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A Novel Approach to Eradicate Space Debris with Eddy Current

Bhavana MS*

Department of Mechanical Engineering, Kerala Technological University, Kerala, India
ORCID: 0009-0004-3590-3514

Abstract: The exploration of space and the ever-expanding network of satellites have led to remarkable advancements in aerospace technology. However, the proliferation of space debris has become a growing concern. This paper delves into the future implications of space junks, the current efforts in space debris management, and the vital role of advanced technologies in controlling space traffic. Specifically, it explores the uniqueness and potential of utilizing eddy current technology as a promising approach to tackle the space debris challenge.

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1. Introduction

The rapid progress in space exploration, exemplified by the historic launch of Sputnik1 on 4th October 1957, has sparked an era of revolutionary advancements in aerospace technology. Today, even private universities have joined the race of rocket launching, resulting in over 7000 functional satellites orbiting the Earth. However, the issue of space debris generated by defunct satellites has been a largely overlooked aspect of space exploration. In addition, refers to non-functional man-made objects left in space that no longer serve any useful purpose. This debris encompasses a variety of items, including nonfunctional satellites, abandoned launch vehicle stages, and mission-related remnants. The Space Surveillance Network (SSN) utilizes sensors to track thousands of these objects, ranging in size from small chipsets to large rocket components. Unfortunately, the gravity of the issue only gained serious attention after the collision between Cerise, a French microsatellite, and the European Ariane rocket.

The year 2009 marked a significant turning point when the first collision occurred, resulting in the destruction of the Iridium (America), a communications satellite, and Cosmos (Russia), a military communications satellite. This alarming event posed a troubling question for the scientific community. Consequently, numerous missions, innovations, and actions have been undertaken to address the challenge of space debris. Efforts have been made to devise measures aimed at mitigating the risks posed by space debris. However, the complexity of the issue demands ongoing research and development of effective strategies to ensure the sustainability of space missions and the safety of active satellites. The gravity of the space debris problem has spurred a collective effort from space agencies and organizations worldwide, seeking innovative solutions to control space traffic and maintain a clutter-free orbital environment. By exploring various avenues and implementing robust measures, the scientific community endeavors to minimize the impact of space debris on current and future space missions.

2. Growth of Space Debris

Lower Earth Orbit (LEO) is the orbit closest to Earth and is significantly influenced by gravitational perturbations. Approximately half of the satellites in LEO have become defunct, yet they traverse the space at speeds far exceeding that of a jet. On the other hand, higher altitudes, such as the Geostationary Earth Orbit (GEO), experience fewer gravitational perturbations. Satellites in GEO complete an orbit around the Earth in 24 hours,

*Research Scholar, Mechanical Engineering, Kerala Technological University, Kerala, India. **Contact**: ms.bhavanaguptha@gmail.com
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allowing them to remain fixed above the same location on the Earth's surface. Unfortunately, GEO has become a concerning area of concern as it has accumulated an alarming number of space debris.

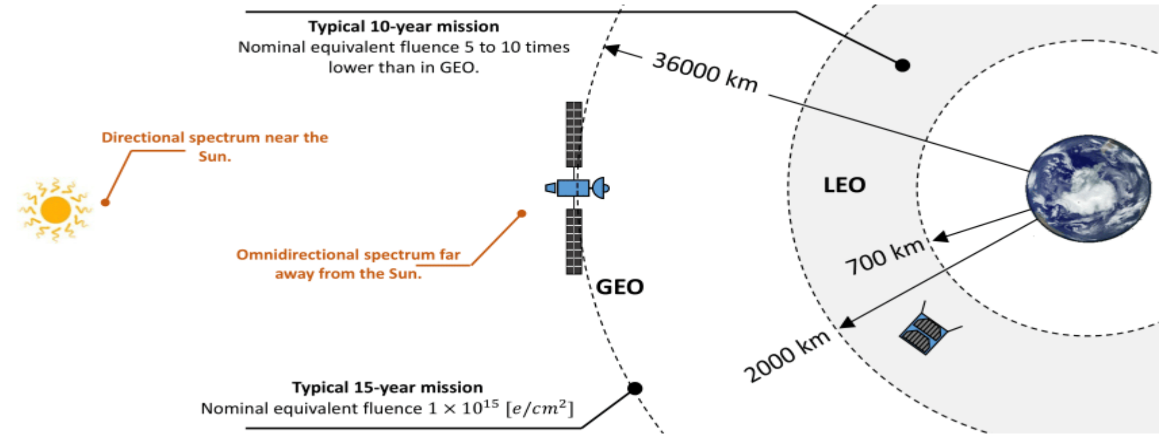

Figure 1 Satellite Orbits for Typical 10-15 Year Mission [Image Courtesy: NASA]

The notion introduced by NASA scientist Donald Kessler posits that the density of objects in LEO has reached a critical level due to space pollution. This heightened density raises the likelihood of collisions between objects, potentially leading to a cascading effect. Each collision generates additional space debris, further increasing the risk of subsequent collisions in a chain reaction. Addressing the issue of space debris has become a crucial priority for the scientific community and space agencies. The potential for cascading collisions in LEO and the accumulation of debris in GEO highlight the urgency of implementing effective space traffic management and debris mitigation strategies. By fostering international collaboration and employing innovative technologies, we can work towards safeguarding the future of space exploration and ensuring the sustainable use of outer space.

