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ENSURING SAFE ORBITS: ADDRESSING THE CLEARANCE OF DEFUNCT SATELLITES IN OUTER SPACE

AUTHORED BY - SUBHAHARINI A K

Abstract:

“Sustainable exploration begins with clearing the path left behind by defunct satellites”

Space exploration fuels human curiosity and innovation, offering boundless opportunities to discover new worlds and understand the vast space environment. In this modern era, where it is possible to explore outer space for many purpose comes along with certain contradictoriness, especially the environmental backdrop. Space debris is one of the cause of such environmental damage. Particularly the defunct satellites which is one such part of larger debris, floating all around the space orbit may hit any other objects or working satellites and creates more debris in space as of Kessler syndrome¹. Bringing back the defunct satellite without causing environment damage was still in question. It was not adequately addressed in past because of its less percentage of contribution to the environmental damage. Several states around the world are lagging in enacting a proper legislation in addressing the removal of such debris. Hence, the basic design of this research paper is to provide certain measures to protect the outer space and to know the existing regulations, policies of international organizations, international space law and international environmental law which could properly address the removal of space debris without causing environmental damage and if not, what are the measures can be included further to tackle this hectic situation caused by such debris. Specifically, the study examines the applicability and flexibility of the Outer Space Treaty, the Liability Convention, and the Registration Convention considering current issues. This is a concern for future, where the space is to be explored in a better way without causing any environmental impacts.

¹ The Kessler Syndrome holds that space debris of critical mass will fragment in further collisions leading to a cascading chain activity. See Donald J. Kessler & Burton G. Cour-Palais, Collision Frequency of Artificial Satellites: The Creation of a Debris Belt, 83 J. GEOPHYSICAL RES. 2637, 2637 (1978); see also STUFF IN SPACE, <http://stuffin.space/?intldes=1993-016CH&search=1993-016CH> [https://perma.cc/V9TJ-ARBQ] (STUFF IN SPACE is a real-time 3D map of objects in Earth orbit that updates daily).

Keywords: *Defunct satellites, Space Debris, Space environment, Environmental damage, Kessler syndrome, Legislations, Regulations*

CHAPTER I

INTRODUCTION

“Space” just by saying the word, it creates a sparkle in the eyes of the one who admires it. The outer space with twinkling stars, moons, planets are always an exciting nature for the humans out there. Exploring the outer space is like a fantasy of exploring the darkness, and out of such excitement and curiosity man started reaching space and explored as he wished for with the help of advanced technologies. As time passes, the rate of exploration gradually increased for various purpose by various nation which leads to increased number of satellites in the space environment. Space environment is the larger void which occupies the (relatively) empty area of the universe outside the atmosphere or surface of any planet or other celestial body.² The satellites out there which are floating around because of the lag of the gravitational force hits each other and creates debris. There are even defunct satellites which may collide or as of the way of bursting the defunct satellites leads to creation of more debris which may cause effect to the space environment. It is no way doubt that the international community have taken measures to address these consequences. The clearance of space debris is a long way talk, but still being a big question. Space is not a junk, it’s something more beyond it. It is the peak time to regulate the space debris or to bring back the defunct satellites without giving a way to create more debris by recognizing the environmental consequence at the earliest. This research attempts to legally analyze the present International Environmental Legal regime and International Space Law regime to know the status quo legality of defunct satellites management and its regulations. Also, this research attempts to analyze certain technical aspects to suggest for a regulatory framework for the clearance of defunct satellites in the outer space.

1.1 Background of the study:

The amount of space debris in orbit continues to rise quickly. Some 35,000 objects are now tracked by space surveillance network. About 9,100 of these are active payloads, the other

² Horneck G, ‘Space Environment’ (*SpringerLink*, 7 October 2015) <https://link.springer.com/referenceworkentry/10.1007/978-3-662-44185-5_1469#:~:text=Definition,%,20magnetic%20fields,%,20and%20neutrinos> accessed 8 September 2024

26,000 are pieces of debris that are larger than 10 cm in size.³ As I came across this recently, it created a curiosity to dive me deeper into this aspect. To know about the space environment, and the effects to it by way of accumulation of space debris which might also burn as it enters the lower earth orbit which leads to ozone depletion and some other environmental degradation factors too. The basic background of the study is out of curiosity in the concept of outer space and the damage of such outer space environment by the way of immensive accumulation of space debris.

