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Space Debris Hazard Mitigation Operations

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Abstract:- Space debris in Earth's orbit poses a significant danger to satellites, humans in space, and future space exploration activities. In particular, the increasing number of unidentifiable objects, smaller than 10 cm, presents a serious hazard. Various technologies have been studied to remove this Space debris. This paper discusses the technique of removal of Space debris from Earth's orbit and bringing it back to Earth safely. A 2-stage rocket with a unique method of propulsion system will be sent into space where the 2nd stage will act as an orbiter comprised of a Robotic arm covered by a durable Metallic Micro-lattice net. The mechanism will be used to capture the space debris. This system will include multiple cameras and sensors for detecting the debris. Live tracking and identification will be supported by AI and ML. Also, an active hydraulic system filled with MRF will be attached between the sections of the robotic arm. The active hydraulic system will help/protect the mechanism to resist the impact force. The fairing will be permanently attached to the 2nd stage just like doors and windows are attached to the frame which will be reused to protect the system as well as the debris during re-entry. The hot side of the thermoelectric pad will be in contact with the inner surface which will act as a heat sink. The other/cold side will be directly exposed to the mechanism and debris. As a result, it will create a cold ambient temperature inside the fairing keeping the payload safe and cool from the re-entry heat. Using a modified propulsion system, we will achieve this mechanism which will also produce electricity as well as act as an ignition system for the fuel. When the whole system will be in re-entry phase, thrust vectors fitted at the body of the 2nd stage carrying the payload will come in use. It will rotate the system by 180 degrees. Further the thrusters will turn on and will act as a reverse thruster. This will slow down the freely falling system. Moreover, parachutes will also increase the air drag which will further slowdown the speed while returning and the hydraulic legs fitted at the bottom of the mechanism will result in minimum impact with the surface.

Keywords:- *Space Debris, Robotic Arm, Metallic Micro-Lattice Net, Thermoelectric Pad, Modified Propulsion System.*

I. INTRODUCTION

Space debris are one of the major concerns for the aerospace industry and related missions. They possess risks for any further space operations. Based on the risk involved many nations and agencies have been actively working on the space debris removal techniques.

The main aim of the paper is to suggest a mechanism for removing the debris and bring it safely to the ground surface for further use (if possible). The main risk of starts when it is close to planet earth at Low Earth Orbit (LEO) and Geostationary Earth Orbit (GEO).

At present there are uncountable satellites operating in our Earth orbit and 3 areas hold 95% of the satellites as shown in Fig.1.

- Low Earth orbit (LEO): 300 to 2000km altitude, 7 to 8 km/s orbital speed, 1.5-3 hour period
- Semi-Synchronous: 20,000km altitude, 4km/s orbital speed, Navigation Satellites, 12-hour period.
- Geosynchronous: 36,000 km, 3km/s orbital speed, Communication and Broadcasting Satellites, 24 hour period.

