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Satellite Systems-Space Debris: Survey

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Abstract **- This paper is a survey and mainly focuses on existing satellite systems and debris. The number of satellites sent to the space is enormously increasing. Hundreds of satellites are around Earth and are used for navigation, education, communication, military etc. All the satellites are not operational i.e., due to ageing some satellites are non-operational and they are called Debris. Debris are potential threat to objects in space, debris can vary from tiny paint flecks to a soft ball size. For the removal of debris net, harpoons, magnets can be used. These methods take thousands of years make space debris free.**

Index Terms **- Debris, flecks, harpoons.**

I.INTRODUCTION

A satellite is basically a self-contained communications system with the ability to receive signals from Earth and to retransmit those signals back with the use of a transponder—an integrated receiver and transmitter of radio signals. Satellites are used as various services to broadcasters, Internet server providers, military, and other sectors. There are three types of communication services that satellites provide: telecommunications, broadcasting, and data communications. Broadcasting services include radio and television delivered directly to the consumer and mobile broadcasting services. Data communications involve the transfer of data from one point to another for corporations and organisations that require exchange of financial and other information between various locations.

Fig.1: Solar Maximum Mission Satellite

SATELLITES IN SPACE

There are totally 19,235 satellites around Earth in which 5,695 are non-junk satellites and remaining 13,060 are junk satellites from 1950-2020, size varying from small to large radar sections. There are five orbits around Earth:

In Geosynchronous Earth Orbit, a satellite matches Earth's rotation and has 176 junks, 1105 not junk. In Geostationary Orbit, a spacecraft appears to observer on Earth to be stationary in the sky and has 1 junk, 386 non junk. High Earth Orbit is a geocentric orbit, which lies above geosynchronous orbit and has 12 junks, 35 non junk In Middle Earth Orbit, the Navigation Satellites Systems are present and has 478 junk, 467 non junk In Lower Earth Orbit, Satellites are closest to the ground than other orbit satellites has 10450 junk, 3849 non junk.

II.NAVIGATION SATELLITES

The Navigation Satellites provide autonomous geo-spatial positioning. It allows small electronic receivers to determine their longitude, latitude and altitude to high precision using time signals transmitted along a line of sight by radio from satellites which are used for positioning, tracking the position of something fitted with a receiver [1].

GLOBAL NAVIGATION SATELLITE SYSTEMS

GPS: It is now called as Navigation System with timing And Ranging Global Positioning System "Navstar" has 24 satellites in 6 orbits owned by US Government [table as in appendix].

Fig.2: GPS Satellite

GLONAAS: It is global navigation satellite system of Russian. It has 24 satellites which are operational in 3orbital planes. It is owned by Russia [table as in appendix].

Fig.3: GLONASS Satellite

BeiDOU: Originally the system was planned to have a regional navigation satellite system with only 14 satellites and now it has been expanded at global scale. So, it is also a Global Positioning System like your GPS and GLONASS. The global system, this consists of 49 satellites in which 44 are operational and this is owned by China [table as in appendix].

Fig.4 BeiDou Satellite

GALILEO: It consists of 26 satellites in which 3 are non-usable,1 is not available. It is created by Europe Union under Europe Space Agency [table as in appendix].

Fig.5: A Galileo Satellite

REGIONAL NAVIGATION SATELLITE SYSTEMS

IRNSS: The Indian Regional Navigation Satellite System, it is also called as NaVic (Navigation with Indian Constellation) which means sailor in Sanskrit. NAVIC will have a 7 satellite constellation. It is not global. So, that is why limited number of satellites would be sufficient; 3 satellites in Geo-Stationary Orbit and 4 satellites are in Geo-Synchronous Orbit. It is owned by India [table as in appendix].

Fig.6: IRNSS Satellite

QZSS: Quasi Zenith Satellite System which is also called as Michibiki which means to guide. It is owned by Japanese Government and has 3 satellites in Higher Earth Orbit and 1 in Geo-Stationary Orbit [table as in appendix].