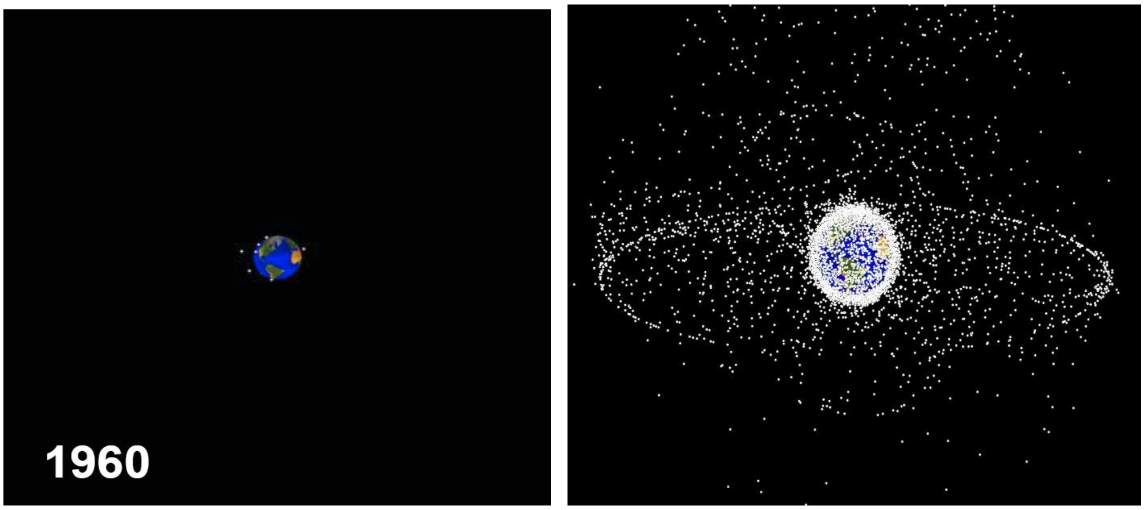

Figure 2 Growth of Space Debris from 1960-To-Present [Image Courtesy: NASA]

3. Future Consequences of Space Debris

The accumulation of space debris poses serious threats to space missions, active satellites, and the overall safety of astronauts. Collisions between space debris and functioning satellites can lead to expensive damages, loss of critical data, and, in extreme cases, cascade collisions exacerbating the debris problem. It is crucial to address these future consequences proactively.

4. Current Efforts in Space Debris Management and Need for Space Debris Mission

Various space agencies and organizations have initiated efforts to mitigate the proliferation of space debris. Strategies such as satellite deorbiting, collision avoidance maneuvers, and space debris tracking have been implemented to control the orbital space traffic. However, these methods face challenges in terms of efficiency and scalability. The exploration of space has long captivated the human spirit, driving us to unveil its hidden mysteries. Over the years, numerous discoveries in space have proven to be invaluable assets to humanity.

However, as the saying goes, every solution gives rise to new challenges, and space exploration is no exception. The aerospace industry has witnessed remarkable innovations, with companies like SpaceX and Amazon envisioning vast constellations of satellites, known as Mega constellations, to provide widespread internet coverage to Earth. If realized, these ambitious plans will result in thousands of additional satellites orbiting our planet. This rapid increase in satellite deployment has raised significant concerns among the scientific community about the pressing need for robust measures to prevent collisions.

International space stations, like the ISS, are now compelled to make continual adjustments to their positions to avoid potential collisions with space debris. The burgeoning growth of space debris poses a grave threat to the existence and smooth functioning of such vital space installations. To address this escalating issue, the groundbreaking Remove Debris Mission was launched, marking the world's first mission to demonstrate capturing technology capable of deorbiting space debris. This mission has introduced various removal technologies, including net capture, harpoon capture, vision-based navigation, and drag sail. Efforts to find innovative solutions for space debris removal are critical for the sustainability of space activities and the safety of astronauts. By developing and implementing advanced technologies like those demonstrated by the Remove Debris Mission, we can foster a safer and cleaner space environment for future generations. Collaborative endeavors and continued research in this area are pivotal to mitigating the risks posed by space debris and preserving the immense potential of space exploration.

