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Active Space Debris Removal by Extreme Ultraviolet Radiation

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Abstract—*The problem of space debris has become very serious. The mass of the artificial objects in the orbit has been increasing steadily at the rate of about 145 metric tons annually, leading to a total tally of approximately 7000 metric tons. About 97% of space debris occupies the LEO. The catastrophic collision could be mostly occurred in LEO region, thus causing new debris. The innovation deals with the creation of the drag force in front of the space debris by exhausting the Extreme Ultraviolet (EUV) radiation from the re-orbiter also with the feasibility study of a mission for the active removal of space debris objects in low Earth orbit at attitude from 300km to 800km.This drag force is used to reduce the velocity and attitude gradually and finally enter into the earth's atmosphere. This method removes the space debris object without catching debris object. Thus it can be applied to a wide range of debris object without regard to their shapes or rotation.*

Index Terms*: Active space debris removal, extreme ultraviolet, ionospheric expansion, re-orbiter.*

1. INTRODUCTION

The space age began 50 years ago with launch or SPUTNIK I by Soviet Union on 4th October 1957. About 6,600 satellites have been launched.

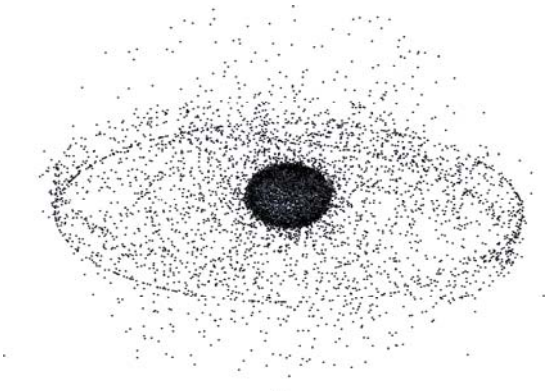

Fig. 1: Space debris around the earth

The latest estimates are 3,600 remains in orbit. Were 1000 are operational condition and the rest have lived out their useful lives and are part of space debris. Approximately 500 operational satellites in LEO, 50 are in MEO and others in GEO. Space debris is any human made object in orbit that no longer serves a useful purpose. This includes everything from spent rocket stages, Old satellites, Fragment from Disintegration erosion and collision. The problem of Space debris recognized for gears is now assuming Dangerous proportion. Most of the debris is formed by the collision or explosion of large sized debris such as dead satellites, Rocket bodies.

Mankind has so far as it stands the total amount of space debris amount to

a) 29,000 larger than 4 inches (10 cm).
b) 670,000 larger than 0.4 inches (1 cm).
c) 170 million larger than 0.04 inches (1 mm).

Cataloged objects in orbit around the earth. Only 25% of the pay loads are active satellites, 48% is of breakup debris, 13% of Rocket stages, 12% of mission related debris, 1% of anomalous debris. Approximately 65% of all cataloged space debris originated from breakups in orbits, including those caused by about 240 explosions (mostly explosion of rocket bodies) and some 10 collision. Two large objects collide and procedure thousands of smaller ones. For instance when a satellite that belonged to the company Iridium, collided with an Old Russian satellite in 10th February, 2009 and it created 2,000 pieces of new debris. A couple of year earlier, the Chinese added 3,000 pieces to the Junk when they intentionally destroyed a satellite FV – 1C in polar orbit at 865km altitude of their for testing an anti-satellite weapon in Jan 11, 2007. In LEO most percentage of space debris are present and also active satellites are present. So in LEO the density of objects is highly enough that collision between objects. Beyond this point a runway chain reaction may occur that would rapidly increase the number of debris in orbit and increase the risk to operational satellites called Kessler syndrome. According to Kessler syndrome the LEO debris is high enough to produce catastrophic collision between debris. The hundreds of fragments large enough to catastrophically

breakup other satellites and ten thousand of fragment large enough to damage other satellite it is Predicted in 1978 by NASA scientist “Donald J. Kessler”. The international space station, Hubble telescope and other many satellites are orbiting in the ionosphere region an altitude of 300km to 800km. Most of the rocket leaves their stages during their satellites launches and dead satellites are present in the ionosphere. The space debris are travel extremely fast some as fast as 18,000 mph and take 90 minutes to rotate one time the earth at 400 km altitude. At this speed it can rotate the earth in 16 times in one day.so it can more chance to hit one another. ISS risk being 1 in 300 debris and Hubble Telescope to be 1 in 185 debris. So we can first De-Orbit the large sized debris in LEO (300-800 km) to reduce the cascade effect (or) collision with international space station, operational satellites and other debris and prevent the growth of the space debris at this region. Effective debris mitigation is necessary to clear the space debris.

