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De-Orbit Kit Technology for Space Debris Mitigation

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Abstract- Space debris has become an important issue to deal with in the past few years as the probability of collision in space has augmented. Spacecrafts, Satellites, International Space Station, Probes and various other space objects are under threat as risk of collision at high orbital velocities can be damaging and highly destructive. It has hence become a prior need to find a solution for mitigation of space debris as armouring and shielding satellites and other objects is no longer feasible as it prolongs mission's and makes it cost derivative. The following is an arbitrary paper to solve the important issue of space debris and its mitigation. This paper is a semi technical survey of the expanding literature of the subject. The paper explores the different sources and mitigation methods of space debris. We have proposed a simple method to deal with this problem of space debris. We feel it can be very effective in the process of mitigation of space debris. The paper proposes the technique of a De-orbit Kit Technique and Magnetic Whipple Cone & Hydraulic Press. This paper inspires to remove all forms of debris orbiting space regardless of its size or material.

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De-Orbit Kit Technology for Space Debris Mitigation

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Abstract- Space debris has become an important issue to deal with in the past few years as the probability of collision in space has augmented. Spacecrafts, Satellites, International Space Station, Probes and various other space objects are under threat as risk of collision at high orbital velocities can be damaging and highly destructive. It has hence become a prior need to find a solution for mitigation of space debris as armouring and shielding satellites and other objects is no longer feasible as it prolongs mission's and makes it cost derivative. The following is an arbitrary paper to solve the important issue of space debris and its mitigation. This paper is a semi technical survey of the expanding literature of the subject. The paper explores the different sources and mitigation methods of space debris. We have proposed a simple method to deal with this problem of space debris. We feel it can be very effective in the process of mitigation of space debris. The paper proposes the technique of a De-orbit Kit Technique and Magnetic Whipple Cone & Hydraulic Press. This paper inspires to remove all forms of debris orbiting space regardless of its size or material.

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I. INTRODUCTION

Man made orbital debris continues to pose a threat to manned and unmanned missions in Earth orbit. Not only does the problem of orbital debris put at risk man made craft, it also endangers the lives of passengers in current and future manned spaceflight. An analysis of currently proposed methodologies for orbital debris mitigation and space remediation was compiled and an evaluation of their potential applications was performed. The analysis covers a broad spectrum of proposed solutions for a variety of different types of orbital debris. During our analysis the realization was made that the highest concentration of defunct satellites is found in Low Earth Orbit (Henceforth referred to as L.E.O.). Also determined was that current methodologies proposed for de-orbiting satellites in L.E.O. were mostly designed for de-orbiting a single space craft per mission. This helped narrow our search for a solution. We began developing a methodology with the primary objective of de-orbiting

multiple defunct space craft within the scope of a single mission.

We propose a solution in the form of a satellite system serving as a delivery unit which houses a plurality of remote operated semi-self-attaching de-orbiter modules. These are assisted in deployment via robotic arm which is fixed to the delivery satellite chassis.

In this technique our main target is 46% non-functional satellites or other defunct objects in LEO. We began developing a methodology with the primary objective of de-orbiting multiple defunct space craft within the scope of a single mission. We propose a solution in the form of a satellite system serving as a delivery unit which houses a plurality of remote operated semi-self-attaching de-orbiter modules. These are assisted in deployment via robotic arm which is fixed to the delivery satellite chassis. The whole mission is divided into four phases from launching to de-orbiting of de-functional object followed by ejection of satellite system (delivery unit) into LEO at a height of 600-2000KM (depend upon the target object) and detection & de-orbit installation system phase (Detection can be done with the help of photon camera/sensor attached on satellite, optical sensors or database from IADC).

II. MODULES USED IN TECHNIQUE

The proposed solution presented here is a satellite package consisting of the following systems.

a) Communication System

Comprises of two way radio communications arrays enabling live broadcast of satellite telemetry from all systems and providing ground control with an interface for controlling satellite systems.

b) Electrical Power System

The electrical power system is made up of a dual axis gimbal actuated solar panel array which provides power to a battery bank through a power converter. A power supply then supplies electricity to individual satellite systems.

c) Orbital Intercept and Thrust Control System (OITCS)

This system records space craft velocity, altitude and orbital information and performs orbital maneuvers to intercept targeted debris. These intercept operations are performed following a preprogrammed

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course determined to be the most efficient path between targeted debris.

d) *Attitude Determination and Control System (ADCS)*

This system records and controls the satellites rate of rotation and orientation. It is responsible for stabilizing disturbance torques, and is composed of an assembly of ultra-high precision rotary incremental actuators.

e) *De-orbit Module installation system*

This system is comprised of a robotic armature assembly which collects de-orbit modules from a rack fixed to the inside of the chassis.

