Review on Space Debris Clean up mission and proposed methods to tackle it.

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ABSTRACT: Technology has many pros and cons. Humans have reached to other Planets and are exploring new heights of success in science and technology. But we have also polluted space as we have polluted our mother Earth. So far, we were not considering this as an important and immediate problem but now the time has come that we look into this matter deeply and come to a proper solution to eliminate slowly and steadily as many Debris from space as possible. To eliminate a space debris object from its orbit, many techniques have been proposed. This paper summarises the different proposed methods of cleaning space junk like. It also proposes that a special satellite is to be built which can have more than one technique to remove debris from space having lifetime of more than 30-35 years which can reduce the cost of the mission along with space junk.

Key Words: Space junk, debris, multi technique satellites.

I. INTRODUCTION:

Aerospace missions are at a greater risks nowadays because of increasing population of space debris. Orbital debris comprises human-generated objects like pieces of space craft, leftover rocket boosters, parts of rockets, defunct satellites, or explosions of objects in orbit flying around in space at high speeds. There are millions of small and medium sized pieces of junk flying in Low Earth Orbit (LEO) with an average high speed around 17000-18000 miles per hour. Due to the number of debris and their high speed, future exploration work and space properties which are worth several million dollars are at higher risk along with the safety of the ISS members.

Till today there are no international space laws in action to clean up debris in LEO. LEO is now termed as a drifting island of plastic. It's expensive to remove space debris from LEO because the problem of space junk is beyond our imagination as there are 128 million pieces of space debris in outer space of size 1mm, 34,000 larger pieces of size over 10 cm. There is approximately 6,000 tons of materials in low Earth orbit.

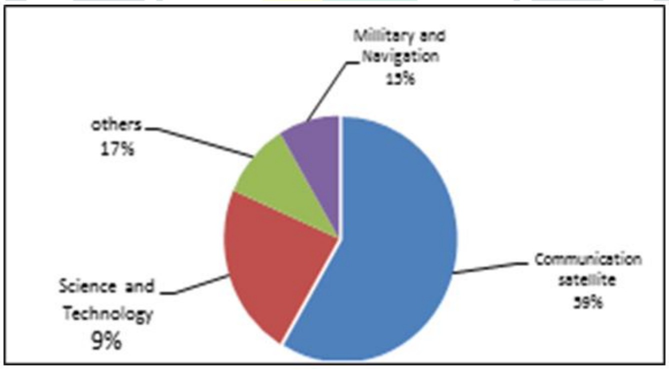

Figure 1: Satellites used in various areas.

Country wise	Orbit wise
United States: 901	LEO: 1,338
Russia: 153	MEO: 125
China: 299	Elliptical: 45
Other: 709	GEO: 554

Table 1: Countrywise and orbitwise satellites Countrywise and orbitwise sattelites in different orbits

Debris	1 to 10 cm	Less than 10 cm
LEO Debris	400000	14000
Debris at all altitudes	750000	24000
Total	1150000	38000

Table 2: Total number of debris in orbit with sizes

The above tables give us the figures of sattelites in LEO,MEO and GEO. In addition to this, it also gives the number of space debris of different sizes and the total number of debris around Earth as reported by NASA.

Presently around 950 satellites are operating in our earth orbit and there are three major areas or orbit holding these satellites.

- Low earth orbit (LEO): 300 to 2,000 km altitude, 7 to 8 km/s orbital speed, 1.5 - 3 hour period.
- Semi-synchronous: 20,000 km altitude, 4 km/s orbital speed, Navigation satellites, 12 hour period.
- Geosynchronous: 36,000 km altitude, 3 km/s orbital speed, Communication or broadcast satellites, 24 hours period.

II. SPACE DEBRIS GROWTH OVER THE YEARS:

On 4th October 1957, Sputnik 1 was launched in the orbit for the first time. Ever since thousands of space missions have been carried out. Lives of every individual depend on applications which turned out to be important and strategically for climate, telecommunications, localization, security and military and defence, science and technology. As a result, for more than 65 years different space agencies have been launching spacecraft into Low Earth orbit (LEO)or in GEO, which has become a quite serious problem now.

