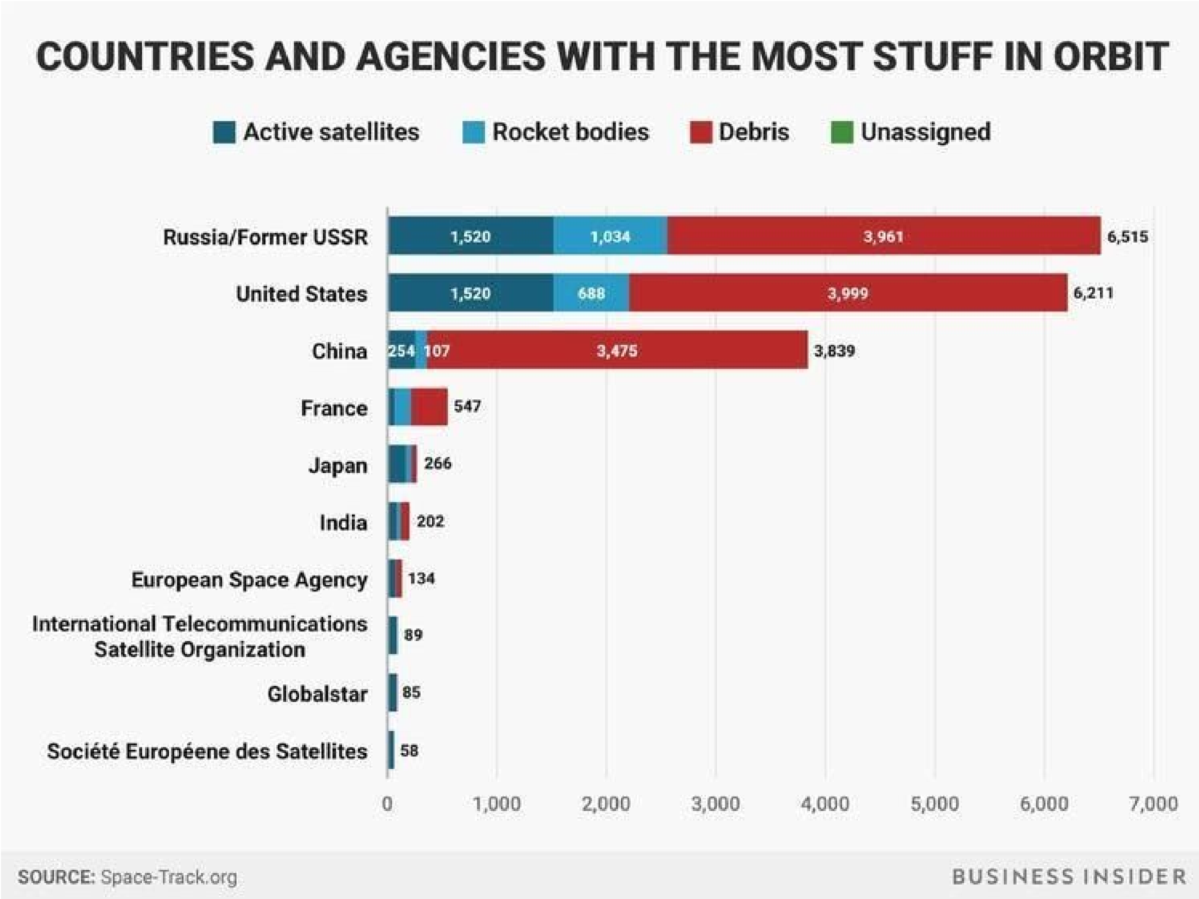
To illustrate how this model works, let’s take an example involving a heavy spacecraft with a mass of over eight tones in the SSO region. If a collision occurs the resulting cloud would have an impact on the orbit:

The blue is getting lighter and lighter further away from the debris-causing spacecraft’s position, illustrating the decreasing added density caused by the debris production. All the objects inside the ellipsoid will suffer from an increased risk of collision due to the increased debris density. In this case the spacecraft is threatening 33% of the total mass of debris (thus possibly increasing the amount of debris further due to inter-debris collisions) and 23% of the total value of the active satellites (for the given data). Removing this potential source of debris would not only improve the quality of the orbital region and lower risk for the surrounding objects but also reduce the total mass of objects is the SSO region. Deorbiting the satellite would represent a reduction of 12% of the sum of the expected number of debris.

