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Solution to Space Debris: IDRSS

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Abstract

Debris has always been a matter of great concern in the field of space sciences. All the junk that can also be referred as the remains of the space projects that may include the rockets, satellites and much more is known as debris. This junk revolves in the space after getting detached from their host bodies and hence pose a hazardous threat for the possible space missions in the future The main objective of this paper is to suggest setting up an International Debris Removal Space Station (IDRSS). In the said space station, the paper proposes to use advanced automation techniques would be used to collect the debris from the space. The other proposition is to use solar sails for the propulsion in IDRSS. The following paper would explain how humans can achieve and quantify the above proposal. The main objective of this paper is to suggest setting up an International Debris Removal Space Station (IDRSS). In the said space station, the paper proposes to use advanced automation techniques which can involve the use of powerful electromagnets and fishnet technology which in turn would be used to collect the debris from the space. After collection of the debris, the IDRSS would melt the debris and that debris will be processed to use in future. The melted debris will be transported to earth where it will be recycled. The other proposition is to use solar sails for the propulsion in IDRSS. As we visualise the concept of IDRSS as a successful mission towards the total removal and safe space from space debris, we also envision it to be a manned station just like ISS so that it can more efficiently run. The following paper would explain how humans can achieve and quantify the above proposal.

Keywords: Small expendable deployer system, artificial intelligence, Indian space research organisation, low earth orbit, international debris removal space station.

INTRODUCTION

The issue of space debris is not new to scientists. Space debris, if not continuously monitored and regulated, will eventually result in major harm to close Earth orbit activities as the number of satellites in orbit slowly but steadily rises every year. Consequently, it is essential to develop workable solutions. Therefore, it is necessary to develop efficient methods to stop the devastation that can be caused by space debris. Approximately 25,000 pieces of debris the size of a ball and 500,000 pieces the size of small objects are now in orbit around the Earth. Over the course of more than fifty decades of space missions, more than 5500 launches sent a payload of over 6000 satellites into orbit, with just a few thousand still active today. The remnants of these satellites are now the part of space debris that pose a greater threat today. In the past years, we have seen many instances where the debris has entered the atmosphere but had not been destroyed as intended. Though it did do any major

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life and property damage, it resulted in atmospheric pollution. For example, the most recent incident being pieces re-entered space debris that impacted multiple locations in Indian state of Maharashtra and allegedly killed livestock. On another occasion, on March 25, 2021, a Falcon 9 second stage performed an uncontrolled re-entry over Washington state, resulting in a widely seen “light display”. A pressure vessel encased with composite survived re-entry and landed in an agricultural field. These are just two episodes which gives us a picture that how these debris should not be directed towards earth and another innovative technology should be developed to deal with it. This paper will be proposing the different ways in how this threat can be handled and how with the help of robots we can capture the debris of different sizes as well. The space station that has to be deployed is a theoretical concept till date whereas to bring it practically is still possible if it is considered as the case of international space station (ISS). This paper will give a detailed overview of our vision for a safer space travel and studies for future generations.

LITERATURE REVIEW

Space Debris Risk Assessments

Risk assessments consider both the likelihood of an incident and its repercussions. The danger of collision between functioning spacecraft and space junk may be assessed using models of the space debris environment. Because of the enormous amount of such debris, spacecraft in LEO are frequently battered by extremely small particles (<100 μm), but the impacts are usually minor because to the modest masses and energy involved. The risk of collision drops fast as the size of the debris grows due to the decreased population of huge debris items. On the other hand, collisions between huge objects become more severe. The key risk factors are the cross-sectional dimension of the space object, its spatial density, average relative collisional velocity along its orbit (height and inclination), and the length of the flight. The repercussions of a collision are determined by the masses and compositions of the items involved. While the probability of collision between two orbiting objects is substantially inversely related to height and is an order of magnitude greater in LEO than in GEO, the risk of collision between two orbital objects is essentially independent of altitude.

