Advanced Space Debris Removable Technique and Proposed Laser AblationTechnique: A Review

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Abstract: **From the beginning of space era human being has launched more than 5500 rockets in space having different types of payload for various space mission carried out. These payloads, mostly satellites have many types of uses, ranging from earth observation to communication. These satellites, post usage hold no utilization but keep orbiting around the earth.This had leaded the space environment to be filled with such space deployed objects that we call as space debris. Such kind of accumulation of space debris is increasing gradually with each space mission carried out, and is posing a serious threat for our future space missions. Space debris around earth, if not resolved can become the most danger problem to upcoming space missions and research in future space exploration journey. Space debris is a very critical problem that would need an ample of time to come up with some feasible solution. Unfortunately, most of the proposed methods for space debris removal are not successfully functional. Whilekeeping in view, the shortcomings of the existing proposed methods for debris removal, we have reviewed a more practical method that could be implementedsuccessfully. We are proposing a combination ofthe already available technologies in a new way for scavenging the space yard. In this paper, we have studied advanced removal technique like-catching and capturing space debris, reuse of rocket systemand have proposedcost effective plans for removal of space junks from earth orbit using alaser ablation technique.**

Keywords: **space debris, ablation, detonation, catching, clean space, NASA, SpaceX, Low earth orbit**

I. INTRODUCTION

As mankind continues to launch number of satellitesday by day, in space, more and more orbital debris is increasing causing a serious threat to the future and already existing spacemissions. Space debris is not a new problem for scientists. Since every year number of satellites in orbit is gradually increasing, space debris if not checked continuously will eventually lead toa serious damage to close Earth orbit activities. Therefore, requirement to create effective solutions is much desired to overcome this havoc of space debris. Currently, there are around 25, 000 parts of debris larger than a size of ball orbiting the Earth and 500, 000 of the size of marbles. In world greater than fifty decades of space mission carried out, more than 5500 launches carried payload of more than 6000 satellites into space, from which less than one thousands satellites are in working condition today. In today condition us space agency continuous track space orbit item regularly by latest network system and published a report on

That, in which objects from 5 cm to 10cm in size are moving around orbit with maximum velocity. Other 30cm to 1m are Rotating in upper altitude called “geostationary altitudes”. Space debris consists of all space items like non-functional wasteand generated by human, in that specially include (42-

44%) in fragments and parts break ups of space objects, mainly are dead batteries from spacecraft, wasted or excess fuel, parts of rockets that in launching vehicles (17-20%) and other debris related to space mission (20%), all non-working condition or other parts moving around earth at the velocity of 8 to 9km/sec this debris in various size are fast enough to danger impact on active spacecraft or any mission.But problem is with latest technology is not enough to trace smaller size debris which are 1 cm in size and that can also serious damaged to Spacecraft, satellites, and human Flights in near earth orbit. The space debris, shredded over orbiting the earth, are shown in figure1, and figure2

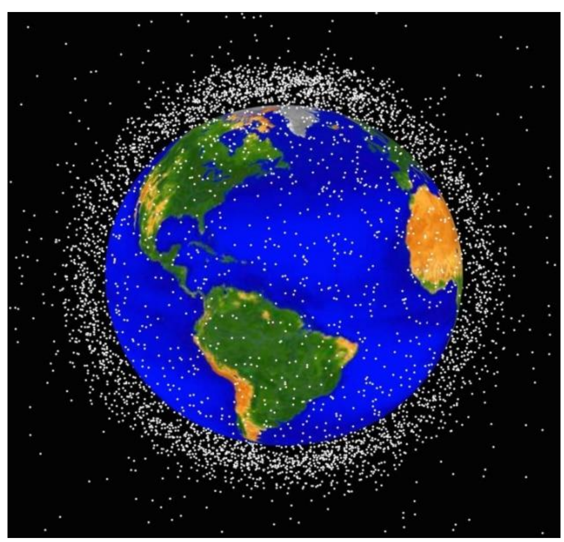

Fig. 1. Space debris distribution in low Earth orbit

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Most man-made space debris greater than 1 cm is closely monitored by space radar and space telescopes. Most of these waste around earth are generated in past 50 decades that this is the most interesting thing in space. Spacecraft's (22-24%), while 35-38% are retired satellite from their work that not actual working in condition, remaining are the part of rocket in upper stage ejection in launching a payload are 56% this all generated by thousands of launching a rockets in space since 1961. The majority of this debris is small particles numbering in the tens of millions. The kinetic energy of small orbiting objects is the major component of impact damage due to high speed. It is clearly seen how that huge number of objects can pose problems for the future of space exploration and exploitability hence the need to find a solution to this growing issue. For reduce or decreasing the number of satellite has various method which actually invented in past 20 some proposed method are still in theory or are in fantasy not actual physical work done on this method. Remaining methods are in implemented stage which are capturing or catching the moving debris, space debris elimination by reusable rocket technique also by ablation lasertechnique etc. These all techniques will be discussed in this paper. This paper shows the possible and cost effective technique for space debris.