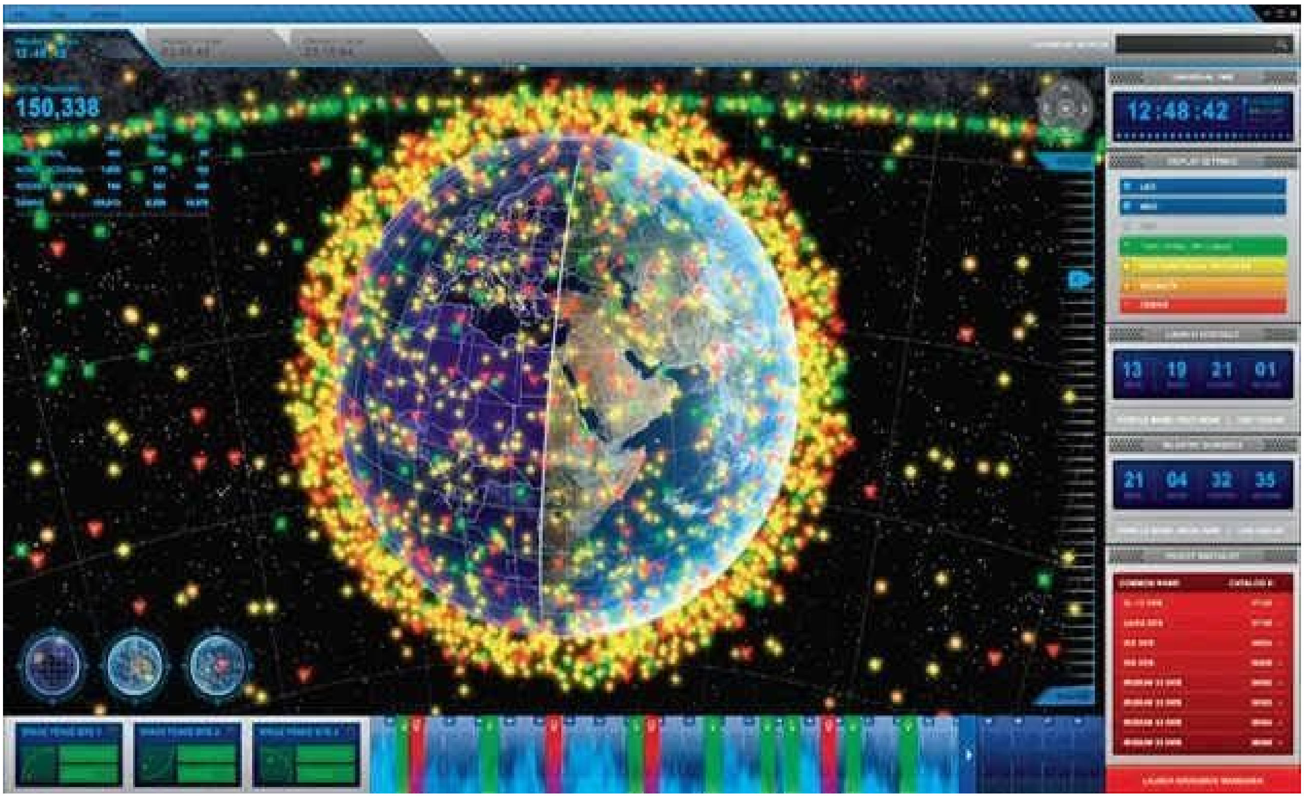
It is clear that Earth orbits are a common pool resource that will not be excluded from tragic depletion if behaviours do not change in the near future. Stabilising the production of debris begins with compliance to mitigation guidelines proposed by international agencies and must be followed by active debris removal to deorbit the most dangerous and influential debris items. This is why it is important to define properly the resource we are exploiting and quantify externalities in order to make space a sustainable environment.