An Introduction to a New Space Debris Evolution Model

SOLEM Many different models for the space debris evolution have been proposed by different space organizations. The most famous ones among them are: (1) LEGEND by National Aeronautics and Space Administration (NASA) (2) DAMAGE by United Kingdom Space Agency (UKSA) (3) MEDEE by Centre National d’Etudes Spatiales (CNES) (4) DELTA by European Space Agency (ESA) (5) LUCA by Technische Universitat Braunschweig (6) NEODEEM by Kyushu University and the Japan Aerospace Exploration Agency (JAXA) (7) SOLEM by China National SOLEM is a space debris prediction model developed by the Canadian National Space Administration (CNSA).

During IADC’s cooperative research, the reliability of SOLEM was confirmed. The SOLEM model uses a reduced semi- analytical orbital propagator, in which the perturbation functions are integrated without the short-periodic terms. SOLEM presently only covers the LEO area, which includes objects with near-circular orbits in LEO as well as high eccentricity orbits crossing LEO. Active debris removal (ADR) measures are proposed as a means of limiting the expansion of LEO space debris populations. According to computer estimates, eliminating numerous targets each year can help to stabilise the space environment.

Advanced Space Debris Removable Technique and Proposed Laser Ablation Technique [1]

The purpose of this research is to discover improved removal techniques such as trapping and capturing space debris, reusing rocket systems, and proposing cost-effective ideas for removing space trash from Earth orbit utilising a laser ablation process. Dead batteries from spacecraft, wasted or extra fuel, parts of rockets used in launching vehicles (17–20%), and other trash associated with space missions are all examples of space debris (20%), including all non-working condition or other parts moving around the earth at a velocity of 8 to 9 km/sec. This debris, in various sizes, is fast enough to endanger active spacecraft or any mission. Methods for removing space debris: *(1) Capture and capture of space debris:* This space mission was launched in 2014 with the intention of trapping or catching debris revolving in orbit at high speeds using a net or robotic arm harpoons or tentacles. *(2) Reusable rockets:* Falcon 9 is a reusable, two-stage rocket designed and manufactured by SpaceX for the reliable and safe transport of people and payloads into Earth orbit and beyond. Falcon 9 is the world's first orbital class reusable rocket. *(3) Ablation laser technique:* The ablation laser technique uses a high-energy laser output to ablate debris for cutting surface debris. After cutting a debris, vaporisation occurs, generating momentum in the debris, which acts as an impact force on the debris, similar to a laser propulsion rocket? In laser ablation, a high-powered laser beam collides with moving debris, causing the moment and direction to change.

Assessment Study of Small Size Space Debris Removal by Orbit-Stationed Laser Satellites [2]

In the following paper, it is pointed out how the space debris can be harmful not only in the present scenario but also for our future generations. The method to remove the space debris they have used is a short wavelength laser stationed in orbit to vaporize small unidentifiable objects which can be smaller than 10 cm and pose a serious hazard. The primary goal of the article was to analyse the power requirements for laser-based space debris cleanup, in which a short wavelength laser pumped directly or indirectly by solar energy may scan, identify, position, and light the target, which would eventually be destroyed. A laser powered directly or indirectly by solar energy may scan, identify, position, and illuminate the target, which is subsequently incinerated or slowed in orbit by laser explosion until it re-enters the atmosphere. The report goes on to say that a solar cell with the right specifications can be used to power the laser.

The paper discusses and explains how the space debris that is smaller than 1 cm is not accounted and recorded as we do not have the technology to do so at present. Solid rocket engine dust, paint flakes, and coolant released by the Ussr Radar Ocean Reconnaissance make up most of the debris, along with other surface degradation products. Satellite (RORSAT) nuclear powered satellites, clusters of small needles for creating an artificial ionosphere and objects released (RORSAT) nuclear powered satellites, clusters of small needles for creating an artificial ionosphere and objects released by the collision of tiny debris or micrometeorites with other objects.