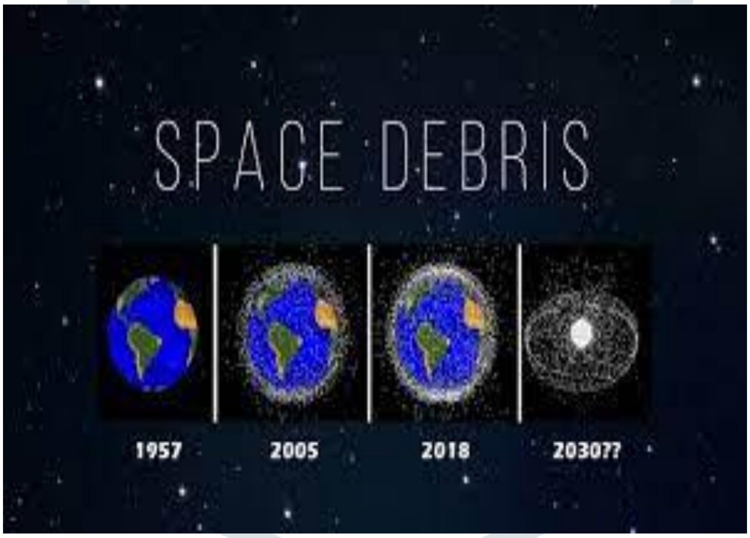

Fig 2: Year by year space debris count.

In between 1957 and 2018, approximately 4600 launches have made satellite count around 6000 into space. Orbital debris are man-made objects that are left in space because of various reasons. Space debris is not consistently distributed on the entire space definitely they move into the more common launch target regions like LEO, MEO or GEO.

This graph describes an overview of entire essence in Earth orbit listed by the US Space Surveillance Network (USSN). “Fragmentation debris” is the satellite and spacecraft fragments, small parts and junks present in space numbered in millions. The Earth orbit is an exceeding predicament by cluster parts of active space debris.

Space track of earth satellite population by 4th July 2018 represents space debris classification. There are about 52.96% breakup debris ,2.3% anomalous debris, 10.5% rocket bodies, 24.4% payloads and 10.4% mission related debris etc.

United States has launched maximum number of operating satellites till 2019. Basically, a greater number of satellite launch for commercial purpose in elliptical orbit. Orbit wise LEO regions have maximum number of operating satellites are 1,338. As of March 2019, total numbers of satellites are 2,062.

This graph shows increasing concentration of space junk year by year as shared by NASA.

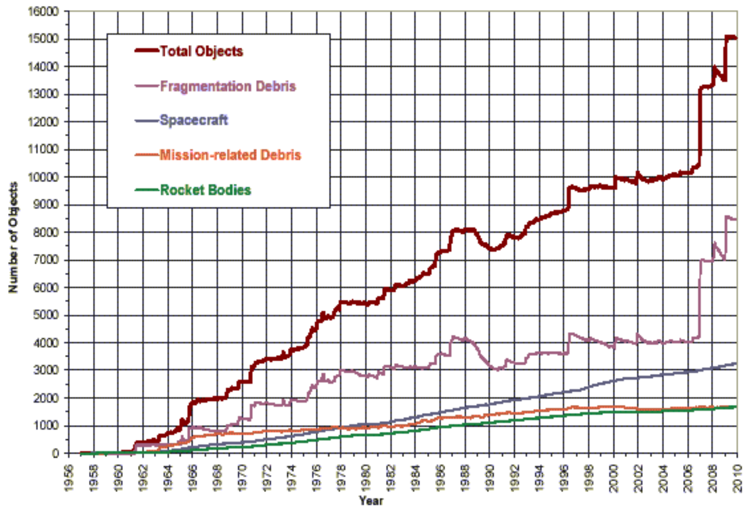

Figure 3: Evaluation of Number of Objects in Space over the Last 60 Years (NASA Orbital Debris, Quarterly News May 2019)

II.I SPACE DEBRIS REMOVAL REFERENCE SCENARIO:

Recent research confirmed that space debris is becoming more and more dangerous issue for upcoming outer space missions. Several research studies pointed that the number of objects in orbit might grow in numbers and there is a possibility of collisions by fragments produced by other collisions. This feedback collision consequence was first time introduced by Kessler and Coeur Palais in 1978.

- 1960-1996: The growth is almost linear at a rate of 260 debris per years.
- 1996-2006: The growth is approximately linear, most likely due to execution of debris mitigation.
- 2006-2010: two impact events created more than 1250 debris per year.
- 2006-2019: the growth is increased rapidly more than 2,062 debris per year.