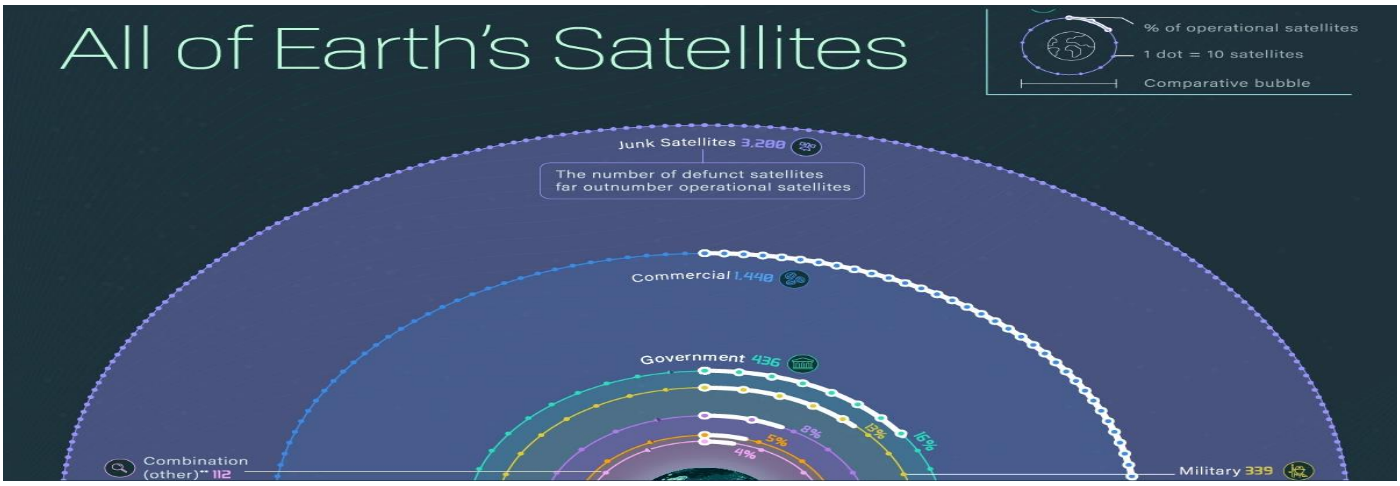

Fig 1 Current Satellite used for various purposes.

Fig.1 shows the collection of space debris orbiting over space. Satellites used today are not only for space studies and research but also for various commercial purposes like communication and navigation. Hence removing satellites from space to clear the cluster may result in a crisis in the world economy as well.

More than 27,000 pieces of orbital debris, or “space junk,” are tracked by the Department of Defense’s global Space Surveillance Network (SSN) sensors. There are approximately 23,000 pieces of debris larger than a softball orbiting the Earth. They travel at speeds up to 17,500 mph, fast enough for a relatively small piece of orbital debris to damage a satellite or a spacecraft. There are half a million pieces of debris the size of a marble or larger (up to 0.4 inches, or 1 centimetre) or larger, and approximately 100 million pieces of debris about .04 inches (or one millimetre) and larger. There is even smaller micrometre-sized (0.000039 of an inch in diameter) debris.

Space Debris have been a very serious issue for the environment related to the space operations and activities. In other words, it has been a threat for the space. The number of satellites launched have been increasing gradually. This ultimately leads to create a serious hazard in space operations. At current times many of these junk that are orbiting earth at a speed of several km per second. Many space organisations are launchings their satellites for their required use in the field of weather, communication, navigation, defence, etc.

II. PRESENT SCENARIO: THE ACTIVE GROWTH OF SPACE DEBRIS

We humans have been interested in space from earlier times of civilisation. With its advancements many satellites have been launched into space for its study and making livelihood easy. In our everyday lives these satellites prove to be compulsory for various purposes like climate change, telecommunications, localization, security, etc. As a result, the debris formed in LEO have become a very reflective issue.

