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Introducing an Innovative Technique for the Process of Removal of Space Debris Orbiting Earth

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Abstract: My research paper tries to contribute to the space engineering field, especially in the process of almost complete removal of debris present in space orbiting Earth by providing an innovative idea. This paper deals with the study of the process of atomization, electrostatic nets, unmanned orbiters refuelling from ISS and orbiting Earth in every orbit (LEO, MEO, HEO, GEO). The paper focuses not only on the process of space debris removal but also on the whole process of launching from the ground to orbiting the Earth then ultimately docking to the ISS. According to my paper, this unmanned spacecraft will be launched into space by a rocket at such a location so that it can set its path in low earth orbit and also near the ISS. Throughout its journey, whatever debris comes in the path, the spacecraft will detect and release its electrostatic net of diameter 10 m - 20 m which will fold itself once it gets very close to the debris. Also, the net will produce an electrostatic force so that the debris (every kind of material and of every size) gets attracted towards the net when it comes closer. The debris will then be sent into the spacecraft in the atomization chamber where the materials will be burned in extreme temperature then highly pressurised fluid will be sprayed to the molten material to solidify and transform them into powder. The powder will either be released into space which will cause zero damage to any spacecraft or satellites or most importantly the powder can also be brought to Earth for recycling and manufacturing of new materials. Every time, the ISS will provide fuel to the spacecraft when needed during its mission. According to this process, there is a high chance of having zero space debris by next 10-15 years.

Key Word: Atomization; Chamber; Electrostatic; Generator; ISS; Refuelling; Powder

1. Introduction

Space debris or garbage or pollution are defunct human-made objects in space orbiting Earth that no longer serve a useful function. These include derelict spacecrafts, non-functional spacecrafts, abandoned launch vehicle stages, mission-related debris, fragmentation debris from the breakup of derelict rocket bodies and spacecraft. In addition to derelict human-made objects left in orbit, other examples of space debris include fragments from their disintegration, erosion and collisions or even paint flecks, solidified liquids expelled from spacecraft, and unburned particles from solid rocket motors. Space debris represents a risk to spacecraft.

More than 27,000 pieces of orbital debris are tracked by the Department of Defense's global Space Surveillance Network (SSN) sensors. Much more debris that is too small to be tracked, but large enough to threaten human spaceflight and robotic missions, exists in the near-Earth space environment. Since both the debris and spacecraft are travelling at extremely high speeds (approximately 17,500 mph in low Earth orbit), an impact of even a tiny piece of orbital debris with a spacecraft could create big problems.

Space junk in numbers

2,000 active satellites in Earth's orbit

3,000 dead satellites in Earth's orbit

34,000 pieces of space junk larger than 10 centimetres

128 million pieces of space junk larger than 1 millimetre

One in 10,000: risk of collision that will require debris avoidance manoeuvres

25 debris avoidance manoeuvres by the ISS since 1999

Figure 1: Shows total number of space debris of various sizes till date

The above-mentioned satellites could nonetheless prove disastrous if they hit something else. Some objects in lower orbits of a few hundred kilometres can return quickly. They often re-enter the atmosphere after a few years and, for the most part, they'll burn up - so they don't reach the ground. But debris or satellites left at higher altitudes of 36,000 kilometres where communications and weather satellites are often placed in geostationary orbits, can continue to circle Earth for hundreds or even thousands of years. Some space junk results from collisions between satellites or anti-satellite tests in orbit. This is rare, but several countries including the USA, China and India have used missiles to practise blowing up their own satellites. This creates thousands of new pieces of dangerous debris. Fortunately, at the moment, space junk doesn't pose a huge risk to our exploration efforts. The biggest danger it poses is to other satellites in orbit. These satellites have to move out of the way of all this incoming space junk to make sure they don't get hit and potentially damaged or destroyed. In total, across all satellites, hundreds of collision avoidance manoeuvres are performed every year, including by the International Space Station (ISS).