Fig.7: QZSS Satellite

III.SPACE DEBRIS

It is also called as Space junk, space pollution or space waste. It has both natural meteoroid and artificial orbital debris. Meteoroids are in orbit about the sun, while most artificial debris is in orbit about the Earth. Orbital debris is any human-made object in orbit about the Earth that no longer serves a useful function. Such debris includes non-functional spacecraft, abandoned launch vehicle stages, mission-related debris, and fragmentation debris. The small pieces of unusable satellites when broken often causes damage to the other satellites. The debris is monitored by the United States Department of Defence with the help of Space Surveillance Network to avoid the collision between the debris and working satellites. A lot of effort and money involves repairing the damage caused to the satellites even by tiny flecks of paint [2].

One of the incidents: In 2009, nearly 500 miles above Siberia, two satellites collided at some 22,300 mph, bursting into a cloud of thousands of pieces of debris due to inactive Russian satellite Cosmos 2251 and the US based communication satellite Iridium 33. More than 23,000 known man-made fragments larger than about 4 inches, which is a little wider than two golf balls across, circling around our planet and these are large enough to track. About 500,000 pieces between 0.4 (small)-4(large) inches across join these larger fragments [3].

Space junk impacts other objects at over 22,300 mph, collide with those tiny pieces and cause pits and digs in the satellites, telescopes and other objects orbiting our satellite. The junk in various orbits has effects on their own effects.

Fig.8: Space Debris

JUNK IN ORBITS

The Geostationary ring: This is the only orbit on which satellites move synchronously with Earth. An ideal choice for meteorological and telecom satellites. The average distance between two objects is only 190 km. Defunct spacecraft in geostationary orbit can drift and endanger satellites in their vicinity. This is why experts recommend retiring these objects at least 300 kilometers higher, to a so-called graveyard orbit. With a successful lift, they should no longer interfere with the Geostationary Orbit. But can this be guaranteed for all times? Aging satellites are known to release debris and explosion can occur due to residual energy sources. The resulting fragments can be thrown back and cross the geostationary orbit. The release of residual energy, once the nominal mission is completed, is therefore fundamental. Launcher stages used to deliver spacecraft into the geostationary ring often remain on their transfer orbit and could interfere with active missions. Consequently, debris mitigation guidelines foresee that these stages should be maneuvered out of the geostationary ring and other frequently used regions. Further along, we pass through the region used by constellations for satellite navigation. Like four different constellations make use of four different altitudes. Inside these layers, we also find defunct satellites and upper stages. Stable graveyard orbits are difficult to find here. Fortunately, no explosive break-ups have taken place so far.