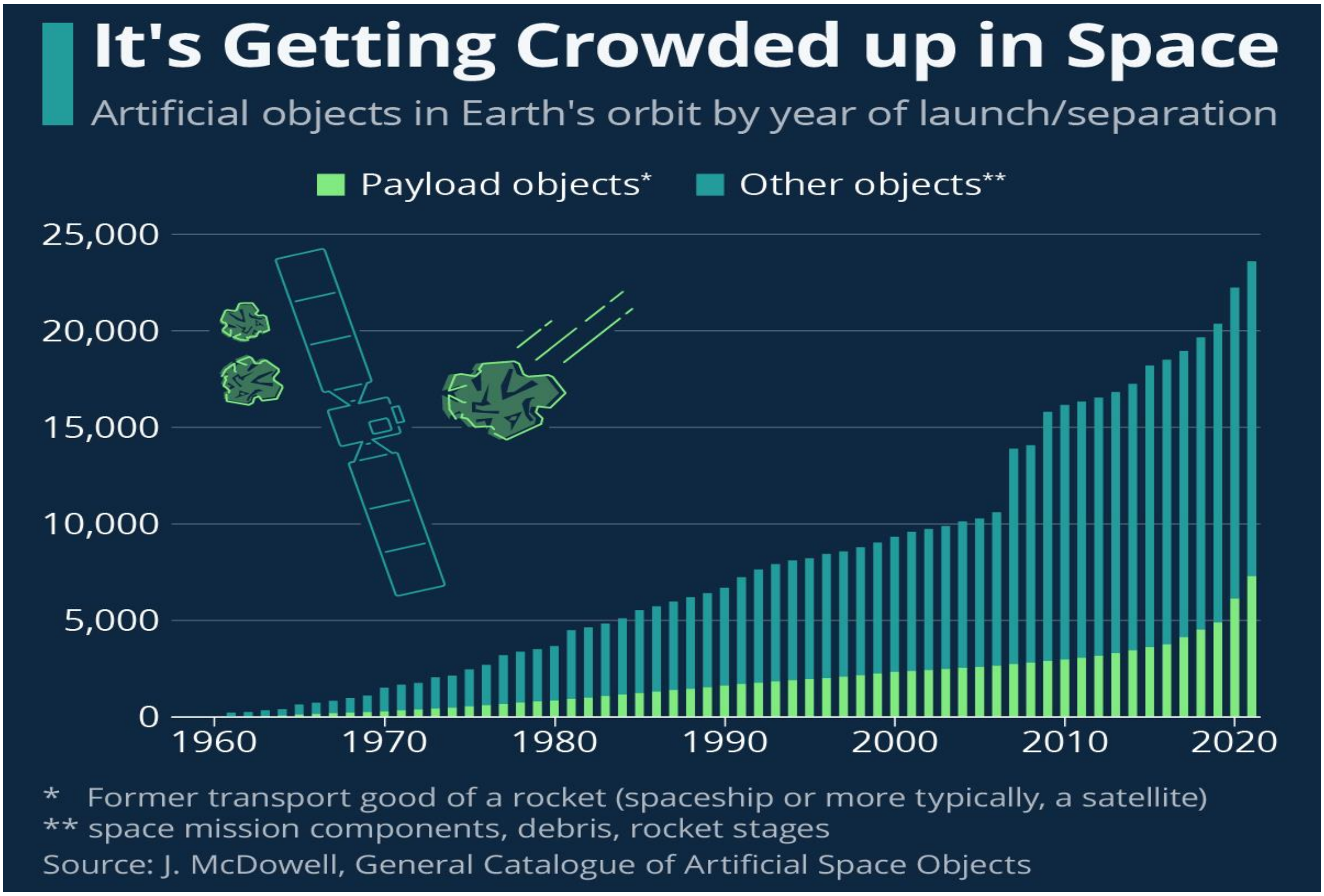

Fig 2 Growing junk from 1960 to 2020

Around 4000 to 6000 satellites were alone sent into space 1960 to 2010. Apart from this 400 were launched for interplanetary missions. However, the staying ones are just around 800 are outfitted means typically 85% of the space objects.

Fig 3 Manmade Debris Left in Space

Orbital debris are the man-made objects left out in space that are formed due to various reasons as shown in Fig.3. These are not uniformly distributed in the space. They move to such areas where the launch target region is more common, more precisely, in the LEO and GEO regions as shown in Fig.3.