This rack can be designed to hold multiple de-orbit modules.

f) *De-Orbit Module*

The de-orbit module consists of an assembly of systems in a compact package. It includes an automated installation system comprised of guided drills in an armature affixed to the de-orbit module, a computer control module, communications array which connects remotely to the satellite, power system and a pulsed plasma thruster system using solid Teflon as fuel, as well as a GPS device intended to enable

tracking on de-orbit. This module connects to the arm via an electromechanical connection.

III. PARAMETERS

We understand that debris can be thoroughly differentiated by its size and the strength of material it has been made up of. It has been observed that most hazardous space debris size more than 1 cm in diameter. Let us classify various types of debris according to their size.

OA: *Size (1cm – 10 cm)*

This debris mainly consists of paint flakes, lost tools, slag and dust from solid rocket motors, surface degradation products such as paint flakes, clusters of small needles.

OB1: *Size (10cm – 150 cm)*

Lost equipment, spare parts of rockets, satellites.

OB2: *Size (150cm – 300cm)*

Rocket boosters, dead spacecraft parts.

OC: *Size (Debris > 300 cm)*

Non functional spacecrafts, defunct satellites.

Table 1 : Table predicting the space debris behaviour

Debris size ϕ (cm)	Speed (m/s)	Mass (kg)	Momentum (kgm/s)	kinetic energy(joule)	Impact time (s)	Impulse force(N)
$\Phi < 1\text{cm}$	7350					
0.01	-	0.001	7.35	27011.25	10 ⁻³	7350
0.04	-	0.004	29.4	108045	10 ⁻³	29400
0.08	-	0.008	58.8	216090	10 ⁻³	58800
$1 < \phi < 10$	7350					
4	-	0.04	294	1080450	10 ⁻³	29400
6	-	0.06	441	1620675	10 ⁻³	441000
8	-	0.08	588	2160900	10 ⁻³	588000

As most of the artificial spacecrafts and human inhibitions have taken place in the Low Earth Orbit (LEO). It has been found that a debris of size() 10 cm will have the mass of 1kg. So taking this mass as a referral mass we have calculated and formed the list of the impact force the debris will do.

If 10 cm of debris has mass = 1 kg, so 1 cm of debris will have the mass = 0.1 kg.

Momentum (p) equation is given as = mass * velocity.

Average speed at low earth orbit = 7350m/s.

Impulse force = Rate of change of momentum = dp/dt

From the table we can predict the even the smallest of the debris (i.e. $\phi = 0.01\text{cm}$) is possessing a high amount of energy and can a possible collision threat.

With respect to the strength of material, we need to know if any particular debris can be burned into the atmosphere and if not, how it can be safely brought down to Earth. As it is unfeasible for us to send debris

out of orbital limits by giving enough thrust to reach its escape velocity, it is only easier to bring it back down to Earth or burn it in the atmosphere.

Thus, every size comes with a simple and effective solution.

Object A:

Let us consider debris of the size (1cm – 10 cm) as Object A (OA). Our simple solution for OA is to decrease its velocity, bring it to lower orbits and burn them in the atmosphere.

Object B1:

Let us consider debris of the size (10 cm – 150 cm) as Object B1 (OB1). We can use hydraulic press. It will generate enough power to break the speed of the debris travelling at orbital velocities without causing it damage and redirecting it's trajectory into lower orbits where the debris will get burned in the atmosphere.

Object B2:

Object B2 (OB2) will be of the size (150 cm – 300 cm). Although the same process of hydraulic press will be used to break orbital velocities for OB2, however if it does not burn in the atmosphere, to avoid catastrophe, OB2 will be attached to a De-Orbit Kit. The De-Orbit Kit will mainly consist of a GPS tracker and a Parachute. The remnants of this debris will be brought down safely to Earth.

Object C:

For object C (OC) as defined above we can use De-orbit kit technique followed by retro thrusters followed by De-orbit kit.

IV. METHODOLOGY

In order to achieve the goals of this project, we are proposing this program as a multifaceted approach to the issue of space junk mitigation. The primary steps of this project are the establishment of a test bed for future expansion of this project, and the establishment of protocols, standards and best practices in this attempt to mitigate space junk.

In the beginning, a selection process would be brought forward to determine a target satellite for de-orbit. This selection process would involve the space-faring community at large as there are several international, legal and specific implications to a project with such scope.

Once candidate target orbital debris has been selected, and all relevant information about the target is fully studied, the project would move forward to the next step.

To accomplish the objectives of said test mission we would propose the construction of Debris De-orbit Satellite, containing de-orbit modules for four distinct sizes that are proportional to the size of the debris. This satellite will be designed to be equipped with a De-Orbit Kit (DOK) and a Harpoon Retro Thruster. It will also be equipped with autonomous robotic arms, drilling tools, radar, photon cameras, Inertial Reference System (IRS)

The servicer craft would next locate and meet with the defunct satellite unit, by using its remote sensors to intercept the defunct satellite and achieve orbit lock. Once in orbit lock, controllers on earth can manipulate the on board robotic arm in real-time via a relayed down-link, and pull itself into a close operating range to the defunct unit. Once the servicer is in position, a securing “foot/claw” would deploy from the base of the servicer, securing the servicer craft to the orbital debris, freeing up the robotic arm for the next task at hand. Once the debris is identified categorically, one of the above mentioned methods will be implemented.