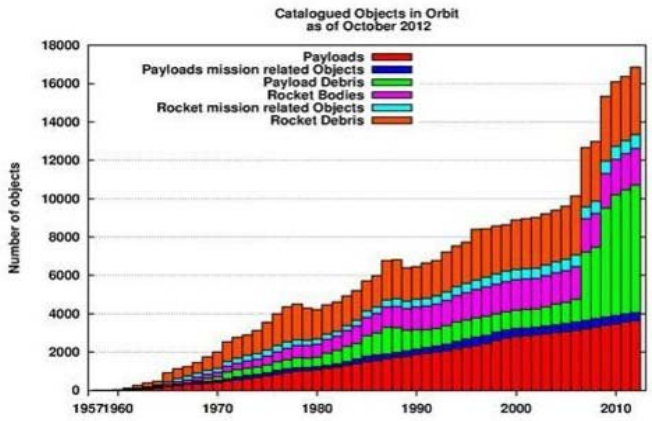

Fig. 2: Growth of space debris

2. PROPOSING SOLUTIONS TO DEBRIS PROBLEM

There are variety of solution has been proposed to clean the space debris from the space. The few names are,

- Attaching De-orbiting kit.
- deploying clouds of tungsten dust
- blocks of aerogel
- ground or space based laser system
- gas balloons
- harpoons and nets

In attaching de-orbiting kit it have required large spacecraft and large propellant tank to reach the target debris to match the speed and path of the target debris. In this method to attach the de-orbiting in rotating objet will be difficult. But this method is most expansive that 27 m$ per large object.

In ground and space based laser system has many difficulties are occurred. In ground based system it may strike the overflying aircraft and operational satellites. It is difficult to pass the laser into object. It also creates environment distortion. In space based laser system is most expansive and difficult to build the laser system in space. In both laser systems are possible to form a weapon system and terrorism in space.

In gas balloon solution the balloon are 100km diameter and 160 kilotons. They are placed in space to strike the debris and blast into the debris. During blasting the gases in the balloon are flow over the debris and create the drag and slowdown the debris. But they are one time solution (one balloon per target). During one balloon launch cost is $ 1600nbillion in today launch technology

The aerogel solution has similar problems. It is easy to show that an aerogel “catcher’s mitt” solution designed to clear the debris in two years would require a slab 50 cm thick and 13 km on a side. Such a slab would have 80-kilotons mass, and would cost $800M to launch. Even if we ignore the difficulty of maintaining this shape, a fatal problem is the steady 12 KN average thrust required to oppose orbital decay of the slab facing ram pressure over an elliptical orbit ranging between 400 km and 1100 km altitude. To maintain this thrust over a two-year lifetime would require a fuel mass of 150 kilotons, in addition to the mitt mass, tripling the cost.

From the above methods are proposed to clean the space debris from space. But every methods has more cost and so many difficult to clean the space debris from the space safely and successfully.

3. IONOSPHERIC EXPANSION

Ionosphere is the layer of the earth’s atmosphere. It expands from 60km to 800km approximately. The international space station and other many satellites are orbiting in the ionosphere. In the ionosphere atomic oxygen (O), atomic nitrogen (N) and helium are main components of the air. Solar activity strongly influences temperature in ionosphere. In this layer the temperature ranges from climbs from about 500^{o}C to 2000^{o}C or highly due to absorption of the solar X-radiation and Extreme Ultraviolet rays with the gaseous particles in the ionosphere.