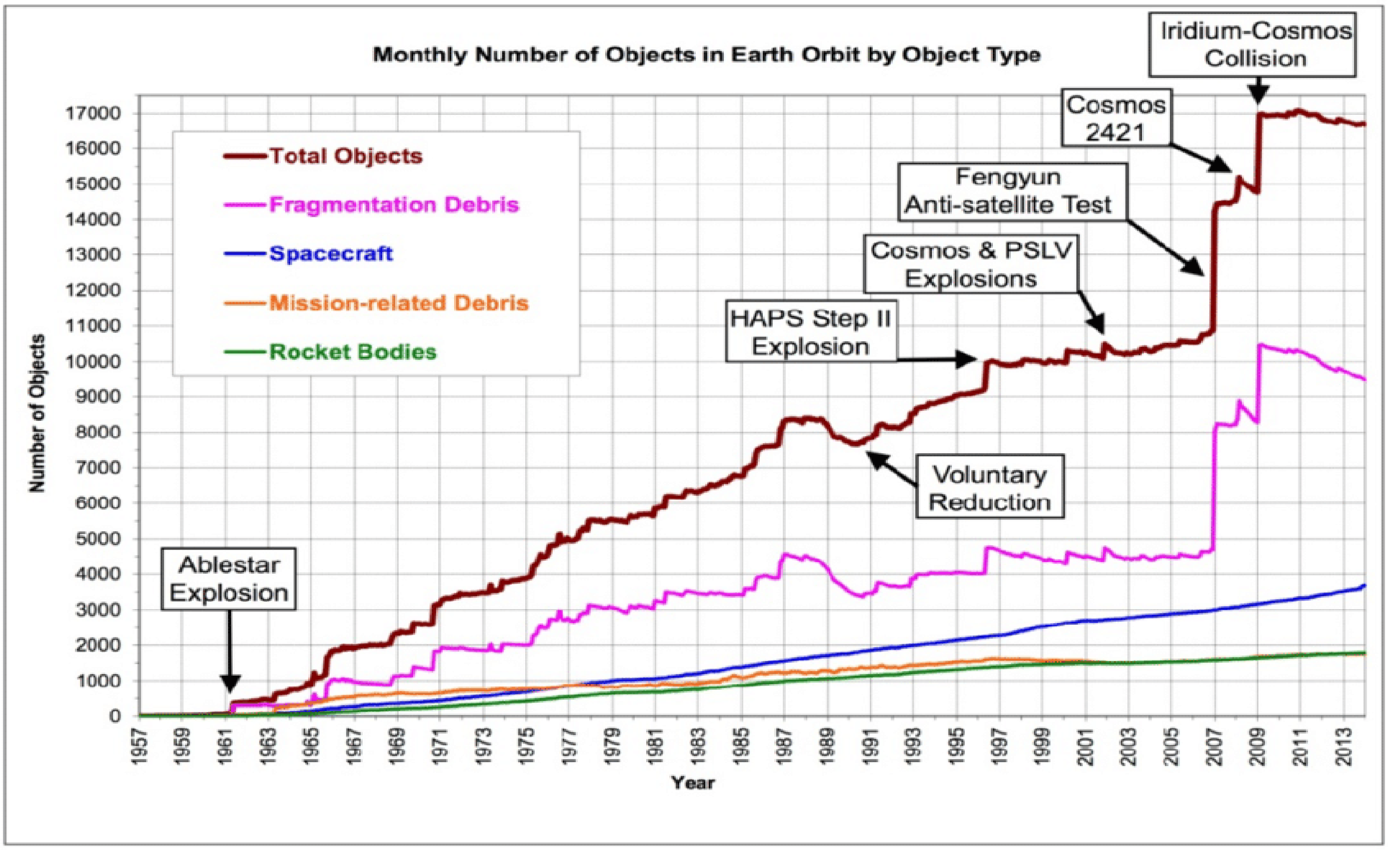

Fig 4 Growth of Number of Objects over the last 60 years (till 2013).

The above shown graph depicts the evaluation of the number of objects within Earth orbit. Fig.4. shows the monthly number of registered objects present in Earth's orbits listed by the US Space Surveillance Network (USSN).

III. ACTIVE SPACE DEBRIS REMOVAL MECHANISM

At first a 2-stage rocket is taken. Staging is used for increasing the overall efficiency of the operation. The final stage will be equipped with an active space debris removal mechanism. This mechanism will be having multiple robotics arms attached to its periphery. The arms will be engulphed with a net of micro metallic lattice. An active tracking sensor and software installed in the onboard computer will determine the orbit of the debris and the propulsion system will propel the mechanism to the desired orbit and the speed necessary to capture the debris. To protect the mechanism from the impact, the robotic arms and the net made of micro metallic lattice will come into action. The robotic arms will be using hydraulics filled with MRF Fluid for better compression and resistance of impact force. The role of the net is not only to increase the surface area and capture minute particles but also to resist the force due to collision as depicted in fig.5.