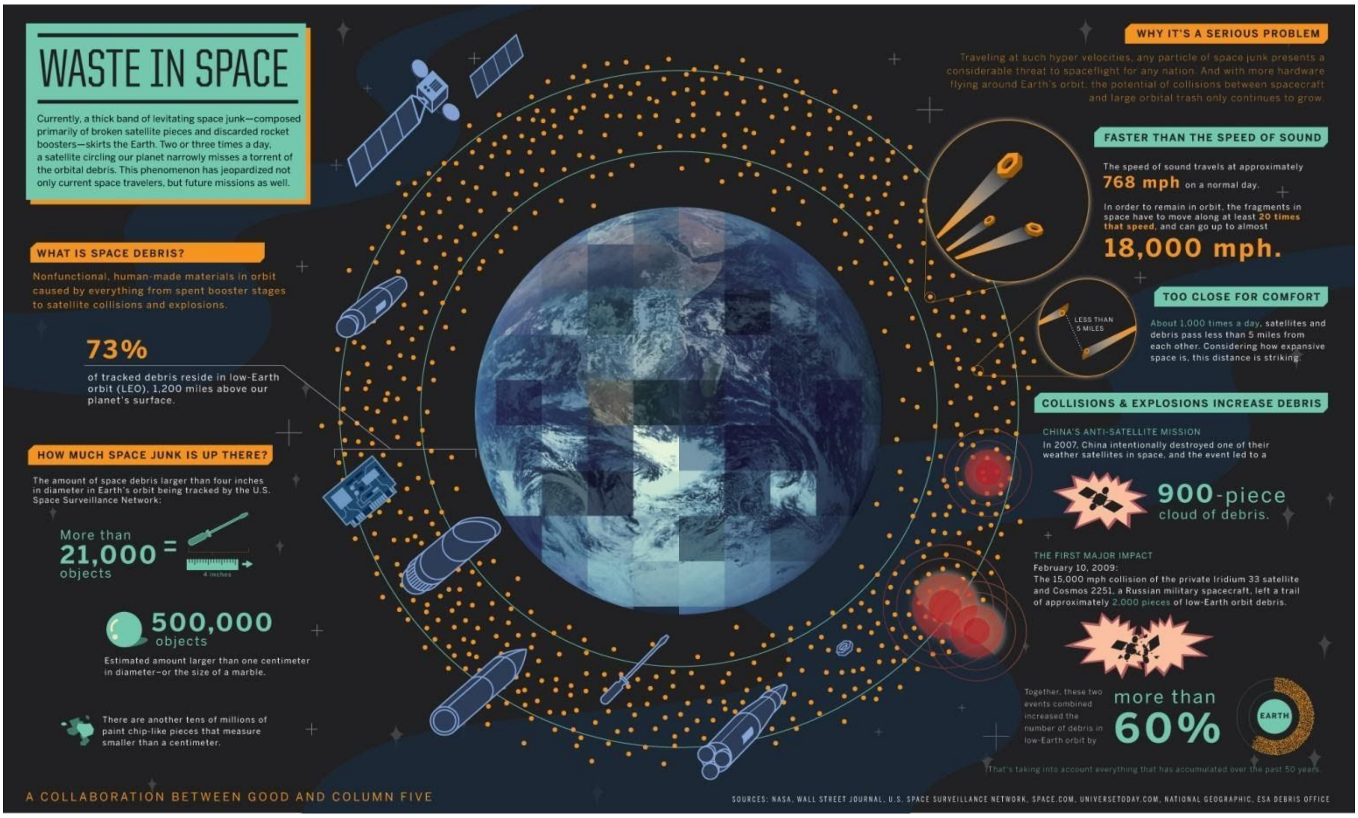
REPORT





A picture from economic times of space debris





Waste in space –The final Junkyard

FACTS ABOUT SPACE WASTE

1: On February 6th, 2018, Elon Musk and his company SpaceX launched the first car into space. Elon's personal Tesla Roadster is on an infinite loop of David Bowie's "Space Oddity." You can even track its location here.

2: In 2007, China deliberately destroyed one of their weather satellites to test a new weapon. That test contributed to over 3,000 pieces of space debris — the largest ever tracked.

3: A piece of space debris can reach speeds of 4.3 to 5 miles **per second**. That's nearly 7 times faster than a bullet and just about the equivalent of being hit by a bowling ball moving at 300 miles per hour.

4: There are about 4,700 satellites still in space, but only an approximate 1,800 are still working.

5: Donald Kessler, a NASA scientist, imagined what is now known as "Kessler Syndrome" in which he theorized that continuous collisions of man-made objects in space will potentially destroy telecommunications and keep humanity trapped on Earth.

6: On February 10, 2009, a privately owned American communication satellite, Iridium-33, accidentally crashed into a Russian military satellite, Kosmos 2251, marking the first ever accidental in-orbit collision.

7: In one year, the International Space Station had to coordinate three shifts in position to avoid disastrous collisions with space debris, a feat that requires days of effort.

8: In 1998, one satellite failed and more than 90% of all the pagers in the world stopped working, a sneak peek of the consequences that space debris could have if it collides with our technology.

9: According to the National Oceanic and Atmospheric Administration, an average total between 200 – 400 tracked space debris enter Earth's atmosphere every year.
10: Most of the debris burns up upon reentry, but if it doesn't, don't worry! Your chances of getting hit by a falling piece of space waste is 10 million times smaller than the annual odds of being struck by lightning.