Risk of collision in orbit generate various consequences: it not only becomes a problem of safety but also a commercial risk which is associated with the damage of active satellites which are useful or fundamental in our day to day lives. There were some collisions in past few years. For example, in 2009, a US commercial Iridium satellite smashed into an inactive Russian communications satellite called Cosmos-2251, which created thousands of new pieces of space shrapnel. In 2015 when a piece of a defunct Russian satellite was traveling at the speed of eight miles per second caused three ISS crew members to take emergency shelter in the Soyuz capsule.
The most recent event happened in 2020 September when ISS astronauts had to do an "avoidance manoeuver" to get out of the way of a wanton piece of celestial junk. So far there have been recorded 750,000 individual pieces larger than one centimetre. The risk of debris collisions could prohibit future human and robotic space missions.

III. ACTIVE SPACE DEBRIS REMOVAL METHODS

There are various space debris removal concepts such as JAXA's electro-dynamic tether method, ESA's drag augmentation method, solar sail propulsion method and Texas A.M University's slingshot method.

Active removal is often additional efficient in terms of the number of collisions prevented versus objects removed once the subsequent principles are applied for the choice of removal targets which may be used to generate a criticality index and therefore listed accordingly.

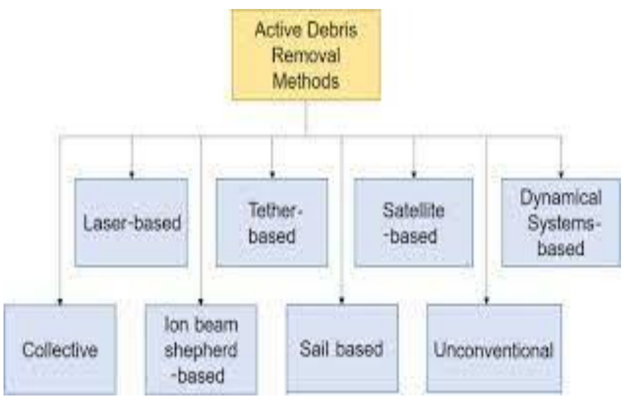

Figure 4: Space Debris Removal General Methods

There are some basic assumptions which are listed below.

- The chosen objects should have a high mass (they have the biggest environmental impact just in case of collision)
- Should have high collision chances (e.g., they must be in densely inhabited regions and have an outsized cross-sectional area)
- Should be in high altitudes (where the orbital period of the ensuing fragments is long).

Space debris removal methods are very diverse from capturing methods and they are classified into two forms specifically space environment-based methods and non-space environment-based methods. The most relevant and capable removal methods are Electro-Dynamic Tether (EDT), Drag Augmentation System (DAS), contactless and contact-based removal techniques etc. Space Environmental based methods basically consist of Drag Augmentation methods and Electro Dynamic Tether drag Augmentations.

III.I DRAG AUGMENTATION SYSTEM:

The European space agency Clean-Sat program Cranfield University is producing family of drag augmentation system modules to change small satellites in Low Earth Orbit (LEO) to accommodate space junk mitigation which is the need of the hour.

It is a method of debris removal in which drag of the object is increased by increasing the area towards a mass ratio of the objects. There is no need of close-range rendezvous as this method allows larger distances between chaser and target object. Different sizes of debris can be removed by this method. There are three different methods proposed by research personnel, the first one is foam based method, second is a fiber-based method and the third one is inflated method.

III.I.I Foam-Based Method

The chaser satellite ejects foam onto the target which gets stick on the target and covers it to make a ball of foam.

III.I.II Fiber-Based Method

A fiber is thrust out from a heat resource on the target. Principle behind this technique is related to foam-based method only difference is that it uses fiber instead of foam.

III.I.III An Inflated Base Method

This method is similar to the foam-based method, in which foam ball is replaced simply by an inflated ball. The inflated ball can be attached to the satellite or on an active space debris object.

Each one of these three proposed methods can be supported considering their pros and cons but, as a matter of fact, the second method represents the most feasible choice. To target each one of the millions of debris we require time, technical requirements and more than thousands of million dollars.

III.II ELECTRO DYNAMIC TETHER

In this method a clean semiconducting tether and two field electrode array cathodes use the power of electricity which uses the geomagnetic field to re-enter the Earth's atmosphere. It is developed by EDT JAXA.