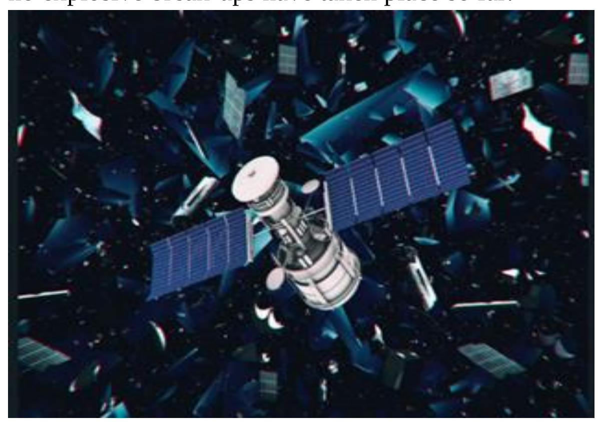

Fig.9: Space Debris around working satellite

Junk in Lower Earth Orbit: As we move even closer to Earth, the number of objects around us is growing. This is the region of the Low Earth Orbits. Two-thirds of all large manmade objects are concentrated here. About 600 active satellites provide us with science and Earth data, and tele-communications. They are surrounded by thousands of defunct satellites, rocket stages and fragments. Plus, this area is facing a surge in spaceflight activity. Smaller and more cost-effective satellites are increasingly launched to Low Earth Orbit. The only chance to ensure the future use of these orbits is to strictly apply debris mitigation measures. The first is to monitor the environment while spacecraft are still active. ESA satellites like Cryosat-2 have to perform 1 to 2 manoeuvres per year to avoid collisions. The second measure to combat the harsh rigors of years in space is to release residual onboard energy by depleting fuel venting pressure tanks and discharging batteries. Finally, the longer spacecraft stay in orbit, the higher the risk of collisions becomes. Experts fear that one day a cascading effect of collisions and follow-on collisions might set in making spaceflight in this orbit extremely difficult. A maximum of 25 years in orbit after mission completion is, thus, recommended. This can be achieved by moving the spacecraft downwards into the denser layer of Earth's atmosphere. In 2011, ESA successfully conducted such a disposal manoeuvre with ERS-2 lowering it from an operational altitude of 800km to 600km, where the remaining fuel was burned. Instead of otherwise 200 years, ERS-2 will now re-enter in less than 10. On their way down, objects pass through the altitude of another manmade object, our human outpost in space: the International Space Station. Although the environment here is relatively clean, it is not risk-free, as shown by the many impact chips on its surface and the regularly conducted collision avoidance manoeuvres. In even lower altitude, uncontrolled objects are bound for a re-entry. To minimize risk, larger spacecraft must be brought down using a complex, controlled manoeuvre to a selected, safe spot-on Earth. Without such a manoeuvre, the time and location of re-entry, are not under control. The uncontrolled re-entry will start after a final orbit revolution at about 100 kilometers. First, the aerodynamic forces will cause exposed external parts of the spacecraft to be sheared off. During deceleration, the object will be exposed to extreme heat. Some materials, such as aluminum, will begin to melt. The outer shell is gradually destroyed. Internal elements are released to the airflow and dissolve. In addition, strong aerodynamic deceleration enhances the destruction process. With complete disintegration only components made of heat resistant material like titanium or glass will have survived. They cool down and fall with a terminal velocity of about 300km/h mostly into the vast seas. Occasions to find space debris objects on the ground are very rare. And, unlike meteoroids, they do not form craters.

Fig.10: Space Debris around Earth

Fig.11: Space Debris burning while re-entering Earth

DEBRIS THREAT TO EARTH'S ENVIRONMENT

The Old satellite and spacecrafts enter planet's atmosphere regularly, estimated at 200-400 pieces a year. These parts burn up on re-entry has minute direct impact on terrestrial regions and do not completely disappear. By burning up, due to the intense friction of travelling from a vacuum to an atmosphere full of gases, noxious chemicals and Greenhouse Gases are released in the upper atmosphere. The gases are atom in amount, can deplete ozone layer because they are more potent than Carbon dioxide. Continuously, the junk in space collides with each other, also with operational satellites and can make Lower Earth Orbit unusable, as there is an increase in debris. Even though, space pollution is different than other pollutions on Earth. In future, it will sure have immense effect [4].

REMOVAL OF SPACE DEBRIS

Using power of electricity: JAXA, Japan's space agency, is testing an electronic space whip that stretches six football fields long, known as the electrodynamic tether (EDT). The electrified line, nearly 2,300 feet long, is capped with a 44-pound weight. When deployed, it is intended to knock debris out of orbit, sending it to burn up in Earth's atmosphere.

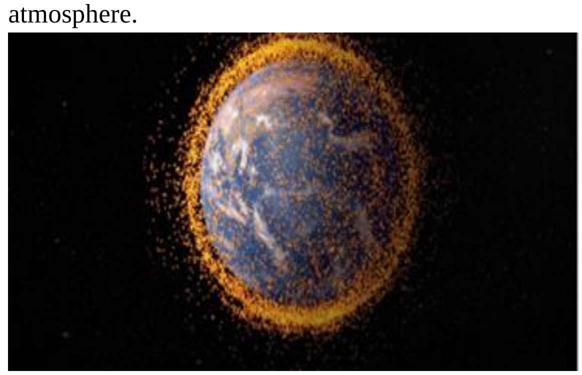

Fig.12: Electrodynamic Tether

Snagging and Moving Space junk:
It was proposed in 2014, satellite debris in a polar orbit at an altitude between 800 and 1,000 kilometers (500 to 620 miles). The European Space Agency is considering several kinds of capture mechanisms to pick up the debris, such as nets, harpoons, robotic arms, and tentacles.