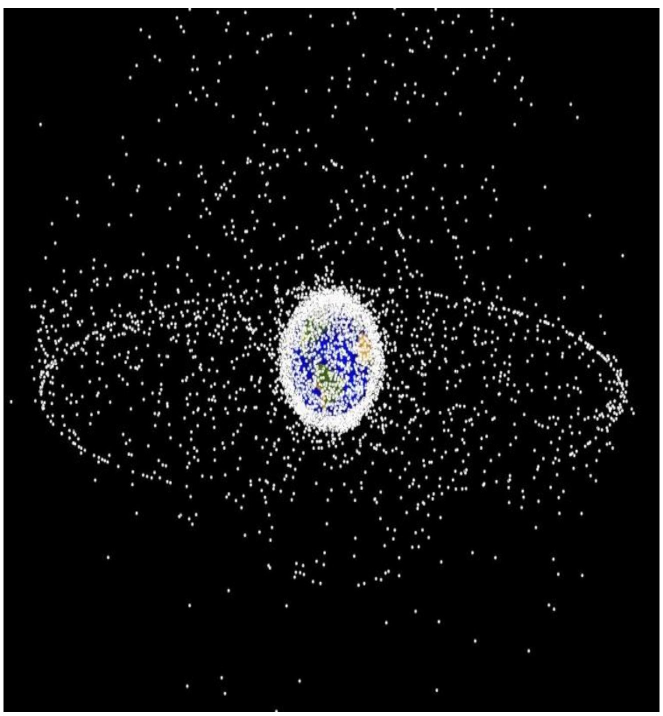

Fig. 2. actual picture of space debris high altitude or in upper orbit

II. PROBLEM DESCRIPTION

The number of increase space debris in past few years which main threat to future world space activity andmission, and human being get maximum access of space since 1951 that era called "space era". The risk of debris collisions could prohibit future human and robotic space missions. Examples of the negative effect on the space environment caused by collision can be seen in Fig.3 [10].

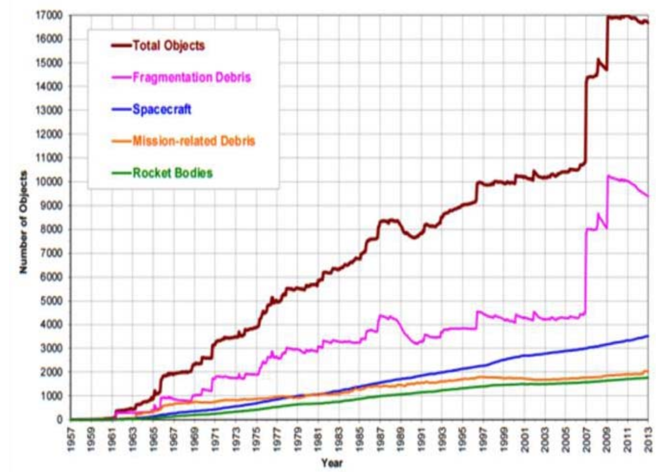

Fig. 3. Debris population growth in the last 60 years

Hence designer's engineer has to design spacecraft's and their mission for reduce the amount of space debris in space. Analyses showing that achieve a future goal for decline of debris population it would be enough to remove approximately 7-8 of the bigger debris in the 700 km to 1000 km altitude band every year, [11]. It is worth noting that currently there is no any international committee or organization that working on old satellites has to be removed, but recently, NASA and other space agency have implemented a guideline rules and regulation for their space mission and activities in future to and likely that will be law in space.

III. LIMITATION OF THE WORK

Before starting the space debris mission we have expected to explain the kind of assumptions that were made.