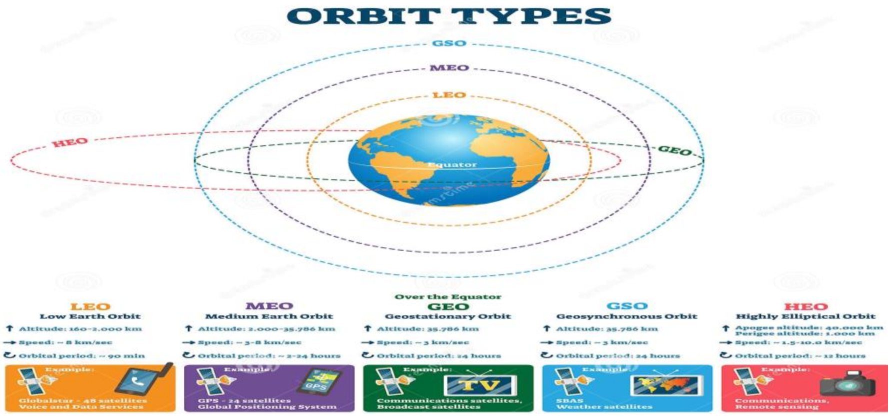

Figure 2: Shows different orbits at different range of altitudes where debris are present

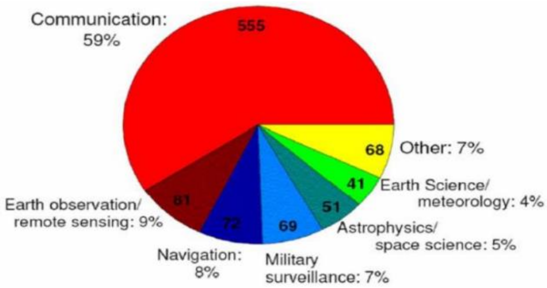

Figure 3: Shows satellites used in various areas at present

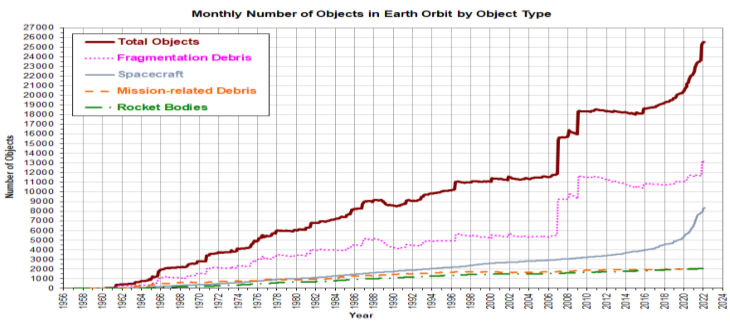

Figure 4: Shows both debris and functional spacecrafts/satellites (future debris)

There are many research/review papers discussing different kinds of innovative ideas and concepts for introducing new techniques for the process of removal of space debris. Here are the following techniques: -

1. Drag Augmentation System
2. Electrodynamic Tether
3. Contact Based Removal Method
4. Slingshot Method
5. Adhesive Removal Method
6. Contactless Removal Methods
7. Laser Satellite
8. Ion Beam Shepherd