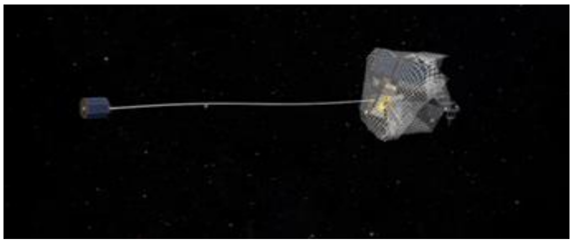

Fig.13: Snagging

Pushing debris out of the Space: In 2025, Clear Space will launch the first active debris removal mission by using robotic arms, ClearSpace-1, which will capture and take down for re-entry the upper part of a Vespa used with Europe’s Vega launcher. This object was left in a ‘gradual disposal’ orbit (approximately altitude 801 km by 664 km)

Fig.14: Clear Space-1

Slingshot: Sling-Sat Space Sweeper proposes capturing an object, swinging it towards Earth's atmosphere, and then using the momentum to sail on to the next piece of space debris for removal. The researchers were examining design ideas in 2013 and still underway.

Fig.15: Slingshot

Solar Sail: Cube Sail would use the drag of a solar sail to push orbiting space debris down to lower orbits, but it was an unsuccessful launch.

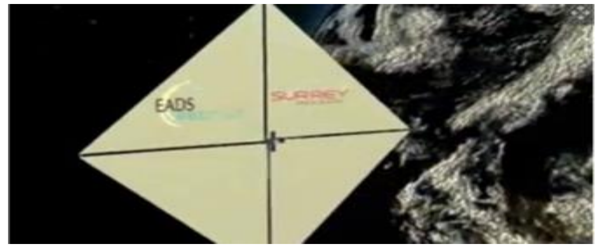

Fig.16: Cube Sail

Huffing and Puffing: This method would push satellites into a lower orbit by using air bursts within the atmosphere and this might disturb the paths of lower orbital debris.

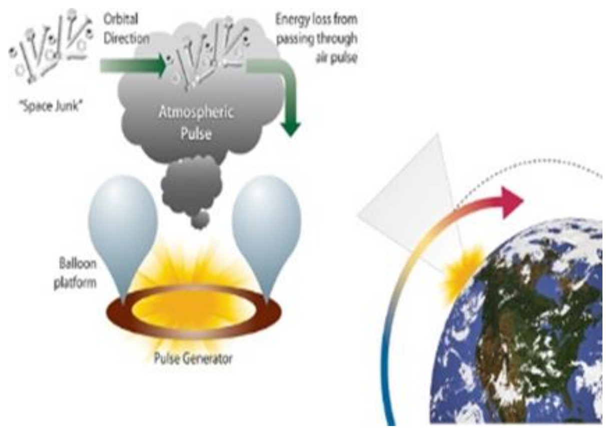

Fig.17: Huffing and Puffing

Knock Junk down with a net: A network of nano satellites, connected with a piece of electrically conducting tape that could be as long as 2 miles (3 kilometers), could knock satellites down as it passes through Earth’s magnetic field and produces voltage. The solar-powered Electro Dynamic Debris Eliminator could get rid of all large pieces of satellite debris in low-Earth orbit within a dozen years.

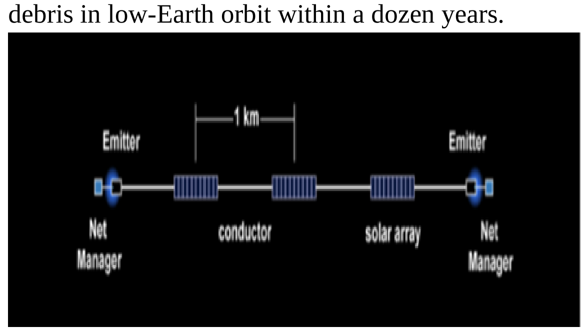

Fig.18: Electrodynamics Debris Eliminator

These might be some methods to remove debris [5].

SUCCESSFUL DEBRIS REMOVAL METHODS

Magnets: Elsa-d is the first demonstration of end-to-end process of capturing debris and then lowering it to of earth's orbit. It consists of a servicer spacecraft & a client spacecraft. The two spacecrafts will fly together, releasing the client and then catching it with the servicer. So, the mission simulates a scenario where we would capture a piece of debris and then lower such that it re-enters Earth's atmosphere & stays out of the way of other spacecraft. It was successfully launched on 22nd March 2021.