- The mass of the spacecraft is considered constant during all phases of the mission and equal to the initial total mass of the satellite.
- The motion of the satellite was considered independent from the effects of atmospheric drag, solar radiation, reflection, planet gravitational force field in our solar system, oblations effect.
- All the orbits are assumed to be circular due to their low eccentricity ($0.0012 \leq e \leq 0.0109$).
- The debris is considered as cooperative-targets in the meaning that they do not have angular momentum. This will simplify a lot the rendezvous phase between the deorbiting vehicle and the debris.
- The orbits of debris are considered unchanged during the time required to perform orbital transfer, so neither drag

nor Earth oblations effect were considered during the low thrust transfers.

IV. TECHNIQUES TO REMOVE SPACE DEBRIS

A. Capturing and catching space debris:

This technique was first give the world by Europe agency name called de-orbit mission. This space mission was designedin 2014 and this mission having aim to use a method to capture or catching debris which are rotate in orbit with high speed velocity by use some kind of net or robotic arm harpoons or some tentacles. Which gives deorbit the satellite in orbit at altitude 500 to 620 miles that 700 to 1000 km.the space clean new proposed theory by Nasa and European agency for take or remove debris from space and decreasing environment impact and space mission impactthis also like we are going in river to fishing with fishing stick. Replace River with space vacuum and fish are debris.The scientists are free-falling through the air, shooting nets at but beforecatching the target, we track debris with accuracy and precision from ground technology there is no any error in tracking and update repot or catalogue. Target identification carried out by scientist. Depending on current technology need to be perform an operation like docking and ejection.In today condition Docking with target never been carried out by without human astronaut. To capture and de-orbit a large piece of spacedebris hardware is no small challenge, both technically, legally and financially. Considering that such a large number of targets need to be removed every year, the question raised is how to make it affordable, and who would pay. This again raisesthequestionofwhethermultipletargets could be removed in a single mission. The idea is simple; a net ejector mechanism ejects a net from a canister.

Fig. 4. Capture Technique

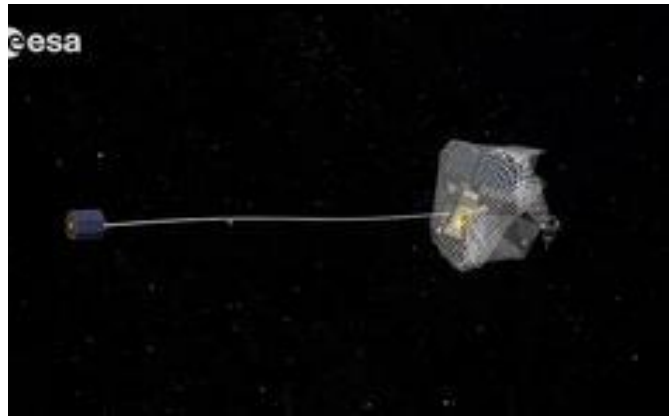

Fig. 5. net capture technique

B. Future rocket reusable

Re-usable rockets were a dreams of scientist for decades, after the first reusable experiment are successfully done in December 2015 the development of this type of rocket is challenging for designer and engineer for that innovative due to the little number of a mass rocket that can eject to the orbit. In actual condition payload of rocket is only 2-3% of the mass, that which so the at re-entry vehicle required mass of amount of fuel The return, vertical landing and recovery was done by big startupSpaceX gives technique which manufacturing process and their methodologies that gives increase efficiency to 3-4% . A SpaceXcompany rocketfalcon which isoperating with a reusable configuration carried 30-35% less payload lifting capacity than traditional rocket in one time use configuration.

C. Ablation Laser technique

Ablative laser technique is one type of laser evaporation that also used in medical field for cutting cancer cell easily. Today time this method proposed for removing space debris from earth orbit. Ablative laser method depends upon output power of laser is high energy to ablate debris for cutting surface debris. In that after cutting a debris vaporization take place that generate momentum to debris that are impact force on debris like laser propulsion rocket. In laser ablation high powered laser beam impact on direction of moving debris that change the moment and direction. These benefits in low input we get high efficient laser ablation that laser evaporation that having continues laser impact. We required that amount of energy that ablate debris material like aluminum or metal or alloy or space material composite. For that purpose we track moving debris over earth very precise and accurate those are our first step towards the debris remove. We use our latest technology from ground to identify the size and speed of debris that rotate and at which altitude or we launch a satellite to take measurement from space of debris in actual condition.If we want cost effective method so that ground approach is best option so that we don’t want to launch high cost satellite in space.Tracking of debris first we actually calculate the speed and momentum of various mass of debris and altitude and update our catalogue. Then we launch a satellite to space having laser facility that laser high energy beam which impact on debris for several times with high pulse so that debris reduced its speed of rotation and direction when required speed not obtained by debris that fall on earth. For that we required laser beam at specified frequency that ablate the debris easily. The we give more power impact to debris that momentum also change high which for big size debris. The material which absorbed the laser beam energy is high then momentum also change high. Basic expression for momentum changes that vector between laser and size of debris.