1.2 Review of literature:

1. Capturing space junk and bringing it back to Earth, Ralph Cooney, Science Learning Hub⁴: This article gives the basic idea of what is space debris and what are the ways available for the clearance of such debris in a scientific way of approach. This helped me to involve more in this concept in a scientific approach to tackle the current issue.
2. Bringing 'space trash' safely back to Earth, Sarah Olson, Purdue News Service,2018⁵: This news article is based upon the concept of Spencer's (who is a Purdue alumnus ('89 and '91) with a background in planetary robotics. He spent 17 years at NASA's Jet Propulsion Lab in Pasadena, California as a mission designer and project manager for a number of planetary missions) thought of approach to bring back the space debris, which specifically address the defunct satellites. This provides the basic idea for me to analyses how and what are the possible ways to bring up the defunct satellites.
3. How Can We Clean up Space Debris, Karthik Yadavalli, Daily Paper Summaries, 2024⁶: This article gives the foundation for where and when the present issue get started? An analytical approach of rate of increase in accumulation of space debris was calculated and some ideas were provided for the clearance of such debris. This article specifically helps me to know about the massive increase rate of space debris and the background of such cause.

³ 'ESA Space Environment Report 2024' (European Space Agency) <www.esa.int/Space_Safety/Space_Debris/ESA_Space_Environment_Report_2024#:~:text=The%20amount%20of%20space%20debris%20grows,than%2010%20cm%20in%20size> accessed 8 September 2024

⁴ Ralph Cooney, 'Capturing space junk and bringing it back to Earth'. (Science Learning Hub). <<https://www.sciencelearn.org.nz/resources/3185-capturing-space-junk-and-bringing-it-back-to-earth>>accessed 2 October 2024

⁵Sarah Olson, 'Bringing 'space trash' safely back to Earth'. (Purdue University). <<https://www.purdue.edu/newsroom/archive/releases/2018/Q4/bringing-space-trash-safely-back-to-earth.html>> accessed 2 October 2024

⁶ Karthik Yadavalli, 'How Can We Clean up Space Debris', (Daily Paper Summaries), <<https://astrobites.org/2024/04/18/how-can-we-clean-up-space-debris/>> accessed 2 October 2024

4. Mitigating space debris generation,ESA⁷: This article of European Space Agency provides the information about how space debris get mitigated and provides some guidelines for sustainable space. This also address the international efforts that are taken to handle this issue. This provides me the basic idea of regulatory framework which are preexisting in nature.
5. Space Debris: India's Contribution and Efforts to Tackle the Problem, civils daily⁸: This article provides the overview of countries responsibilities and liabilities of such countries to tackle this issue. This helps me to analyze the basis responsibility of the countries to contribute in clearance of space debris. This present article is much narrower in sense. So this brings me the curiosity to dive deeper into this aspect to know the liability of the state involved in this current issue.
6. International Law, Malcolm N Shaw, 6th Edition, Cambridge⁹: This book is a definitive textbook for researchers and students especially in academics. This comprehensive international textbook helped the researcher understand the concept of Outer space, the treaties and conventions regarding the air space, etc.
7. Research Methodology: Techniques and Trends (Taylor & Francis Group 2022), Kothari DP and Dubey UKB¹⁰: This book provided me with understanding the basic techniques and methods of research methodology.

1.3 Objectives of the study:

1. To study the legal dimension of environmental consequence of Space debris at the onset of Space exploration under the regime of International Environmental Law and International Space Law.
2. To provide for a regulatory framework adequately addressing the pressing environmental damage and thereby ensuring clearance of defunct satellites in a sustainable way.