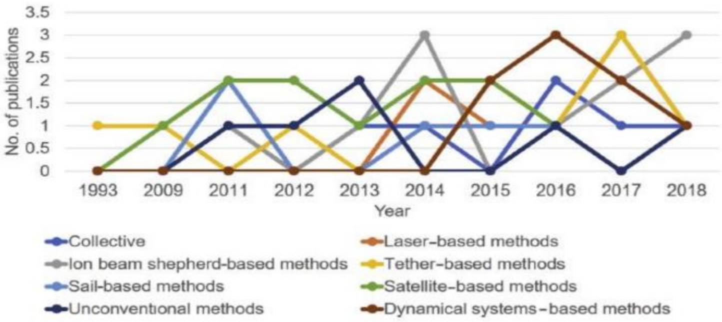

Figure 5: Shows recent trends on active debris removal

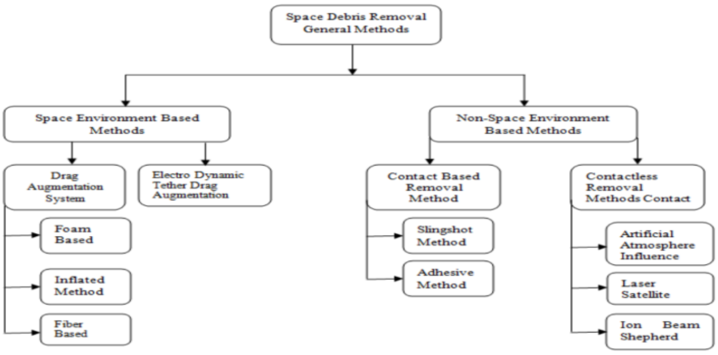

Figure 6: Shows space debris removal general methods

2. Discussion

Before proceeding towards discussing about my partially innovative technique, based on this technique some terms that are needed to be known are introduced as well as described below:

Atomization: Atomization refers to the breaking up of bonds in some substances to obtain its constituent atoms in gas phase. It is the process of converting an analyte in solid, liquid or solution form to a free gaseous atom. The range of metals that can be atomized extends to all metals that are capable of being melted industrially.

The process involves the formation of powder from molten metal using a spray of either a gas or liquid. This is the most significant method of producing metal powder particles. In gas atomization, generally inert gases like nitrogen, helium, or argon are used for breaking up the stream of molten metal. The liquid metal is disintegrated by rapid expansion of the gas out of a nozzle. Super alloys are ideal candidates for this type of preparation. During the flight of the particles in the collection chamber, the particles cool and solidify. The particle size can be controlled by adjusting the melt temperature, the nozzle orifice opening, and the volume and pressure of the gas. Powders made by gas atomization tend to be somewhat spherical in shape. Many metals are made by atomization using a liquid as the medium and water is quite often the choice because it is inexpensive. As with gas atomization the process is controlled through the metal melting temperature, the nozzle design, and the liquid volume and pressure. The process is generally designed so that the particles are somewhat irregular in shape. This is done so that the particles have a certain amount of interlocking during the compression cycle, and the compacts have good green strength so that they resist fracture while being transported to the sintering furnace. After atomization, the particles thus formed are screened and annealed. During annealing the oxides that might have formed during the atomization are reduced and the particles are softened so that they are capable of being hardened by quenching. The annealing is done in a protective reducing atmosphere and the temperature is high enough to be effective for the reduction process, but not sufficiently high to get particles to sinter. After the annealing there is at times a light cake formed which must be broken up. Care is taken so as not to induce any cold work into the particles.
Atomization is the dominant method of production of metal powders due to:

- Alloying (chemical and electrolytic)
- Particle size and shape control
- Chemical purity

The basic processes associated with methods of atomization, such as the conversion of bulk liquid into a jet or sheet, and the growth of disturbances which ultimately lead to disintegration of the jet or sheet into ligaments and then drops, determine the resulting spray's characteristics such as:

- Shape
- Structure
- Penetration
- Droplet velocity
- Drop size distribution

The characteristics of droplets are strongly affected by: Atomizer size and geometry

- Physical properties of the liquid
- Properties of the gaseous medium into which the liquid stream is discharged

Atomization occurs as a result of the competition between the stabilising influences of surface tension and viscosity of the liquid, and the disruptive actions of various internal and external forces.

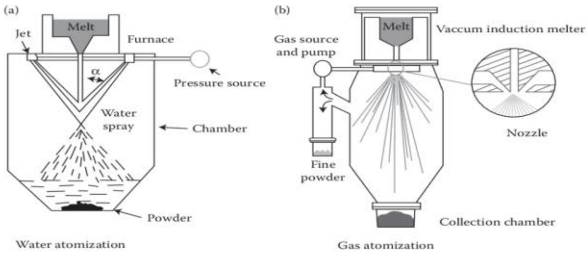

Figure 7: Shows two types of atomization processes

Electrostatic tether-net: Electrostatic force between two bodies can be either attractive or repulsive depending on the number of electrons present in each body and also the flow of electrons which makes a body charged (positively or negatively). Here, we are definitely focusing on the electrostatic force of attraction and that also between a negatively charged body (especially tether net) and a neutral body (especially debris).