$$\Delta p = C_c D_e$$

Cc = coupling coefficient is varies with material of the debris. For aluminum maximum thec_c = *2 x* 10^{-5} *Ns/J.* delivered energy De that is laser function of laser power at point of impact (laser power at output, losses in space, properties of optical and other more, absorptivity for material, and the area at which exposed debris to beam of laser energy, laser's activation for course, output of energy approximately in constant value. during process mass is not constant s process. At ablation rate Mass is removed in piece, βvalue for aluminum approximately $\beta = 82 \times 10^{-9}$ *kg/J*, so the for laser varies mass denoted by$\Delta M = \beta E_d$. output laser high energy pulse at specific frequency isαthat amount of pulses generated, the equation that give change in velocity expressed by velocity equation for laser that as below.

$$\Delta v = \sum_{j=1}^{\alpha} \Delta vi = \sum_{j=1}^{\alpha} \frac{Cc * De}{Mj} \quad Mj = m0 - \sum_{i=1}^{j} \beta De$$

TABLE 1: ***output power of modern laser***

Laser	**Power at output**
Simple laser pen	6 MW
Defense laser for tactical	120 kW
Prototype of solid state Northrop	115 kW
Air to air laser	>2 MW

1) Power Required for laser ablation

Laser ablation technique is best among various proposed idea. Ablation technique for small size partsvarious laser beams, optics, monitoring and tracking, and precision optics technologies are readily available. However, both approaches require good amounts of laser power. For this study, several key laser parameters including the beam power, mode, wavelength, and optics were analyzed. The most required laser wavelength is ultra-violet (UV), which is most effective for laser-materials interaction [14]. By repeated laser detonations, the orbital debris speed and altitude are changed and the debris can eventually fall into Earth's atmosphere. Figure 8 shows the approximate number of pulsesrequired for stopping a 3 kg aluminum block orbiting at 10 km/s using laser pulse energy. In this estimate, a UV laser with 488 nm and 1 µs pulse width for an ablation rate of 3 mg per 100 J was usedHowever, it is not necessary to completely stop space debris; changing the orbital velocity is sufficient for gradual orbital decay and re-entry.

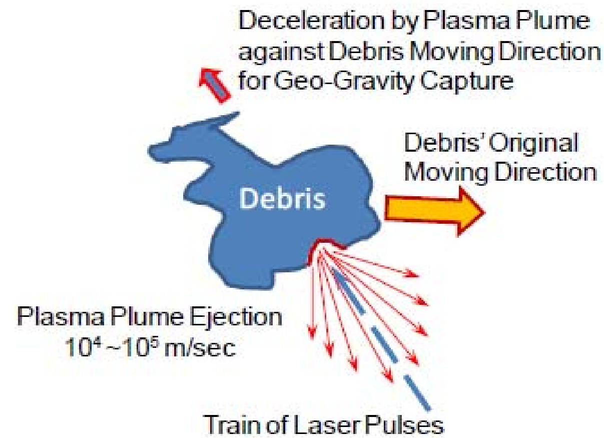

Fig. 6. Space debris is ablated after hitting by train of laser pulse. The plasma plume (red arrows) by laser ablation is ejected by approximately 105 m/s velocity and decelerates debris for geo-gravity capture.

Suppose that the orbiting speed of debris is reduced by 30% to 7 km/s, which requires approximately 27000 laser pulses. The use of higher pulse energy would require fewer amounts of pulses. The ablation point should not be always the same. The laser pulse may detonate the debris off from its own center of principal momentum, which will make the target rotate. However, the period of spinning caused by the off-center hit of impact is large compared to the repetition number of laser pulses, that the pulsed laser beam can repeatedly hit the same precise area. Regardless of where the laser pulses hit the target, the debris will continuously change its speed. If the object is reduces is speed which mean decelerated, the debris will continuously decrease altitude and momentum.so that at some level it falls on ground.