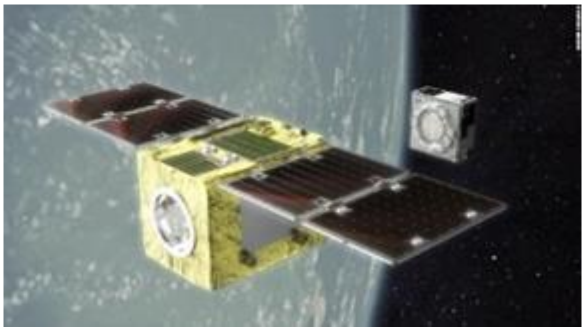

Fig.19: Elsa-d

Harpoons: Remove DEBRIS's Harpoon Experiment successfully captured space debris. The 10x10 cm target was deployed from the Remove DEBRIS satellite at a 1.5-meter distance. The harpoon was fired at 20 meters/sec to penetrate the target and demonstrate the ability of a harpoon to capture debris.

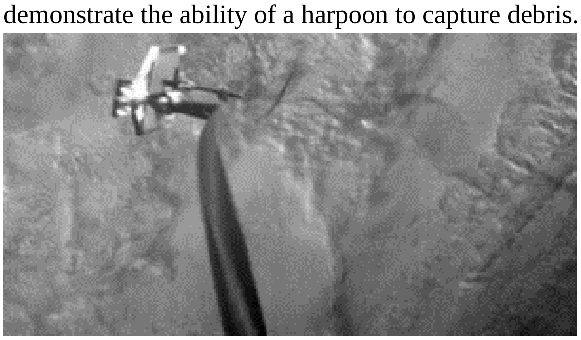

Fig.20: Harpoon catching a debris

Net: Remove DEBRIS mission was launched aboard SpaceX CRS-14 on 2 April 2018. The main satellite platform was deployed from the International Space Station on 20 June 2018. For Remove DEBRIS Net Experiment, a target CubeSat (DS-1) was ejected at a low velocity and inflated a balloon to provide a larger target area. A net was ejected from the platform when DS-1 was at 7 m distance. Remove DEBRIS's net wrapped around the target on 16 September 2018 and the CubeSat was left to deorbit at an accelerated rate.

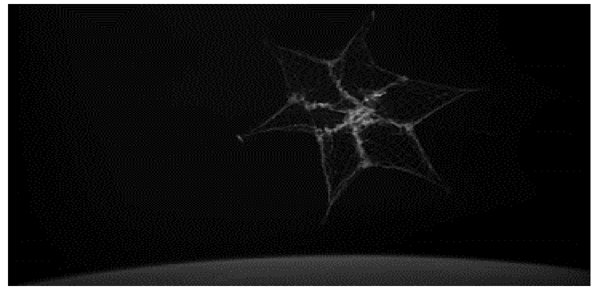

Fig.21: A net formed by satellite to catch debris

CHAWLA: Chawla was on her second space journey as mission specialist on STS-107 in 2007, the mission was being delayed for several times and in 2003 it was launched successfully. It was 16 days course in space 80 experiments were needed to be performed.

On the returning day that is on Feb 1st,2003, when shuttle passed through the atmosphere, hot gases streaming into wing, broke the shuttle. This happened because at launch time, a piece of insulation was broken and destroyed the thermal protection system of shuttle's wing. This incident has costed us lives of seven people including Chawla [6].

Fig.22: STS-107 re-entering Earth

ROBO ARM: On May 12, 2021, during inspection NASA, CSA had found damage of Canadarm2.ISS robotic arm is functioning even after being hit by debris. The damage is limited to a small section of the arm boom and thermal blanket, a hole of diameter 5mm was visible [7].