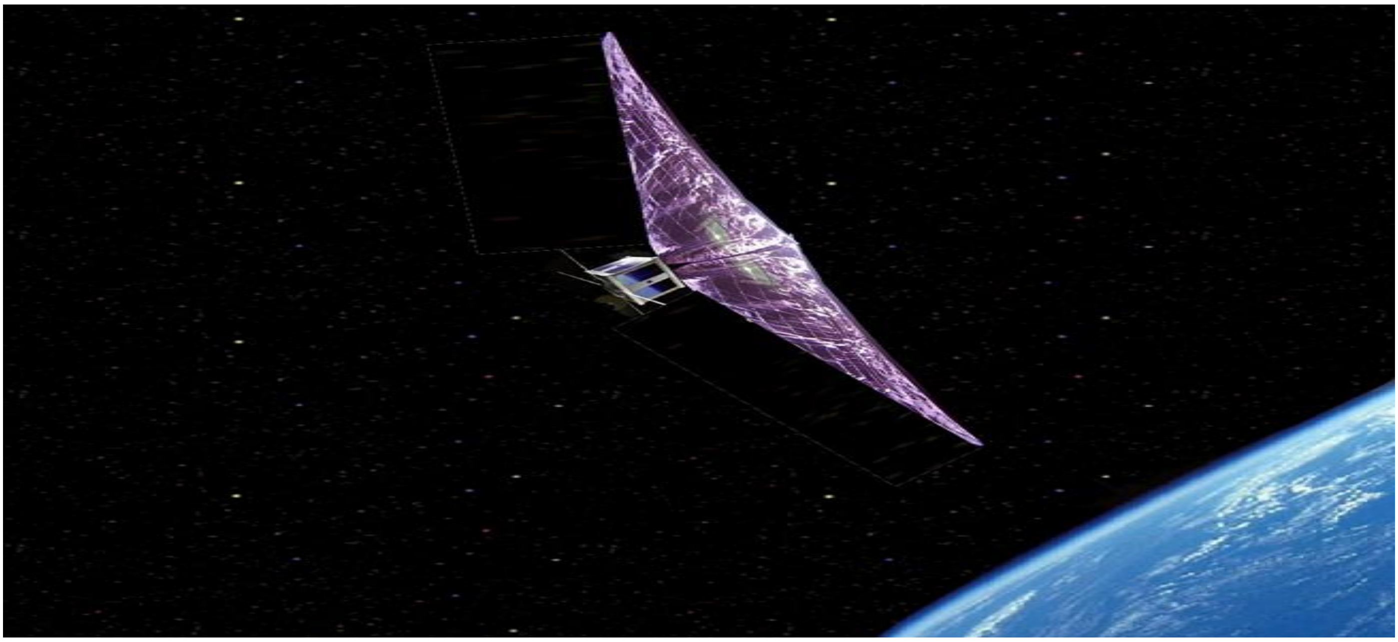

Fig 5 Robotic Arms Enclosed with Micro Metallic Lattice Net

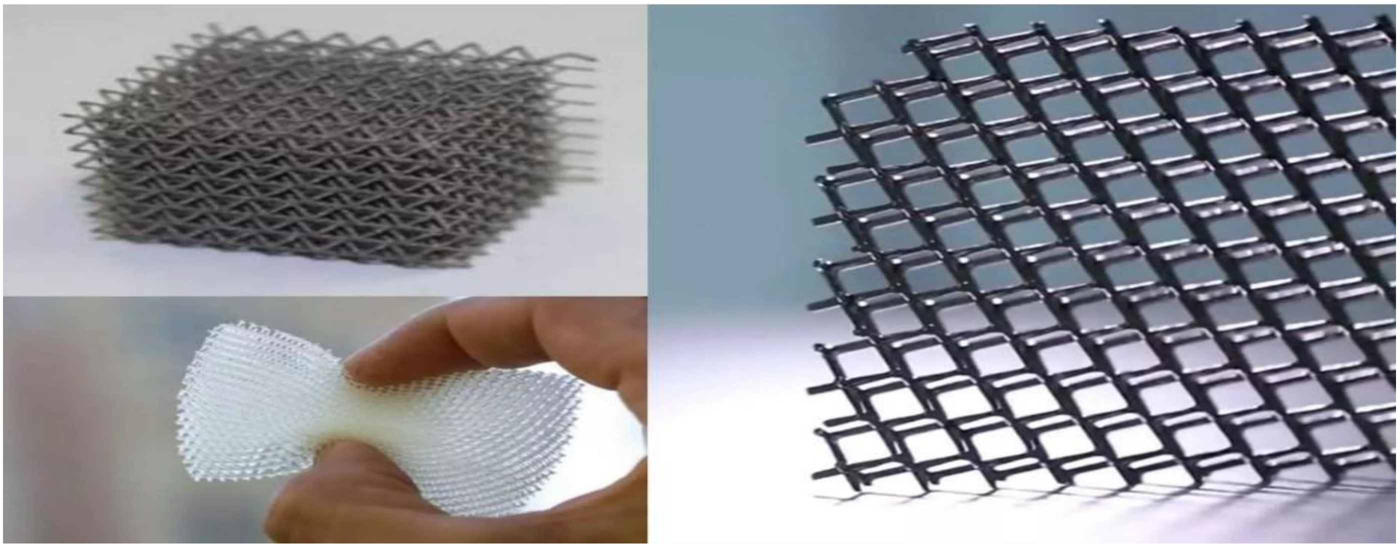

Fig 6 Metallic Micro-Lattice

Metallic micro-lattice as shown in Fig.6 is a synthetic porous metallic material consisting of an ultra-light metal foam. With a density as low as 0.99 mg/cm^3 (0.00561 lb./ft^3), it is one of the lightest structural materials known to science. To produce their metallic micro-lattice, the HRL/UCI/Caltech team first prepared a polymer template using a technique based on self-propagating waveguide formation, though it was noted that other methods can be used to fabricate the template. The process passed UV light through a perforated mask into a reservoir of UV-curable resin. Fiber-optic-like "self-trapping" of the light occurred as the resin cured under each hole in the mask, forming a thin polymer fiber along the path of the light. By using multiple light beams, multiple fibers could then interconnect to form a lattice. The fairing or the heat shield of the final stage will be permanently attached with the help of hinge joints as shown in Fig.5.