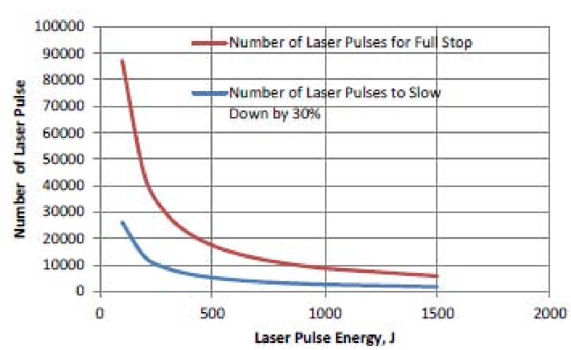

Fig. 7. Red line: No. of laser pulse required to stop 3kg aluminum block orbiting with 10-12 km/s Blue line: No. of Laser pulse to slow down the debris speed by 30%.

Its orbit and eventually reenter Earth's atmosphere. Based on this hypothesis, laser ablation is much more required than laser evaporation in terms of laser cost effective energy requirements and efficient operation.

V. CONCLUSIONS

In today's condition, the most feared problem towards space disaster is space debris that we are self-generating day by day. In this paper, we discussed various techniques among other that are both cost-effective and efficient and practically possible as well.These debris removal techniques mostly uses fundamental of physics. SpaceX give reusable rocket which is an efficient way of ejecting payload.Ablation laser technique will be proved very useful in future. The power required for either case can be obtained from solar energy. Paper proposed that ablation laser method would use less energy as compared to laser evaporation making this approach more useful and preferable in future.The reduced energy consumption by using laser ablation results from the lower laser pulse energy required for slowing the orbiting velocity of unwanted debris. This is also very cost-effective method as it uses the already available technology and with a more focused research could be employed practically. Manymethods are proposed but are either not economical or not practically possible. Thus suggesting more research to be carried out in the proposed possible techniques could result into creating a more cost effective and possibly efficient way to clean space debris so that in future space activities, various missions and journey are safe.

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REFERENCES

[1] S. Kibe, S. Kawamoto, F. Terui, S. Nishida and G. Gilardi; "R&D of the Active Removal System for Post-Mission Space Systems", IAC2003, Bremen, 2003Z. L. Li, et al. "SIMS study of plumes generated from laser ablation of polymers", Appl.Phys. A 78, 611-616, 2004

[2] B. K. Deka, P. E. Dyer, and J. A. Sayers, "Investigation of Laser Supported Detonation Waves and Thermal Coupling using 2.8µm HF Laser Irradiated Metal Targets", Journal of Physics Colloques, Vol. 41, No. C9, 1980. S. H. Choi, M. D. Williams, J. H. Lee, and E. J. Conway: "Diode Laser Power Module for Beamed Power Transmission, " Proceedings of the 26th IECEC, Boston, MA, Aug. 4-9, 1991.

[3] B. Carpenter, "Mitigation Of Orbiting Space Debris By Momentum Exchange With

[4] Drag-Inducing Particles", U.S. Patent pending, PCT/US2011/025181, Aug. 25, 2011.

[5] "History of Analytical Orbit Modeling in the U. S. Space Surveillance System"

[6] www.esa.int/SPECIALS/Space_Debris/index.html

[7] 05/science/27257957_1_space-debris-space-agencies-orbit

[8] Colorado Center for Aerodynamic Research http: //ccar.colorado.edu/asen5050/projects/projects 2010/borowski/Space Debris Environment.html

[9] Cranfield University Space Research http: //www.crantalk.com/cranspace/projects/projects-sustainable-space/

[10] Nasa.gov, https: //www.orbitaldebris.jsc.nasa.gov/library/usgod standard practices.pdf.

[11] esa.int, http: //www.esa.int/Our Activities/Operations/Space Debris/International cooperation

[12] T. Bando, K. Abe, and M. Yamashita, "Effect of ZnO Plasma Plume Dynamics on Laser Ablation", Optical Review, Vol. 17, No. 3, pp.309-312, 2010.

[13] S. Kibe, S. Kawamoto, F. Terui, S. Nishida and G.Gilardi; "R&D of the Active Removal System forPost-Mission Space Systems", IAC2003, Bremen, 2003

[14] J.R. Sanmartin, M. Martinez-Sanchez, E. Ahedo: "Barewire anodes for electrodynamic tethers", J. of Propulsionand Power, 1993

[15] S.Kawamoto, T.Makida, F.Sasaki, Y.Okawa andS.Nishida; "Precise numerical simulations of electrodynamictethers for an active debris removal system", ActaAstronautica 59, pp.139-148, 2006