Space tethers are long cables used for propulsion, momentum exchange, stabilisation and attitude control, or maintaining the relative positions of the components of a large dispersed satellite/spacecraft sensor system. Depending on the mission objectives and altitude, spaceflight using this form of spacecraft propulsion is theorised to be significantly less expensive than spaceflight using rocket engines. Now, let's imagine a large square-shaped net of side length 10m - 20m is attached to one end of the tether at its centre and the other end of the tether is attached to the unmanned orbiter. Not only that but also the four corner ends of the square net have small satellites that will propel as well as manoeuvre the whole net along with the tether towards the nearest debris that are detected. The net must be light and strong so for that, ultra-lightweight polyethylene Dyneema (commonly used to make mountaineering ropes) is the perfect material and for the tether, aluminium strands and steel wire are perfect.

By allowing the flow of electrons through the whole tether-net, it can be turned into a negatively charged tether-net which will definitely help to capture debris of different sizes varying from 1 millimetre to less than a metre other than the large debris around which the net will directly wrap/fold itself. Both these smaller and larger debris are neutral objects which means they do not have any charge on them and the electrostatic force between a negatively charged body and a neutral body is always attractive in nature. As a result, this attractive force will attract debris of size less than a metre when the net will reach very close to the debris. Generally, most of the time small debris are found around the large ones.

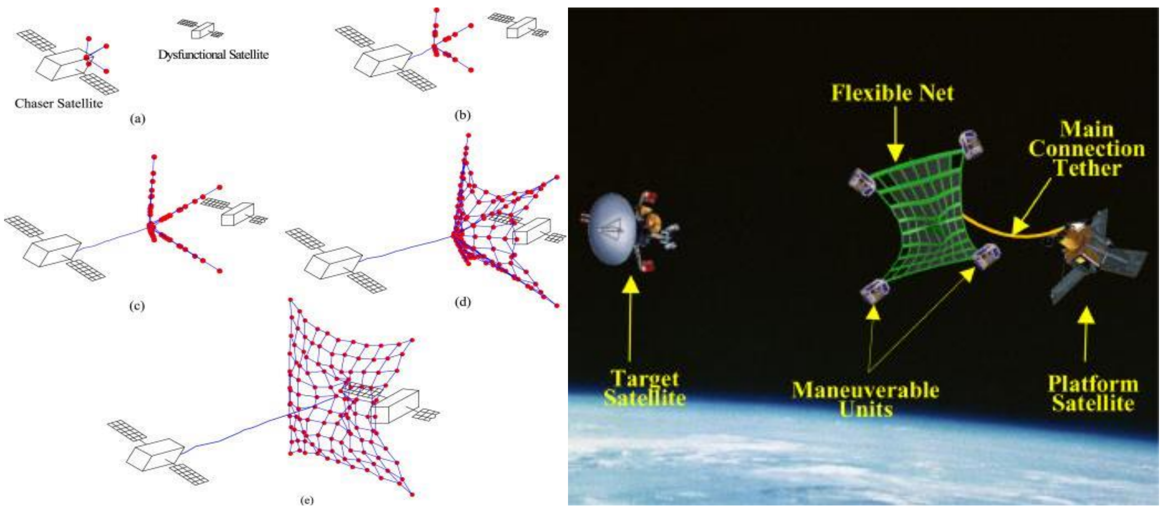

Figure 8: Shows the mechanism of electrostatic tether-net along with four tiny satellites at the corner ends of the net

Overall technique description:

Case I: A big unmanned orbiter needs to be designed in such a way that it will contain two separate chambers or compartments where in one chamber, there will be tether-net and four tiny satellites in a packed form and the static electricity generator. And the other chamber will be for the atomization process. Now if this case is possible then the orbiter will be sent to the exact location where the International Space Station (ISS) will be located or at least near the ISS so that it will move along with the ISS but ahead of it which means basically the orbiter will lead the route of the ISS and whatever debris will come in its path, orbiter will constantly capture the debris and sent them into the atomization chamber. Now, those tiny satellites and the tether-net which are in packed form initially, will be released. These satellites will help the tether-net to propel towards a debris after detecting it and when it will reach very close to the debris or come in contact with the debris, those tiny satellites will manoeuvre in such a way that the net will slowly fold or wrap itself around the debris and after capturing it, the tether-net will be pulled into the orbiter. Just before releasing the tether-net, static electricity will be generated through the tether-net. While capturing the large debris, the smaller ones will also be attracted towards the net due to electrostatic force. Then the static electricity generation will be stopped and the debris will be sent to the atomization chamber. There, the debris will be provided with extremely high temperature and pressure till it turns into a molten liquid state and then highly pressurised fluid (either water or inert gases) will be sprayed to the molten material so that it breaks into tiny droplets which will then be solidified by cooling and transform them into tiny grains or powder of size less than 1 millimetre. The temperature and the pressure of the substances inside the chamber will be set up accordingly. The powder will either be released into space which will cause zero damage to any spacecraft or satellites due to their size or most importantly, the powder can also be brought back to Earth for recycling and manufacturing of new materials.