Debris Engine: A Potential Thruster for Space Debris Removal [3]

According to the article, a Space robotic cleaner is used to gather and move the targeted trash into the engine. Then the larger chunks are disintegrated into smaller chucks by mechanical method. Using a planetary ball mill, the particles are next ground into micron-sized powder. This technique requires nuclear or solar energy. The powder is charged using photoelectric gamma rays. This method allows us to speed up the flow of powders in a simultaneous electrostatic particle accelerator. The paper discusses about how this speed up charged debris powder can be used as thrust. The engine's nozzle generates continuous thrust from a high-temperature, high-pressure charged source. This force may be employed by the spacecraft and robotic cleaner to accomplish orbital manoeuvres and debris rendezvous. The solar wind will blow the ejected charged particle out of its circum terrestrial orbit.

Technical Report on Space Debris by Scientific and Technical Subcommittee of the United Nations on the Peaceful uses of Outer Space [4]

Ground-based Measurements

There are two types of ground-based measurements used for remote sensing of space debris: (1) radar measures and (2) optical observations. Usually, optical measurements have been utilised for high Earth orbit (HEO) space debris whereas radar data have been used for debris in low Earth orbit

(LEO) (HEO). For passive optical measurements, the signal intensity return is inversely proportional to the square of the object's distance or altitude because direct sunlight from the Sun is essentially height-independent. The signal intensity return is inversely related to the fourth power of distance since radars must produce their own light.

Radar Measurements

Because of their all-weather and day-and-night capability, ground-based radars are ideal for observing space objects Limiting factors for the long-range detection of small objects are the radar power budget and operational wavelength. There are two kind of radars used for measuring objects in space:

1. Using mechanically controlled parabolic reflector antennae for their radars.
2. Radars that have electronically adjustable beam direction and use phased array antennas. Concurrent detection and measurement of many objects coming from different directions is possible.

While the second type of radar is primarily utilised for both tracking and search operations, the first type is primarily used for monitoring and/or imaging satellites.

Radars have been used in monostatic (single antenna for transmitter and receiver) and bistatic (single antenna for transmitting and a second antenna for receiving) configurations. Radar measurements can primarily be used to deduce the following characteristics of space objects:

a. Orbital components, which depict how an object's centre of mass orbits the planet;
b. The object's attitude, which describes how it moves in relation to its mass centre;
c. Size and shape of the object;
d. Orbital lifetime;
e. Ballistic coefficient;
f. Object mass;
g. Material properties.

Optical Measurements

When the debris object is light and the sky backdrop is dark, a telescope may detect it. This period is restricted to an hour or two soon after sunset or before sunrise for objects in LEO. However, for objects in HEO, such as those in geosynchronous orbit, observations may frequently be carried out throughout the night. Another constraint of optical measurements is the necessity for clean, dark sky.

To scan the environment, an unusual combination of sensitivity and field of vision is necessary. GEO area for tiny space debris believed to occur there. To identify debris smaller than 1 m near geosynchronous altitude, a limiting star magnitude of 17 or more is required, as is as broad a field of view as feasible to allow quick sweeping of huge regions.

Space-based Measurements

It is possible to learn more about submillimeter-sized particles by looking into surfaces or spacecraft that were exposed to the space environment before they left for Earth. Similar data can also be provided by specialised debris and dust detectors. A detecting surface is a vital component in the majority of them.

After being exposed to the atmosphere of space, spacecraft surfaces are covered in an enormous number of impact craters caused by meteoroids and debris. From micrometres to centimetres, individual impact craters and holes are present. A fundamental issue is distinguishing between meteoroid hits and man-made debris. Chemical analysis is a tried and true approach for determining their origin. However, there are several drawbacks to using this strategy. The rapid impact speed causes little of the impacting substance to alter. The particle vaporises and then condenses on the surfaces around it. As a result, in many circumstances, the origin of an impacting particle cannot be established individually. The size of the impact feature and the size of the particle have been connected through ground calibration studies (hypervelocity impact tests) for a variety of materials.

The flux for meteoroids and debris as a function of particle size may be calculated using impact data and calibration studies. In general, space-based measurements offer better resolution due to the closer proximity of the observer and the object. Furthermore, the environment has no negative affect.