11: Scientists in Beijing, China are working on a way to turn orbital waste into fuel by turning debris into a plasma of positive ions and electrons through high temperatures. Just picture the DeLorean in "Back to the Future."

12: The U.S. Air Force is working on a program called Space Fence to help track the current amount of debris in orbit and extend a "virtual fence" around the planet.

13: The U.S. government logged 655 "emergency-reportable" alerts to satellite operators for potential collisions with space debris.

14: In September of 2018, scientists successfully tested a net to help snag orbiting debris and burn it in Earth's atmosphere.

DISCUSSION

Humans filled waterways, landfills, and streets with trash, so it’s no surprise the same thing happened in Earth’s orbital neighborhood. Now our species will finally take a crack at cleaning up. Some missions focus on dead satellites, aiming to catch them with robotic arms, spear them with harpoons, or slow them with sails or tethers. Others aim for smaller places with lasers or stick for them with adhesive. It’s all an effort to keeping low-Earth orbit, the region up to 1,200 miles from the surface usable. “Keeping all this litter in space. It’s like litter on the floor,” was said by Jason Forsha, a research fellow at the University of Surrey. “It’s becoming more of a risk.”

The next few missions are Remove Space junk from Britain, on which Forshaw is one of the lead scientists; Japan’s just-launched Kounotori 6 satellite, carrying the KounotoriIntegrated Tether Experiment; and e.Deorbit from the ESA. Even the private sector is getting into the act: Japanese startup Astroscale is designing a space junk-removal satellite.

RemoveDebris is planned for 2017, while Astroscale plans to launch in 2018. e.Deorbit’s flight is scheduled for 2023 or 2024. Low-Earth orbit is certainly crowded. There are currently about 780 satellites in the region as of mid-2016, with more planned all the time, according to the Union of Concerned Scientists. The satellites share the area with about 500,000 pieces of junk a half inch across and larger, according to NASA estimates. Paint chips, pieces of blown-up satellites, spent rocket stages it’s all there. Since everything moves at thousands of miles an hour,a paperclip can smack into a satellite with more energy than a heavy machine gun round. In

April, a micrometer-sized piece of space junk put a half-inch pit in an ISS window, even though the station orbits well below the majority of the junk.The ISS shielding is limited to objects less than about a half an inch across.NASA, working with the Department of Defense;Space Surveillance Network, can track anything larger than about two inches, which covers about 21,000 objects. There’s a gap between what they are shielding for and what they can track, was said by Gene Stansberry, program director of NASA’s orbital space junk office. While the new missions are testing ways to pick up junk, technology isn't the main reason we haven't already got a United Galaxy Sanitation Patrol.

Salvage rules don't apply in space, says Brian Weeden, technical advisor at the Secure World Foundation and author of several studies of space junk.The launching state has jurisdiction and control.And yes, that means you have to get their permission to interact with a piece of space junk

Liability is another complication; officially the launching state is responsible for anything that happens. The liability provisions of various international agreements simply haven't been invoked, largely because proving fault in space is time consuming and costly. Other countries facing a private party may feel differently. Imagine I'm company X and I touch a satellite and it explodes, and six months later it hits someone else's satellites,was said by Weeden . That could involve any of a dozen spacefaring nations.

These legal wrinkles are one reason governments would rather have anin stitution like the University of Surrey back a mission, which at 15 million euros is cheap, Forshaw said. RemoveDebris will go after whole satellites, because tracking small objects and targeting them (to say nothing of determining a fragment's owner) is harder. Using cubesats, small satellites that can be fit together like Lego bricks, it will test three technologies for bringing satellites down: a net, a harpoon, and a sail — two of which would work in tandem.

For the net, a cubesat will launch from the ISS and inflate a balloon. A second cubesat will follow and fire a net to grab the inflated satellite. The inflated satellite should fall back to Earth as the slight atmospheric drag causes it to slow down. In a real deployment, the net would likely have a tether line attached to the firing satellite, which would tug on the target spacecraft to create even more drag. The harpoon will test one satellites ability to target and hit another — an important point if the aforementioned net is going to scale. In this case a cubesat will extend a target on an arm, and another will fire the harpoon. Last is the dragsail, in which a cubesat deploys a huge sail like a parachute. The increased drag will, again, bring down the satellite.

Deorbit is after bigger fish. The target is the ENVISAT, a 8-ton remote monitoring satellite launched in 2002. The ESA hasn't settled on a design yet; it is considering either a robotic arm which would grab the satellite, or a net. In the meantime the agency wants to demonstrate tracking, guidance, and capture technologies to see what will work best.