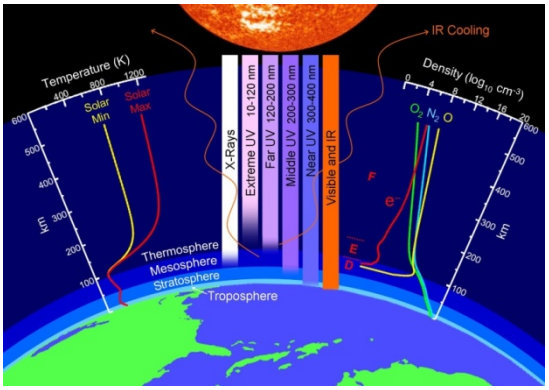

Fig. 3: Layer of earth upper atomsphere

Due to this absorption of the solar X-rays and solar Extreme Ultraviolet (EUV) in ionosphere get ionization and expands or puffs up, because the atomic oxygen and atomic nitrogen are efficient absorber for solar X-rays and solar EUV. From this expansion the density of the ionosphere will be increases and satellites feel aerodynamic drag when they move through the ionosphere. So the international space station and other satellites are experienced orbital decay due to drag force strongly acting on it. It results reduction in the speed and altitude of a satellite's orbit.

From this natural ionosphere expansion we concluded the EUV and solar X-rays are cause drag on the satellites orbiting in the ionosphere. So we can use the artificial Extreme Ultraviolet radiation to remove the orbiting space debris in the ionosphere when passing the artificial Extreme Ultraviolet radiation in front area of the space debris to create the ionospheric expansion.

4. SELECTION OF THE TARGET

According to the NASA and NORAD report on the debris that most of the rocket leave their stages during their satellites launches and dead satellites are present in the region an altitude of 300km to 800km. In this region debris population is high, so it is high enough to produce the cascading collision between international space station, operational satellites and other debris present in the region.

So suggest that optimal debris removal should be carried out in this region an altitude of 300km to 800km and possibly reduce the cascade effect (or) collision with international space station, operational satellites and other debris and prevent the growth of the space debris.

5. MISSION CONCEPT

In this section a preliminary concept for removing the space debris by Extreme Ultraviolet (EUV) radiation is presented.

1. Overview
2. Re-orbiter system
3. Approaching the target
4. Removal of space debris

5.1 Overview

The re-orbiter is equipped (or) installed with Extreme Ultraviolet generator. This re-orbiter is directly launched into the orbit of the first target object selected for removal. After the rendezvous with the target objects assumed to be a dead satellites or rocket upper stages in a certain distance. The extreme ultraviolet radiation exhausted continuously from the extreme ultraviolet generator in re-orbiter to in front of the target object. This extreme ultraviolet radiation is capable to create the ionization and expand or puffs up the region ahead of target object. This expansion generates the drag forces to the target object. For example the target object travelling at the speed of 10km/s, so this drag forces is high enough to reduce the velocity to 8km/s. due to this reduced velocity the target object will automatically lose their altitude and enter onto the earth atmosphere. During the atmospheric re-entry the target object will be burnt due to aerodynamic heating or splash into the oceanic part in the earth. After the first target object is removed, the re-orbiter can goes to the approaching the next target.

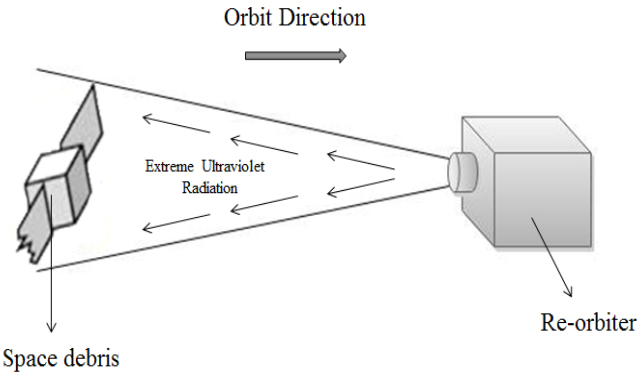

Fig. 4: Schematic drawing of the re-orbiter concept

5.2 Re-orbiter System

The ionospheric region has low density than below earth atmosphere. In this region the Extreme Ultraviolet radiation is fully absorbed by the gaseous particles presented in the region than the solar X-rays. So the re-orbiter is equipped with Extreme Ultraviolet generator is used to remove the orbiting space debris object in the region.