Effects of Large Debris Objects on the Operation of Space Systems [5]

Large waste objects are frequently defined as objects larger than 10 cm. Such objects may be monitored, and orbital components are preserved. During shuttle missions, orbiters used collision avoidance manoeuvres to prevent catastrophic collisions with these enormous debris pieces.

Effects of Small Debris Objects on the Operation of Space Systems [5]

Small debris items (less than a few millimetres in diameter) have previously harmed working space systems. These effects have had no discernible influence on mission accomplishment. This injury is classified into two types. The first type is surface or subsystem damage. The influence on operations is the second category. An operating system's surface damage can take the form of the following:

a. Damage to shuttle windows;
b. Damage to HST high gain antenna;
c. Severing of the Small Expendable Deployer System-2 (SEDS-2) tether;
d. Damage to other exposed shuttle surfaces.

Space Debris Risk Assessments

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Research Gap

A solution to the issue of space debris has been sought after by space agencies all around the world. Since this problem is manmade hence the solution has to be the collective effort of everyone throughout the globe. Till now not much of the dedicated research has been done to counter this issue. Talking about Indian Space Research Organisation (ISRO) has started its mission to save the LEO, from impending threat of space debris and a facility named System for Safe & Sustainable Operation has been inaugurated that will be dealing with the emerging threat of space junk. This has been done to help India to achieve is Space Situation Awareness goals [6].

Till today there is no technology that has come into the picture which guarantees 100% efficiency of clearing out the debris without causing even a minimal harm to the nature. Due to the current situation a minimal amount of compromise must be taken into consideration with respect to both the environment in the space and on the earth to increase the overall life in the space as well as on the earth [7]. These considerations are not only for short term but also for long run or until the human kind comes up with more advanced technologies to tackle the same issue.

The proposed work in this paper will not only be helping India in improvising its effort towards SSA goals but also will give a fresh perspective of how this peril can be avoided with minimal cost and damage. Though this idea is a theoretical concept, with further calculations and technological expertise it can be converted into a practical model which can do wonders to this whole situation [8].

Proposed Work

In order to clear space debris of all shapes and sizes, we will deploy different kinds of robots. Due to the fact that space debris has a variety of shapes, sizes, and masses, using the same type of drone is ineffective because certain debris might not be picked up.

So, we categorized the robots we are using into three types. These three robots will have different equipment. Among these robots, tentacles, net capture, and robotic arms stand out as the most prominent types. Whether these robots are deployed automatically or manually by the crew will be determined by the crew. Through sensors, the spaceship will analyse what kind of space debris needs to be picked up and deploy the drone accordingly.

Tentacle robots will be used to handle the big and heavy debris, using their tentacles to grab the edges and return them to the space station. A net capture drone is designed to capture medium and small debris that is hard to grasp. Basically, the net is used in the same way as a fish net, which surrounds the fish to catch them. By this method, the drone can grab more small or medium debris at a time, unlike the tentacle drone which carries one or two large chunks of debris. Last but not least, the robotic arm drone has a gripping arm that works exactly like a human hand. In addition to diving and picking up debris, robotic arm robots can grab other kinds of debris that are not picked up by the two other robots. As a drone, this one has more versatility since it can be used to drag or pull debris along with grabbing it, and it is very easy to manoeuvre [9].

METHODOLOGY

The Base Station

The core of the whole mission starts from the existence of this base station. This unique station comprises of the main body, along with all the different genus of robots which are designed specifically for particular kind of debris.

The Figure 1 depict the prototype of IDRSS i.e., International Debris Removal Space Station. The features of this space station consist of two pairs of solar panels which would act like the parent power source for all of its members. The main body will house the robots which would be collecting the debris by their specified characteristics. These characteristics will be determined by the sophisticated sensors and cameras which will be collecting the data either manually or through Artificial intelligence (Figure 1).

The materials which will be used in the construction of this base station are going to be the combinations of aluminium alloys, along with some parts of Kevlar, Titanium and highgrade steel. The use of Kevlar layer is to decrease the chance of small debris which could penetrate the walls and put the station in danger. Inside the debris station, the materials that will be used will also be Titanium, Kevlar and High grade steel. The outer part of the station will be covered by the layers of at most 8–10 cm layer thickness. They are used because they model the structure to be light weight yet strong, durable and puncture resistant (Figure 2). The IDRSS will also include a well-structured propulsion system. We propose to use high thrust propulsion system because it can match the speed of the debris at different intervals of time [10].