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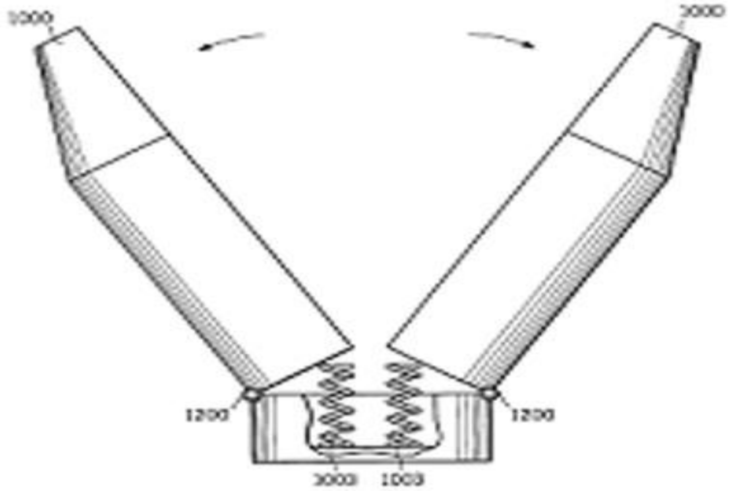

Fig 7 Fairing Attached using Hinge Joint

To protect the debris collected and bringing it back to Earth surface safely the fairing will be used. During the re-entry phase, due to the atmosphere of the Earth, air friction will produce too much of heat (in the mesosphere) which will not only damage the debris collected but also the mechanism. To overcome this the fairing will be attached using hinge joints and springs attached to the bottom. As soon as the debris is collected the fairing will close again as shown in Fig.7. Thrust vectors and parachutes will also be used for decreasing the vertical velocity of the rocket for maximum drag and improving efficiency by using less fuel. In the propulsion chamber some modification is to be done for achieving greater efficiency as shown in Fig.8. In the inner wall of the fairing thermo electric pads will be attached. Thermo electric pads works on the principle of thermo electric principle. This will be used to use the heat energy produced by the combustion chamber to produce electricity as well as provide a cool ambient temperature inside the fairing. No extra power source is required for this. This will help to achieve more efficient operation in terms of cost and energy consumption.

IV. WORKING PRINCIPLE

The 2-stage rocket will be launched from the launchpad. After that staging will occur and the 1st stage will be back to Earth surface. Now the 2nd stage comes into action. The propulsion system attached to it will park it into a desired orbit. The tracking system with the coordination of the ground station will look for the debris floating around. As soon as the object is tracked the AI will direct the propulsion system to produce thrust to reach the desired orbit and capture the debris. After this the robotic arms will again retract and enclose the debris. Now the fairing will again close and come to its initial position. This will protect the mechanism as well as the debris from the heat and save it from burning due to this heat generated while re-entry into Earth's atmosphere. Now the whole system attached to the 1st stage will be made to fall under gravitational influence of the Earth. As the system approaches Stratosphere, the thrust vectors attached to the wall of the rocket will rotate it 180° keeping the thruster towards Earth surface. As soon as it reaches the perfect inclination, the thrusters will be turned on. This will act as a reverse thruster and will help reduce the speed by applying as an opposite force. When the whole system will enter troposphere, the parachutes attached to the 2nd stage will open and will add extra drag further slowing it down so that by the time it reaches the earth surface it's speed will be minimum. This will help achieve a safe landing rather than crash landing hence reducing the risk of damage and ultimately leading to cost effective operation. After that the debris can be further analysed and reused after repairing (if still operable) or deposited safely. The mechanism can be reused for next operations regarding space debris cleaning.

V. CONCLUSION

Space Debris is a rapidly growing problem and still no solution to it. The risks of debris are no doubtless hazardous. These are not of same size or dimensions. They might be too big like a dead satellite or a minute particle formed due to collision. The travel at hundreds of kilometers per second. Infact the smaller the size more the risk. They are hard to detect and track. Also, the mechanism to capture them should have much accuracy. Many countries and private organisations are actively working on it. The method explained above and the mechanism designed will not only help to remove the debris but also help us to achieve a low cost and efficient operation.

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