OA: For objects falling under this category, we can use the hydraulic press to decrease its velocity and change

the trajectory. Once completely enveloped, the debris will be released from the “foot/claw” arrangement. The press will decrease its velocity, sending it into lower orbits and burning it into the atmosphere.

OB1: For debris falling under this category, the captured debris will match the orbital velocity and lock and align itself with the spacecraft. After a detailed analysis of the debris, a hydraulic punch via the hydraulic press will be initiated on the debris, to move it out of its current trajectory and also decreasing its speed to lower orbits where it will be obliterated into the atmosphere. Before the hydraulic punch, the robotic arms will release the debris. We have to keep in mind that only sufficient power will be used such that it does not destroy the debris and create further junk, but only changes its trajectory and reduces its velocity.

OB2: For debris falling under this category, once it is secured and locked, a DOK will be attached to its body, once attached, a tug test will be initiated with a visual and mechanical confirmation of a secured de orbit kit. The arms will be released and again the hydraulic press will be initiated. Once in lower orbits, the timer circuit with altitude reading capabilities will open a chute, to bring the debris safely back on Earth if it does not get obliterated in the atmosphere. The DOK can be recovered and reused.

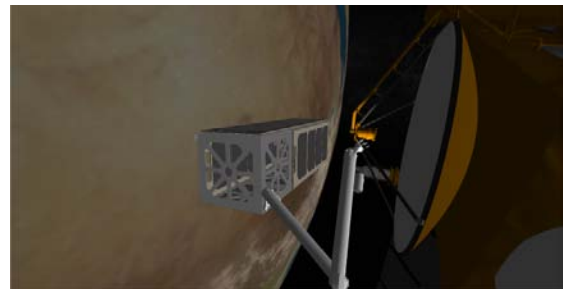


Figure 1 : Artistic View of project

OC: For debris under this category, after the lock, the spacecraft will attach a thruster to the debris, with a high tensile rope and at the other end of the rope will be a retro thruster. Once secured, again a tug test will be initiated. After confirmation, the debris will be undocked from the craft. Finally the retro thrusters will be initiated; thus provided thrust in the opposite direction will reduce the velocity of the defunct satellite. Later a chute from the thrusters will be deployed at preset altitude and the debris will be brought down to Earth safely.

All systems will be controlled and activated by teams working on ground stations. Mathematical calculations will be made to bring down Debris safely and land them on water bodies.

Due to the experimental nature of this test mission, the servicer craft will then be tasked to perform its own de-orbit sequence in order to gather mission data, such as temperatures, speeds, as well as a video feed, and relay it to ground stations in real-time. This will

simultaneously accomplish our obligation to not leave behind any debris ourselves in the course of this work.

V. ADVANTAGES

One of the key advantages of this system-solution is its easy implementation in comparison to currently proposed techniques. We are striving to keep the project costs low and will be relying on a launch of the small-satellite to be executed via the Indian Space Research Organization (ISRO) space agency.

The most crucial aspect of this newly proposed system-solution is that while current techniques are limited to the de-orbiting of only one inactive satellite in one year, we are working to offer its new technology that has the potential to be scaled up to target hundreds of inactive satellites in one mission.

The total aim of the project is the elimination of 43% of the total inactive satellites in orbit. Our design team's meticulous attention to detail, as well as intensive study of existing small sat and larger sat technologies provide our partnership with several advantages, namely: lower mission costs, more efficient weight management, small size of system-sat, and longer and more efficient mission duration. Additional benefits are rooted in the fact that this is a complete system-solution, a package that can deliver de-orbiter units to orbital debris. The system is evolutionary and modular, we have incorporated features such as serviceability, eg. refueling capability as well as re-loadable payload bay, which translates to very long system life, versatility, etc.

VI. CONCLUSION

All attempts to remove orbital debris from the Earth's orbit will be valuable to the international community, as it will provide for not only optimal solutions in solving the space junk and space debris crisis, but also the subsequent accumulation of scientific and intellectual knowledge will be of extreme value for the future.

As we have found that some aspects of this type of technology are not readily available in the international market place. This project needs to be created from scratch, the most logical and effective means to achieve this goal is by employing the strategy of crowd-sourcing expertise from all scientific and research domains in order to ensure all systems meet and exceed industry standards. We also believe an injection of funds from an outside conglomerate of investors would greatly benefit this project.

The future of space flight is at risk due to the *Kessler Syndrome*, *space* remediation is necessary in order to secure that future. Our proposed system provides multiple solutions to problems faced in space remediation. For this reason we have delivered this preliminary proposal in the hopes of producing critical data which may help improve the state of space above

earth and promote the safe and responsible use of space to the international community.

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