This system contains plasma contractors at each end of the tether which alters current to flow in both directions, moreover the EDT removal technique was employed once within orbit transfer and orbit maneuvering.

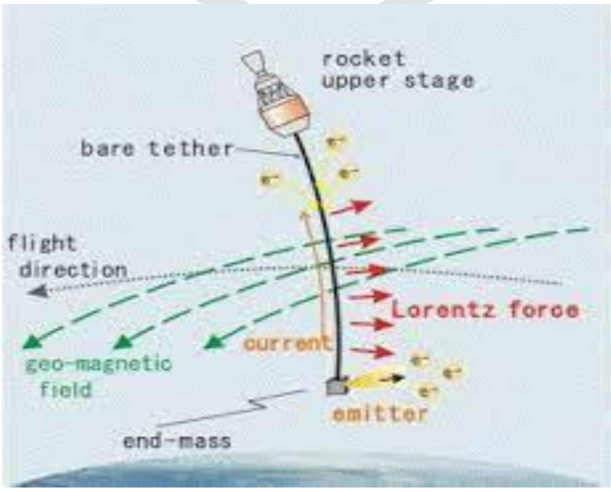

Figure 5: Working principle of Electrodynamics Tether.

This technique is a developing debris capturing technique. It consists of plasma contractors at both split ends of the tether system which permits the flow of current on both sides of tether. First electrode collects electrons and second radiate electrons to produce the current. Tether is generally multi-stranded so that it can be protected from damages due to debris impacts. Usually, Aluminium material is used in tether because of their lightweight construction.

III.III LASER SATELLITE:

This is a contact less debris removal method in which small and large size space debris can be removed by shooting a pulsed laser onto the target which in turn brings down its velocity and changes its altitude to move it to the graveyard orbit. There are basically two types of methods recommended by researcher's ground-based laser and space-based laser methods. Nonetheless, it is more convenient to use space-based laser technique.

III.IV CAPTURING AND CATCHING:

On Sunday 16th September2018, the vehicle, known as the Remove DEBRIS satellite, deployed its onboard net, which then captured a target nearby that the vehicle had released. The demonstration shows that a uncomplicated idea like a net may be an effective way to clean up all the plastic junk orbiting the mother Earth.

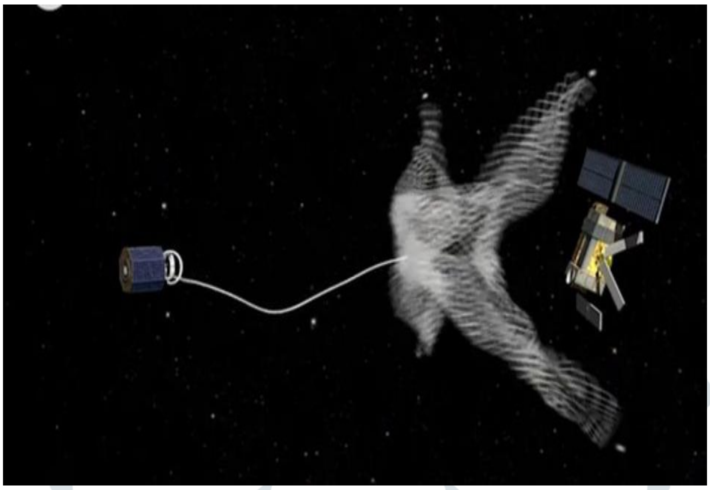

Figure 6: Net to catch space debris orbiting Earth successfully deployed on 20 September 2018.

On March 20,2021Saturday, a new mission is launched that aims to clean up some of the debris that is floating in the orbit around the planet Known as ELSA-d. The mission will also test different techniques to capture an object in low-Earth orbit and move it to a lower altitude.

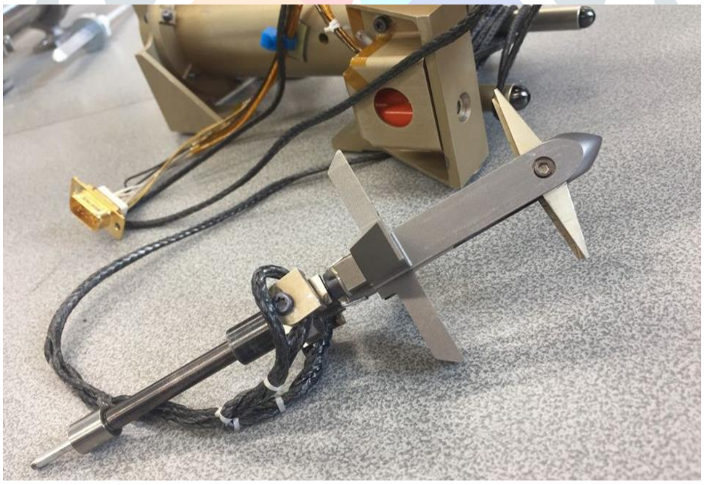

Figure 7: The miniature harpoon to be tested on the mission.