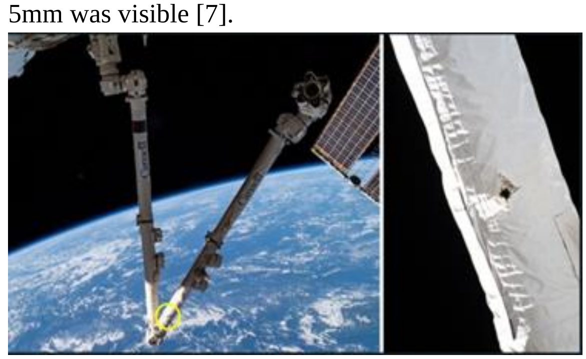

Fig.23: Hole in robotic arm caused by debris

V.CONCLUSION

This paper is a survey made on the existing navigation satellites and the space debris. The number of satellites is increasing day by day in order to match the requirements. Number of operational satellites is increasing and the same rate the nonoperational satellites are also increasing which are left in the space. The space junk or space debris is also increasing. Removal of the space debris is a challenging problem as it would take years to send the junk back to Earth, and it has to be addressed. This paper explains the methods that have been adopted for the removal of space debris.

VI.APPENDIX

GPS: Table I: Some of GPS satellite status as 10.06.2021

Plane	Slot	PRN	NORAD	Type SC	Launch date	Input date	Outage date	Lifetime (months)	Notes
A	1	24	38833	II-F	04.10.12	14.11.12		102.9	
B	1	16	27663	II-R	29.01.03	18.02.03		219.8	
C	1	29	32384	IIR-M	20.12.07	02.01.08		161.4	

GLONASS: Table II: Some of GLONASS satellite status as 10.06.2021

Orb. slot	Orb. pl.	RF chnl	# GC	Launched	Operation begins	Operation ends	Lifetime (months)	Satellite health status		Comments
								In almanac	In ephemeris (UTC)	
1	1	1	730	14.12.09	30.01.10		138	+	+14:52 10.06.21	In operation
11	2	0	705	25.10.20			7.5	-	- 14:52 10.06.21	Flight Tests
11	2		753	29.05.16	27.06.16	19.11.20	60.4			Maintenance

BeiDOU: Table III: Some of BeiDOU satellite status as 10.06.2021

Satellite Number	NORAD	Satellite Name	Type of system	Launch date	Lifetime (days)	Notes
C22	43207	MEO-4	BDS-3	12.02.18	1214	In operation
C57	40749	MEO-1S	BDS-3S	25.07.15	2147	Not in operational orbital constellation
C61	45807	GEO-3	BDS-3	23.06.20	352	Not in operational orbital constellation

GALILEO: Table IV: Some of Galileo satellite status as 10.06.2021

Satellite Name1	SV ID2	Clock3	Status4	Active NAGU5	NAGU Type6	NAGU Subject7
GSAT0103	E19	PHM	USABLE			
GSAT0104	E20	RAFS	NOT AVAILABLE	2014014	UNP_UNUFN	UNAVAILABLE FROM 2014-05-27 UNTIL FURTHER NOTICE
GSAT0201	E18	PHM	NOT USABLE	2021008	GENERAL	GSAT0201 AND GSAT0202 UNAVAILABLE
GSAT0202	E14	PHM	NOT USABLE	2021008	GENERAL	GSAT0201 AND GSAT0202 UNAVAILABLE

IRNSS: Table V: Some of IRNSS satellite status as 10.06.2021

Launch Date	Launch Mass	Launch Vehicle	Orbit Type	Application		Remarks
IRNSS-1I	12-Apr-18	1425 kg	PSLV-C41/IRNSS-1I	GSO	Navigation	
IRNSS-1H	31-Aug-17		PSLV-C39/IRNSS-1H Mission		Navigation	Launch Unsuccessful
IRNSS-1G	28-Apr-16	1425 kg	PSLV-C33/IRNSS-1G	GEO	Navigation	

QZSS: Table VI: Some of QZSS satellite status as 10.06.2021

QZS01 (SVN=001, Block type=IQ)				
PNT	L1C/A, L1C, L2C, L5	193	O	
SLAS	L1S	183	O	
CLAS	L6	193	O	
QZS02 (SVN=002, Block type=IIQ)				
PNT	L1C/A, L1C, L2C, L5	194	O	
SLAS	L1S	184	O	
PTV	L5S	184	O	
CLAS	L6	194	O	

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