⁷ 'Mitigating space debris generation',(esa), <https://www.esa.int/Space_Safety/Space_Debris/Mitigating_space_debris_generation> accessed 2 October 2024

⁸ 'Space Debris: India's Contribution and Efforts to Tackle the Problem',(civils daily), <<https://www.civildaily.com/news/space-debrisindiascontribution/#:~:text=India%3A%20India's%20contribution%20is%200.5%25.&text=While%20all%20the%20trackable%20debris,2001%20are%20still%20in%20orbit>> accessed 2 October 2024

⁹ Shaw MN, *International Law* (Cambridge University Press 2003)

¹⁰ Kothari DP and Dubey UKB, *Research Methodology: Techniques and Trends* (Taylor & Francis Group 2022)

1.4 Research problem:

“At the onset of immensive growth in space exploration, there would be proportional increase in launch and launch rate. The debris in space and bursting of the defunct satellites leads to Kessler syndrome which are likely to damage the space environment is gradually increasing. The clearance of defunct satellites without causing environment damage is still a big deal. However, this pressing issue has been left unfocussed in the present legal regime of International Environmental Law and Space Law.”

1.5 Research question:

1. Whether the International Environmental Law and International Space Law adequately addresses the issue of clearance of defunct satellites at the onset of space exploration?
2. If so, how focused they are to address the environmental degradation out of space debris manipulation due to bursting of defunct satellites?
3. If not so, what could be the nature of regulatory framework in addressing the issue adequately?

1.6 Hypotheses:

There are certain regulatory frameworks which also address the removal of space debris as part of it but there is no such specific convention or any other regulatory framework for regulating space debris accumulation or of removal of defunct satellites. With this inadequate regulations there could not be a proper implementing mechanism. To tackle this growing issue we need a proper regulations.

1.7 Research methodology:

The researcher adopted the Doctrinal Legal Research methodology, in which the instruments of International Environmental Law and International Space Law, along with the domestic laws that govern certain spacefaring nations that have taken action in order to avoid environmental damage for the removal of space debris, are rigorously analyzed in the first part of the study. The researcher also makes use of the Applied Research Methodology to address the pressing matter of environmental degradation brought on by the failure to remove defunct satellites, which at the beginning of space exploration was a larger form of debris that needed to be acknowledged as soon as possible and governed by an international legal framework.

1.9 Limitation of the study:

This research is based on speculations made by the environmental science community rather than verified facts. For instance, the onset of space exploration leads to an increase in the number of launch sites and a corresponding rise in launch rate, both of which enhance environmental damage. Also, the explosive increase of space debris due to bursting up of the defunct satellites in outer space though proved to be environmentally harmful, had not yet been quantified in measurements.

1.10 Tentative chapterization:

Chapter 1 - Introduction

Chapter 2 - Space environmental damage

Chapter 3 - International legal framework on space debris control

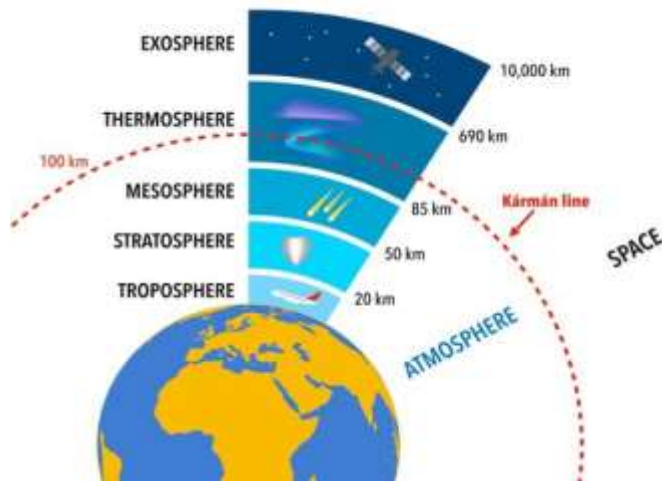
Chapter 4 - Initiatives for managing defunct satellites and space debris

Chapter 5 – Suggestion and Conclusion

CHAPTER II**SPACE ENVIRONMENTAL DAMAGE****2.1 Understanding the Space Environment:**

The environment on Earth's surface has commonalities and differences from the space environment, past Earth's atmosphere; this boundary is defined by the Karman line¹¹. The approximate altitude at which conventional airplanes can no longer fly is marked by the Karman line, which is based on physical fact. Above the Karman line, the air becomes too thin to support any kind of propulsion, hence any vehicle must use a method independent of the lift provided by Earth's atmosphere. To put it another way, the physical rules controlling a craft's capacity to fly change at the Karman line. Earth ends and outer space starts at the Karman line, some 62 miles (100 kilometres) above the planet's surface. This outer space area is known as the space environment.