The extreme ultraviolet (EUV) radiation or High Energy Ultraviolet radiation is the electromagnetic radiation with a wavelength from 120 nm down to 10nm and having photons with energies from 10ev to 12ev. The atomic oxygen (O) and atomic nitrogen (N) are efficient absorbers of the Extreme ultraviolet radiation. The photons of the EUV radiation are reacting with atomic oxygen and atomic nitrogen will break the atom into photon and electrons.

$$O2 + h\nu \rightarrow O + O$$

$$N2 + h\nu \rightarrow N + N$$

$$O + h\nu \rightarrow O^{+} + e$$

$$X + h\nu \rightarrow X^{+} + e$$

This breakage of atomic oxygen and atomic nitrogen are causes the ionization in the ionosphere and expands or puffs up.

In the re-orbiter the Extreme Ultraviolet radiation cannot emit by neutral atoms or condensed matter. The EUV will be generated by the electrons which are bound to multicharged positive ions in a hot dense plasma (or) generated by intense electric field of a very high harmonic laser beams. The EUV radiation can also be generated by synchrotron light sources.

By using one of these methods the re-orbiter generate the Extreme Ultraviolet radiation for removing the space debris from the region an altitude range from 300km to 800km. various sensors are used for rendezvous with space debris and thruster is used for drive the re-orbiter in the correct path

5.3 Approaching the Target

Is assumed that the re-orbiter is injected directly into the selected debris target orbit plane in a lower altitude parking orbit. By exploiting the different orbital periods, approaching the target is achieved in order to start the rendezvous maneuver, which reduces to a few tens of kilometers the separation of the re-orbiter from the target expected location. This last one may have an error upto1–2 km due to uncertainty in ground tracking and available Two-Line Elements (TLE) data set, which, as well known, are updated at prefixed time intervals. Before starting the rendezvous the actual position of the debris object shall be determined by using optical sensors and IR sensors. In far range rendezvous, the far range sensors give the line of sight (LOS) to the target in order to correctly drive the approach maneuver. The range and bearing can be determined by the optical cameras. This optical camera provides the positive identification of the target debris object. In mid-range rendezvous, the visible tracking cameras are used to track the wide field view of the debris object and infrared sensors are tracing coverage the periods of poor illumination. This far and mid rendezvous will give the positive identification of the target debris

After the final positive identification of the target debris, the re-orbiter goes ahead of the target. The final approaching of the target is performed by re-obiter in certain distance for removing operation. This certain distance between re-orbiter and target debris is adjusted by matching the re-orbiter's velocity to target debris velocity using the thruster of the re-orbiter. This phase brings the correct opportunities to exhaust the Extreme Ultraviolet radiation to create the drag on the target debris.

5.4 Removal of Space Debris

After the re-orbiter rendezvous with the space debris object in certain distance, the re-orbiter exhausts the Extreme Ultraviolet radiation to the area ahead of the target debris object. This extreme ultraviolet radiation's photons are absorbed completely by the atomic oxygen and atomic nitrogen present in region. Due to this absorption the EUV photons are break the atoms of the atomic oxygen and atomic nitrogen into protons and electrons and create the ionization in this region. The ionization causes the ionospheric expansion or puffs up and increases the density in the region present in front of the space debris. This increase in density generates the drag on the space debris object. Continuous drag will be generated to the space debris object by continuous exhaustion of the Extreme ultraviolet radiation to the space debris. This continuous drag forces will act on the space debris object, the velocity will be reduced. Due to the reduced velocity the space debris will lose the altitude because of the gravitational pull of the earth. The re-orbiter will continuously pass the EUV to the space debris region, until they lose the velocity and altitude. The space debris has slowly lost the altitude and in certain time it will enter into the earth atmosphere and burnt due to aerodynamic heating or fall in the oceanic parts of the earth.

Considering the debris object relative velocity is 10km/s. it is reduced into 8km/s by re-orbiter. This relative velocity will be high enough to re-enter the debris object into earth atmosphere.

After the first target object's velocity gets reduced, the re-orbiter rendezvous with the next target and remove it from the ionosphere

6. CONCLUSION

The active removal of large debris, such as the rocket body stages, dead satellites and other space debris is a complex operation requiring the combination of several advanced technologies. The system study revealed that effective debris re-orbit missions can be conducted using this re-orbiter system. In this paper, the concept of the re-orbiter to remove the space debris in the region at attitude from 300km to 800km by Extreme Ultraviolet (EUV) Radiation. This extreme ultraviolet radiation produce the drag and to reduce the velocity of the space debris. This technique is more efficient and cost also low when compared to the pother methods.

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