III.V ION BEAM SHEPHERD:

It is a contactless removal method in which a highly collimated neutralized plasma beam is ejected on debris lowering or elevating its altitude. Shepherd satellite is facilitated with a propulsion system which emits a highly collimated quasi-neutral plasma beam with very high momentum towards space debris.

Neutralized plasma beam technique is used to avoid the net charge on satellite and spacecraft. This gives a proficient technique for contactless space debris removal.

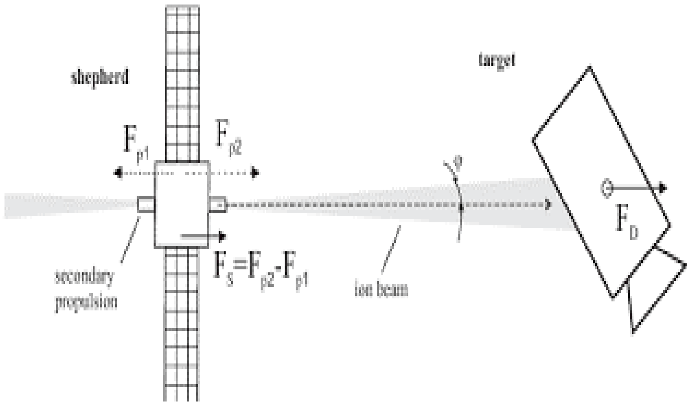

Figure 8: Representation of Ion beam shepherd for de-orbiting space debris

III.VI PROPOSED METHOD: (MULTI TECHNIQUE METHOD)

According to the techniques we have till date, the cost of removing the junk from space is unbearable and we need a technique which can give us exact result not just theoretically but also practically. I suggest manufacturing a satellite having three to four sections wherein different methods to capture junk is deployed. The satellite should be manufactured in such a way that all techniques simultaneously can act at a time. The lifetime of the satellite should be quite more so that it catches and captures debris for a long time before getting defunct. This particular satellite should be having a stretchable garbage bag inside which when gets filled can be moved to Earth's atmosphere where it can get burnt. This satellite should be deployed in LEO first and then can be thought to be moved to GEO as well.

Figure 9: A hypothetical satellite having four sections where different techniques are deployed.

Removal Methods	**Advantages**	**Drawbacks**	**Illustrations**
Drag Augment ation System (DAS)	Concur for Large expanse companionable with diverse sizes of space Junk.	Risk of breakup; Less efficient.	Foam Inflated Fiber-based
Electrodynamics Tether	No requirements For propulsion System; High TRL.	Capture desirable. Unavailable in GEO.	EDT
Contact less Removal	Allows a long distance; well suited with dissimilar sizes of debris.	Less proficient; Partially accessible in GEO.	Laser based system Ion Beam Shepherd (IBS)

Table 3: Advantages and disadvantages of various techniques

VI ANALYSIS AND CONCLUSION:

This paper reviews different techniques that have been proposed by researchers and their brief introduction. All existing removal methods are found to be suitable with unlike shapes, sizes, types, and orbits of space debris. Over the years many techniques and methods have been proposed but till today not a single piece of space junk has been removed by any of the space agency's mainly because of the complication and high cost of the mission. Small debris are difficult to trace, therefore almost "invisible", hence their collisions cannot be avoided. Collisions among large objects are very rare and it takes place every 5 to 8 years depending on models but they generate a large number of new debris which remain in the orbit for many years and increase the global risk in orbit significantly.

It will be advantageous and convenient to design a specialized artificial satellite having 30 to 35 years lifetime having more than one technique in it for protected disposal of the space junk which can reduce the cost of the mission. It's now or never. A special satellite having more than one technique to remove space debris should be deployed as soon as possible so that our future space missions are not threatened, and the space junk gradually decreases to minimal number.

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