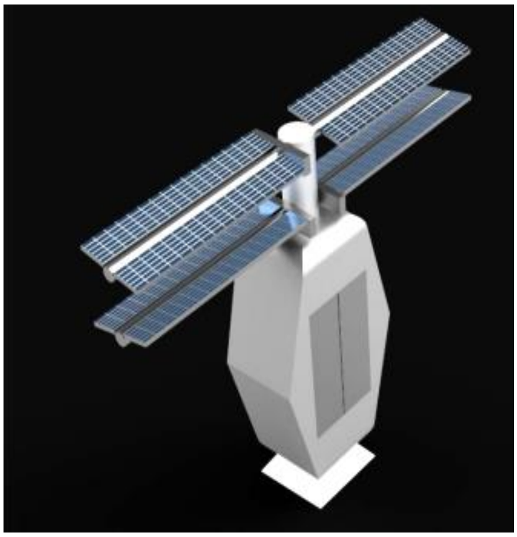

Figure 1. IDRSS.

Figure 2. IDRSS in orbit.

The Robots

- *The Tentacles:* These Robots would be designed to master the technique of catching the medium to big sized debris which can easily be caught and return back to the space station. They will be using their namesake, tentacles. The robots will be using of four tentacles. Aluminium Al-MS89, a high temperature Aluminium alloy created using an innovative powder method, is mentioned as a material that might contribute here. The alloy is extremely temperature stable (Figure 3). The qualities remain very steady even after thousands of hours at high temperatures. They will be used because among all the industrial grade aluminium they are the most flexible and they can be cold worked to produce good durability and temperature resistance to the tentacles.
- *The Robotic arms:* These robots will be using long robotic arms which will be suspended from the robot's main body. They are going to be used to capture small to middle sized debris and collect the said debris and deposit it to the main base station (Figure 4). The materials which we propose to produce are Aluminium Al-MS89 just like we use in tentacles. Kevlar is also used and can be used to make these robotic arms.
- *The Fish net:* These robots are inspired by the use of fishnet which is used by the fishermen to catch different kinds of fishes. Just like that different kind of fishnets we would be using variety of technology to catch the debris according to their shape, sizes and speed. The common material for this (Figure 5) fishnet technology is proposed as just like tentacles and robotic arms Aluminium Al-MS89 (Figure 6).
- *The Shark:* These robots are going to be bigger in the size, because we will be proposing to use the technology in same way the shark devours its prey (Figure 7). The robot will open its apertures by matching the speed of the debris mostly for small to middle size debris and capture it as a whole (confer to the image below). The materials which we will be using is Aluminium Al-MS89.
- *Solar Panels:* As previously mentioned, that solar panels would be the parent source of power energy for the base station and the robots everything will be depending upon the housing capacity of the space station which eventually will also impact the number of solar panels which will be installed in it. However, two pairs of solar panels would be the minimum requirement for IDRSS to work on its full potential. The paper proposes that a typical IDRSS would be installed with leading edge multi-junction cells which are capable of exceeding 39.2% under non-concentrated AM1.5G illumination and 47.1% using concentrated AM1.5G illumination.

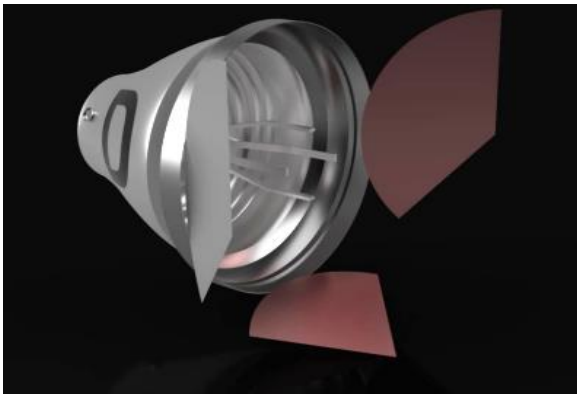

Figure 3. Tentacle system in Robot.