¹¹ The Kármán line is commonly defined as the boundary of space at an altitude of 100 kilometers above sea level. See National Aeronautics and Space Administration, 'Kármán Line'



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2.2 Defunct satellites as Space debris:

In this modern era man started exploring the outer space for various reasons. There are even private space agencies such as SpaceX, Virgin Galactic, Blue Origin, Orbital Sciences, Rocket Lab, Axiom Space, Sierra Space and also Skyroot Aerospace in India dramatically set an era of privatization in space journey. This drastic increase in space exploration leads to more and more number of launches of satellites in outer space. The excessive accumulation of satellites floating in the outer space becomes debris at some point. Space debris, also known as space junk, artificial material that is orbiting earth but is no longer functioning. This material can be as large as a discarded rocket stage or as small as a microscopic chip of paint¹³. This also includes nonfunctional spacecraft, derelict satellites, and fragments from explosions. Space debris poses a risk to operational spacecraft due to potential collisions, which can have significant impacts on satellite functionality and space exploration.

Reasons why a satellite may become defunct:

There are certain reasons why the satellites in the outer space becoming defunct, they include

- Running out of fuel or exhausting its operational lifetime
- Suffering critical component failures
- Being involved in a collision with another object in space
- Experiencing damage during launch or in-orbit operations

Once a satellite is defunct, it can pose a risk to other operational spacecraft due to potential

¹² "Try Our API" (Shutterstock) <<https://www.shutterstock.com/search/karman-line>> accessed October 20, 2024

¹³ "Why Go to Space" (NASA, February 21, 2023) <<https://www.nasa.gov/humans-in-space/why-go-to-space/>>

collisions. This may lead to Kessler syndrome¹⁴.

2.3 The impact of defunct satellites as space debris on the space environment:

Most “space debris” is moving very fast and can reach speeds of approximately 18,000 miles per hour, almost seven times faster than a bullet.¹⁵ About 80 tons of space debris re-enter Earth's atmosphere annually. Although most garbage breaks down unnoticed, the process of fragmentation produces compounds that can cause ozone depletion and contribute to air pollution. Moreover, the debris that makes it back into space could endanger the earth. Clutter complicates space travel and satellite operations by increasing the danger of collisions dramatically while in orbit. This problem is best shown by the rising incidence of Kessler Syndrome.¹⁶ According to this speculative scenario, cascade collisions caused by the density of debris in low Earth orbit (LEO) dramatically increase the debris field and endanger upcoming space missions. Due to the rate of speed and volume of debris in LEO, current and future space-based services, explorations, and operations pose a safety risk to people and property in space and on Earth.



Space debris began to accumulate in earth's orbit after the launch of the first artificial satellite

¹⁴ Donald J. Kessler and Burton G. Cour-Palais, 'Collision Frequency of Artificial Satellites: The Creation of a Debris Belt' (1978) 3Journal of Spacecraft and Rockets 421.

¹⁵ "Space debris" refers to non-functional artificial objects in Earth's orbit. See National Aeronautics and Space Administration, 'Orbital Debris: A Technical Assessment' (2023) <<https://www.nasa.gov/headquarters/library/find/bibliographies/space-debris/#:~:text=Most%20E%80%9Cspace%20junk%E2%80%9D%20is%20moving%20very%20fast,and%20property%20in%20space%20and%20on%20Earth.>> accessed 24.10.2024

¹⁶ Wall M, "Kessler Syndrome and the Space Debris Problem" Space (November 15, 2021) <<https://www.space.com/kessler-syndrome-space-debris#>> accessed October 24, 2024

¹⁷ Gheorghe A, "Space Debris – Visualizing the Risk and Informing Stakeholders by Adrian Gheorghe" (The Market For Ideas) <<https://www.themarketforideas.com/space-debris-visualizing-the-risk-and-informing-stakeholders-a190/>> accessed October 24, 2024

Sputnik 1, in 1957.¹⁸ From then to till now as of On June 19, 2024 there have been an approximate count of 10,019 active satellites, two-thirds of which (6,646) belong to *Starlink*, *SpaceX's* constellation. The majority (9,254) of these satellites are in Low-Earth orbits, mainly between 400 and 1,200 kilometers from the Earth. There were also nearly 3,200 rocket stages and 13,326 pieces of debris orbiting the Earth. This is just a small fraction of the currently unaccounted-for debris, which is estimated to a number close to a million pieces measuring a centimeter or more in size.¹⁹

These drastic accumulation of debris causes environmental degradation by depleting ozone layer, space craft collision, orbital collapse, and it creates space environment as a garbage-yard. The space debris accumulation is highly impacting on the space environment.