OR

Case II: Two separate unmanned orbiters need to be designed where one orbiter will have the tether-net, tiny satellites and static electricity generator and the other one will have the whole atomization chamber. Maybe these two orbiters will need to be launched in two separate rockets. These two must be designed in such a way that after reaching space in the low earth orbit (LEO) near ISS, these two orbiters will assemble into one and function as a whole. And then the rest of the processes will be the same as in case I

Most of the time, the orbiter will roam around near the ISS that means in the LEO clearing the debris within the altitude range 160km - 2000km. At the time of fuel run out, the orbiter will dock to the ISS for refuelling and sometimes carry a backup fuel storage for higher orbit missions. Though the type of propulsion system may also vary on which whether the orbiter needs to be refuelled or not depends.

3. Conclusion

This paper tries to contribute to the space engineering field, especially in the process of almost complete removal of debris present in space orbiting Earth by the presentation of a hypothetical ideology or concept through writings as well as pie chart, flow chart, graphical and pictorial representation though the paper lacks any kind of modelling, analysis and calculations. But still the paper finds it difficult to frame the exact idea. A very raw and rough idea is presented through this paper. But the idea has some potential and if it is somehow possible to turn this hypothesis into reality then not only it will be possible to eradicate the space pollution (space debris population) but also most importantly the powdered form of the debris can be recycled to manufacture new materials. According to this process, there is a high chance of having zero space debris by the next 10-15 years starting from the year when this technique will be brought into action. The sooner the technique will be applied, the quicker we will get the result.

References

[1]. https://www.sciencedirect.com/science/article/abs/pii/S0094576509000320
[2]. https://www.sciencedirect.com/science/article/abs/pii/S0094576517303089
[3]. https://www.sciencedirect.com/science/article/abs/pii/S0016003220302805
[4]. https://www.sciencedirect.com/science/article/abs/pii/S0094576516309961
[5]. https://www.sciencedirect.com/science/article/pii/S0273117723000297
[6]. https://en.wikipedia.org/wiki/Space_debris
[7]. https://www.sciencedirect.com/topics/engineering/atomisation#:~:text=Porous%20Materials%2C%202014-,Atomization,and%20the%20 solidified%20into%20 powder.
[8]. https://en.wikipedia.org/wiki/Atomization
[9]. https://www.corrosionpedia.com/definition/120/atomization
[10]. https://www.space.com/41897-satellite-fires-net-to-catch-space-junk.html#:~:text=A%20space%2Ddebris%20net,used%20to%20make%20mountaineering%20ropes.
[11]. Study of current scenario & removal methods of space debris by Prabhat Singh, Dharmahinder Singh Chand, Sourav Pal &Aadya Mishra, Faculty of Aerospace Engineering, Chandigarh University, Punjab, India
[12]. A comprehensive study on space debris, threats posed by space debris, and removal techniques by Sangita Mullick, Yashwanth Srinivasa, Ashutosh Kumar Sahu, JhanviTharunSata
[13]. Design, development, and experiments of novel tether-net release mechanism by Hirohisa Kojima, Sajjad Keshtkar, Fumika Baba, Yuma Kato, Haruma Suzuki, KaitoKosuge, Pavel M. Trivailo, a Department of Aeronautics and Astronautics, Tokyo Metropolitan University, 6-6 Asahigaoka, Hino, Tokyo 191-0065, Japan b School of Engineering, RMIT University, Bundoora, Melbourne 3083, Australia