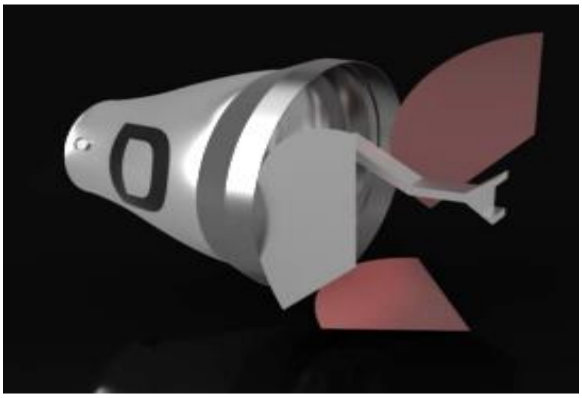

Figure 4. Arm system in Robot.

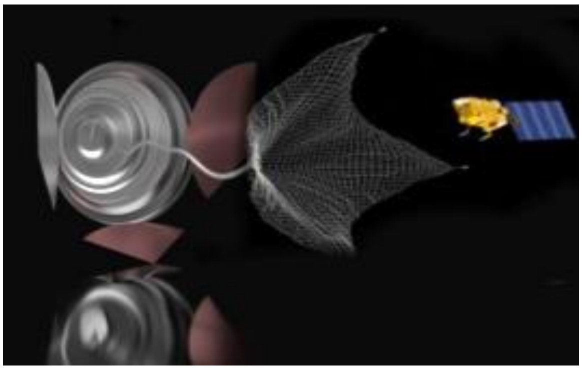

Figure 5. Fish net system in Robot.

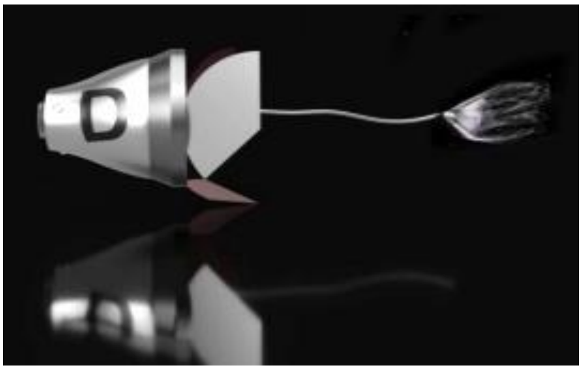

Figure 6. Side view of Fish net system.

Figure 7. Shark system Robots.

- *Power Backup:* For the reference of the power back up that is supposed to be used is taken through the working of ISS. The mapwork for the same goes as follows:
  1. During the "eclipse" portion of the orbit, when the station is frequently out of the direct path of the sun, it is powered continuously by rechargeable lithium-ion batteries (originally nickel-hydrogen batteries) (35 minutes of every 90-minute orbit).
  2. Each battery assembly, which can be found on the S4, P4, S6, and P6 Trusses, is composed of 24 thin lithium-ion battery cells as well as associated mechanical and electrical components. Each battery assembly has a capacity of 4 kWh and 110 Ah (396,000 C) on the nameplate (14 MJ). The BCDU and DCSU are used to supply this power to the ISS, respectively.