2.4 Notable Space debris incident that causes space environmental damage:

The most prominent instance of space debris occurred on January 11, 2007, when the Chinese military destroyed the Fengyun-1C weather satellite. Over 3,000 fragments were produced by this event, accounting for more than 20% of all space debris at the time.²⁰ In addition to this there are even some defunct spacecraft that creates space environmental damage with the effect of Kessler syndrome. For instance, thousands of bits of debris from a 2009 collision between an operational communications satellite and a defunct spacecraft (Iridium-Cosmos Collision) continue to circle the planet. This event highlighted the vulnerability of operational satellites to accidental collisions.²¹ The debris generated posed a long term threat to other satellites in similar orbits, necessitating improved space traffic management and coordination. The impact of these incidents destroys the Space environment and further possess numerous risks in the outer space.

¹⁸ Polyakov DrM, "Where Does Space Junk Come from – and How Do We Clean It Up?" (World Economic Forum, May 5, 2021) <<https://www.weforum.org/stories/2021/05/why-we-need-to-clean-up-space-junk-debris-low-earth-orbit-pollution-satellite-rocket-noosphere-firefly/#:>> accessed October 24, 2024

¹⁹ Gregersen E, "Space Debris" Encyclopedia Britannica (April 16, 2009) <<https://www.britannica.com/technology/space-debris>> accessed October 24, 2024

²⁰ "Chinese Test Anti-Satellite Weapon" (2007) 2007 Physics Today

²¹ Aerospace Corporation, 'Kessler Syndrome: A Hazard to Space Operations' (2015) <https://aerospace.org/sites/default/files/2019-04/Crosslink%20Fall%202015%20V16N1%20.pdf> accessed 24.10.2024

CHAPTER III

INTERNATIONAL LEGAL FRAMEWORK ON SPACE DEBRIS CONTROL

3.1 Existing regulations and guidelines regarding removal of defunct satellites in outer space:

International Environmental Law and International Law does not properly address the issues regarding the removal of defunct satellites directly. However, it provides some treaties to regulate activities in outer space, they are as follows,

- (i) Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies of January 27, 1967;²²
- (ii) The 1972 Convention on International Liability for Damage Caused by Space Objects;²³
- (iii) The 1975 Convention on Registration of Objects Launched into Outer Space;²⁴
- (iv) The Agreement on the Rescue of Astronauts, the Return of Astronauts, and the Return of Objects Launched into Outer Space;²⁵ and
- (v) The Agreement Governing the Activities of States on the Moon and Other Celestial Bodies. Regarding international law, the first four treaties are generally recognized.²⁶

Among these, the first four are widely accepted treaties in the realm of international law between space-capable states, and only the first three address space debris. These Treaties have limited relevance, but commentators overstate their impact on initiatives aimed at mitigating space debris. The significance of these Treaties is minimal, but observers exaggerate their influence on programs meant to reduce space debris.

To address this pressing concern on space debris management, the UN Committee on Peaceful Uses of Outer Space (“COPUOS”)²⁷ has formulated comprehensive Space Debris Mitigation

²² Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies (opened for signature 27 January 1967, entered into force 10 October 1967) UN Doc A/RES/2222.

²³ Convention on International Liability for Damage Caused by Space Objects (opened for signature 29 March 1972, entered into force 1 September 1972) UN Doc A/RES/2777.

²⁴ Convention on Registration of Objects Launched into Outer Space (opened for signature 12 November 1974, entered into force 15 September 1976) UN Doc A/RES/3235

²⁵ Agreement on the Rescue of Astronauts, the Return of Astronauts, and the Return of Objects Launched into Outer Space (opened for signature 22 April 1968, entered into force 3 December 1968) UN Doc A/RES/2345

²⁶ Agreement Governing the Activities of States on the Moon and Other Celestial Bodies (opened for signature 5 December 1979, entered into force 11 July 1984) UN Doc A/RES/34/68.