Some technologies will use the magnetic field of the Earth itself to get the satellites down; that's the aim of JAXA's Kounotori Integrated Tether Experiment. The craft will trail a long conductive cable, and run current through it. As satellites and cables pass through the Earth's magnetic field, the interaction of the field and current generates a small force on the tether. (This is the same way electric motors work). The tests will occur in January, as the KITE ship is currently docked with the ISS doing double duty as a supply run.

All three missions are geared toward sending satellites plummeting to a watery graveyard in the South Pacific, east of New Zealand.For hunting smaller pieces, Astroscale plans is to launch a satellite called ELSA-1, that will track space junk and stick to it with glue. Other more out-there proposals include using ISS- or satellite-mounted lasers to vaporize the surfaces of small pieces and force them down, but that will take more technical development of the lasers so they could maximize the amount of energy delivered to the space junk.

One reason there are so many methods is there's little or no data on what might work — it's largely uncharted territory. Forshaw says there's still a possibility that it's "back to the drawing board" if they fail. Satellite rendezvouses, for example are not trivial,and aiming what amounts to a gun at another satellite at close range adds more complexity. It's not unlike the early days of aviation or automobiles, when engineers tried all kinds of designs before settling on a few that worked best.

No matter which technology proves itself, space junk isn't going away. Even if launches ceased tomorrow, the problem could persist for a couple of centuries and even get worse, according to a 2008 NASA study. In 2009 a Russian military communications satellite and an Iridium collided and scattered space junk, threatening some Chinese satellites; two years later the ISS also had to dodge the shrapnel. New launches — at least those licensed in the US, Japan, and Europe — are required to have a plan for getting a satellite down when it's at the end of its life. Forshaw, however, calls the mitigation a welcome step. People have been talking about space junk since the 1960s. But until now nobody has actually funded missions to study and deal with it.

CONCLUSION

As discussed in the above report space debris has an ever growing impact on spaceflight and travel. If new ways to avoid the creation of space debris or to start removing the amount of debris in the environment are not created, space travel will be faced with a serious obstacle.

As we have seen space debris has become a crucial topic in recent years as well as a topic of great concern. It could be understood that the space debris creation cannot be stopped completely but by adopting various measures could be taken to minimize space debris.

As we have gone through many methods of space debris mitigation have been proposed earlier by many space experts, but some of them have limitation in them, but with some modification to those plans or measures it can be proved beneficial in the process of space debris mitigation, some new methods we have proposed including

(1)DARPA‘s Phoenix is Defence Advance Research Project Agency of United States defence department, which is only looking at the reduction of cost and risk of Launching communication satellites into earth‘s orbit by instead removing and revising antennas from retired spacecrafts from the space, but the question comes to our mind is that what about the other parts of the spacecraft?

(2)Clean Space One is the concept which is think is the one of the recommended way to remove the space debris for the Outer space of the Earth, as this particular satellite will throw debris into Earth‘s atmosphere to burns up on re-entry, ok it could be thought that this could be happen when this so called Clean Space One will be Launched in 2018 using a three stage process involving a A300 jetliner, but is there a possibility that once the debris are thrown in the earth‘s orbit will burn?

(3)Earth based Lasers have been suggested by those scientist who work in NASA they talk about the Lasers which could be installed on the ground and it could be used to push debris in orbit, which could help move dangerous space junk away from satellites and space crafts, could you think this could be the solution?

We have already polluted our planet Earth, we should take care and ensure that the space should be kept least polluted for our safe exploration of outer space and with the same interest for our coming Generations also.

REFERENCES

- http://www.spaceacademy.net.au/watch/debris/debris.html

Tohoku University Press Release: Plasma Thruster: New Space Debris Removal Technology

- Research Paper at Nature.com: Demonstrating a new technology for space debris removal using a bi-directional plasma thruster

- 9-concepts-cleaning-space-junk.html

- www.theverge.com

- www.iflscience.com

- www.wired.co.uk

- www.brightcove.com

- www.digitaltrends.com
- bigthink.com

- www.themarketforideas.com
- www.sciencedirect.com
- www.esa.int

- theconversation.com
- earth911.com
- blogs.voanews.com
- www.scienceabc.com
- science.howstuffworks.com
- www.theguardian.com
- www.nap.edu
- theconversation.com
- "Space Junk Cleanup Needed, NASA Experts Warn."
- https://www.space.com/topics/space-junk
- Images- Recycle space debris