5. Significance of Effective Space Traffic Control Technology

The ever-increasing number of satellites in orbit necessitates the development of advanced space traffic control technologies. A robust and efficient solution is essential to manage space debris and maintain the sustainability of space missions. By implementing effective space traffic control mechanisms, we can reduce the risk of collisions and minimize the creation of new space debris.

6. The Unique Potential of Eddy Current Technology

Among the array of solutions being explored, eddy current technology stands out as a promising approach to tackle space debris. Eddy currents, induced by electromagnetic fields, can exert forces on conductive objects, such as space debris, altering their orbits. This technology offers a precise and non-contact method for debris removal, potentially making it an efficient and cost-effective solution for space agencies.

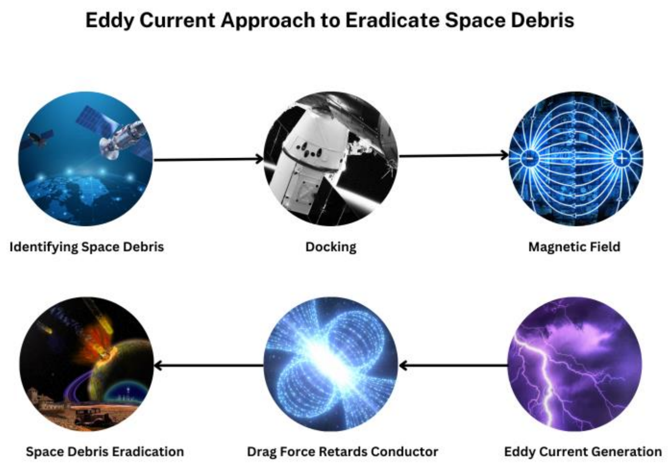

Figure 3 Approach towards Space Debris Eradication Using Eddy Current

7. Working Mechanism

The primary objective of the system is to accurately detect and address space debris through a meticulous docking process utilizing electromagnetism. This process involves the implementation of a high-frequency current traversing a coil. This current induction brings about alterations within the magnetic field associated with the debris, consequently inducing a counteracting current within the debris itself.

The induced current operates in opposition to the factors that brought it into existence, thus initiating the emergence of eddy currents. As a consequence of this phenomenon, the resultant magnetic fields counteract each other, subsequently engendering a drag force. This drag force serves to impede the motion of the conductor. It is imperative to note that the frequency at which the current alterations occur holds significant import. In the event that the current transformations manifest at an exceedingly elevated pace, a substantial accumulation of heat is generated. This heightened thermal output bears the potential to induce the melting of the constituent metals.

In summary, the pivotal goal of the system is the accurate identification and controlled manipulation of space debris by means of electromagnetism. This intricate process hinges upon the intricate interplay of high-frequency currents and induced magnetic fields, culminating in the generation of a drag force that curtails the debris' motion. It is imperative to exercise caution in managing the frequency of current alterations, as their excessive occurrence may result in the undesirable melting of essential metals.

8. Conclusion

In conclusion, the rapid advancements in space exploration have opened up new frontiers for human knowledge and technological innovation. However, this progress has come with the unintended consequence of space debris, posing significant challenges to the sustainability of space missions and the safety of active satellites. The density of objects in Lower Earth Orbit (LEO) and the accumulation of space debris in higher altitudes like Geostationary Earth Orbit (GEO) have heightened the risk of collisions and cascading effects, demanding urgent attention from the scientific community and space agencies.

Current efforts in space debris management, such as satellite deorbiting and collision avoidance maneuvers, have been implemented to control orbital space traffic. Nevertheless, the sheer number of functional and defunct satellites in orbit requires a comprehensive and effective space traffic control technology. The groundbreaking Remove Debris Mission has made significant strides by demonstrating various capturing technologies capable of deorbiting space debris. This mission has opened up new possibilities for future debris removal missions. Among these solutions, eddy current technology stands out as a promising approach, offering a precise and non-contact method to alter the orbits of space debris.

To ensure a safer and cleaner space environment, international collaboration, continuous research, and innovation are vital. By integrating advanced space traffic control technologies and developing effective debris removal strategies, we can safeguard the continuity of space exploration and pave the way for a more sustainable future in space. It is crucial for the global scientific community, space agencies, and private enterprises to work together in addressing the challenges posed by space debris and to preserve the vast potential that space exploration holds for the benefit of humanity.

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10. Biography

Bhavana M S is an accomplished individual in the field of Mechanical Engineering, specializing in Aerospace and Space Science. She earned her Bachelor's degree (B.Tech) in Mechanical Engineering, demonstrating her commitment to academic excellence and dedication to her chosen field. Currently affiliated with Kerala Technological University, Bhavana's academic journey has been marked by a passion for aerospace and space science, which has guided her pursuits and areas of interest. Her curiosity about the intricacies of this captivating realm has led her to delve deeply into the subject matter, making her a prominent figure in the arena.

11. Acknowledgement

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12. Conflict of Interest

The author have no conflict of interest to report.

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