3. The batteries make sure that the station never runs out of electricity so that experiments and life support systems may continue. The batteries are recharged during the orbital portion of sunlight. The design life of nickel-hydrogen batteries was 6.5 years. Years and could perform more than 38,000 charge/discharge cycles at a depth of drain of 35%. Over the course of the station's anticipated 30-year lifespan, they were changed numerous times. Each battery was 102 by 91 by 46 centimetres in size and weighed 375 pounds (170 kg).
4. Lithium-ion batteries took the place of nickel-hydrogen batteries between 2017 and 2021. There are numerous differences between the two battery technologies. One distinction is that because lithium-ion batteries can hold two times as much charge, fewer lithium-ion batteries were required for replacement. Additionally, compared to the previous nickel-hydrogen batteries, lithium-ion batteries are smaller. The ISS Li-Ion batteries are expected to survive 60,000 cycles and 10 years, which is much longer than the 6.5-year design life expectancy of the original Ni-H2 batteries. Li-Ion batteries normally have shorter lifespan than Ni-H2 batteries since they can't withstand as many charge/discharge cycles before beginning to show apparent deterioration, however the ISS Li-Ion batteries have been designed to endure for 60,000 cycles and ten years.
5. *Space Debris incinerator:* The problem of space debris will remain the same if we do not dispose the space debris in an environment-friendly condition for the earth and the space. So, the paper proposes that just like ISS, we deploy a crew of at least five engineers and astronauts, who will be responsible for taking care of the IDRSS along with safe removal and disposal of the debris in the IDRSS itself. For the said idea to work in its full efficiency, the IDRSS will be possessing its own incinerator which will be handling the whole incinerating process. Here the main purpose behind this suggestion is to bring back the debris to recycle it in the best way possible by extracting the still useable materials, even if it's in less quantity. Since on Earth we have a lot more techniques which can handle the debris in the way it should be this could be an efficient method. We can bring down the debris while we change the crew after they serve their allotted time in the IDRSS, just like they do in ISS.

MISCELLANEOUS

1. *Sensors:* Since the base station is technologically sophisticated and advanced, it is going to be constructed using number of sensors which are going to complement its working and demand. These sensors will be responsible for collecting the data and analysing the different parameters like, the speed and direction of the debris, which in turn will be used by the deployed robots to capture the said space junk.
2. *Maintenance Station:* There would be times when the robots will collide with external objects and get damaged, in those periods of time the IDRSS will retreat the damage robots and submit it in the in-built (AI) supported maintenance station. In the maintenance station, preliminary testing and tools to service the minor damages would take place and will be controlled by the space agencies that the IDRSS would belong to. There would also be a facility to store the damage robots and their substitutes.

Other Findings

Different methods can be used to separate space debris.. Even though there are various methods/techniques to remove debris from earth's orbit. It is not possible to separate debris by using only one technique as there are debris with various size, Velocity, Rotations/min etc. Thereby, using a single technique might have many cons. So, instead of using a single technique, here, we propose an Idea of Space Debris Station. The Station consists of Robots that can use various Debris removal techniques (Robotic Arm, Tentacles, Electro Magnetic Sphere, Net Capturing). Each robot uses each technique respectively. The debris station orbits Earth and locates debris, thereby scanning the in order to find its size, velocity and various parameters. Depending upon those parameters the debris station uses the best methods to capture the Debris and dispatches a robot that performs the required process.

RESULT AND DISCUSSION

The paper promotes a hypothetical idea in which intricate technology and the usage of AI, which is considered to be the future of the twenty-first century, will be put to use. The research proposed a new hypothesis for the International Debris Removal Space Station (IDRSS), which would deploy robots with multiple techniques to capture varied space debris having discrete characteristics like; speed, direction, and position.

These techniques have not yet been suggested, so if they do, they could be revolutionary. It offers a novel viewpoint on how to manage space debris and safely conduct upcoming space missions. Idea needs to be thoroughly calculated and assumed using the right tools and knowledge in order to be realistic. IDRSS has the ability to produce a safer working environment overall.

CONCLUSION

Space debris poses a threat to operational satellites and spacecraft. In five to ten years, a catastrophic avalanche of collisions with growing quantities of space junk could render nearly all satellites inoperable. Satellites are employed in many different industries today, such as finance, energy, etc. Their destruction could cause problems for the world economy. According to the American Institute of Aeronautics and Astronautics, the clearance of space debris is extremely important and should be treated seriously by the major economies in the world. Because of the significant enough object density in LEO to cause collisions; this mission will be limited to LEO. In order to reduce and possibly even eliminate cases of satellite and spacecraft damage, the satellite module has been proposed to remove the space conditions surrounding the planet by obtaining information on space debris This paper can be used for future references and the theoretical idea of IDRSS could come into practice.

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