²⁷ A/AC. 105/L: A citation for COPUOS from 2016

Guidelines. These guidelines provide a framework for mission planning and spacecraft operation to reduce the generation of space debris. Key measures include limiting debris release during spacecraft operations, minimizing the potential for break-ups, Limiting the probability of accidental collision in orbit, avoiding collisions, Limiting the long-term presence of spacecraft and launch vehicle orbital stages in the low-Earth orbit (LEO) region after the end of their mission, Limiting the long-term interference of spacecraft and launch vehicle orbital stages with the geosynchronous. Earth orbit (GEO) region after the end of their mission and preventing intentional destruction. They also includes recommendations for the disposal of defunct satellites, such as deorbiting or moving them to graveyard orbit. These guidelines serve as a cornerstone for international cooperation in managing space debris and removal of defunct satellites.

Article IX of outer space treaty²⁸ is somehow in relevance with the space debris management, as it requires the state to avoid harmful contamination of outer space and it insist to take measures to prevent damage to the space environment. But it does not explicitly mention about the removal of defunct satellites. In order to address damages caused by space objects i.e. defunct satellites, the Convention on International Liability for Damage Caused by Space Objects entered into effect. It is often viewed as an extension of Article VII of the Outer Space Treaty. It includes every form of harm to one's life, health, or property when defining "damage." The Convention imposes liability on launching governments for harm that their spacecraft cause. However, Articles III and IV (b) introduce fault-based liability for damages occurring elsewhere than on Earth's surface. Article III holds a launching state liable only if the damage to another state's space object, persons, or property aboard such object was caused by its fault or the fault of persons for whom it is responsible.²⁹ With regard to space debris, a state is only liable if the debris from its space object causes damage due to its fault but it does not mandate the removal of space debris or clearance of defunct satellites. The European Union too has made protocols for the removal and management of debris in space. The ESA, which is constituted of 19 countries, piloted the first such mission that took the issue of space debris cleaning, which is a crucial effort which indeed is first of its kind. This mission which will aim to pick up a 112-kilogram fragment of the European Vega rocket booster – which has been in orbit since 2013 at an altitude of 660 kilometers. This acts a much need step in the right

²⁸ The Outer Space Treaty, 1967, Article 9

²⁹ Convention on International Liability for Damage Caused by Space Objects (opened for signature 29 March 1972, entered into force 1 September 1972) UN Doc A/RES/2777

direction.³⁰

3.2 Space Debris Mitigation Guidelines:

The IADC (Inter – Agency Space Debris Coordination Committee) developed Space Debris Mitigation Guidelines these guidelines describe existing practices that have been identified and evaluated for limiting the generation of space debris in the environment. The Guidelines cover the overall environmental impact of the missions with a focus on the following: (1) Limitation of debris released during normal operations; (2) Minimization of the potential for on-orbit break-ups; (3) Post-mission disposal; (4) Prevention of on-orbit collision.³¹ They include suggestions for moving defunct satellites to orbits that are less likely to pose collision risks. Although they are not legally binding in nature. These treaties, conventions and guidelines provides an over view on the protection of space environment.

CHAPTER IV

INITIATIVES FOR MANAGING DEFUNCT SATELLITES AND SPACE DERIS

4.1 India’s initiatives for managing debris:

India has demonstrated its commitment to the sustainability and safety of space operations through its space debris management programs. With the use of contemporary technology and cooperation between the Indian government and commercial businesses, India is in a position to take important actions to lessen the risks posed by space debris and safeguard its space resources for future generations. The actions taken by India to manage space debris are as follows:

³⁰ “Mitigating Space Debris Generation” (Mitigating space debris generation) <https://www.esa.int/Space_Safety/Space_Debris/Mitigating_space_debris_generation> accessed October 30, 2024

³¹Inter-Agency Space Debris Coordination Committee, IADC Space Debris Mitigation Guidelines (2007) <https://www.unoosa.org/documents/pdf/spacelaw/sd/IADC-2002-01-IADC-Space_Debris-Guidelines-Revision1.pdf > accessed 30.10.2024



Debris free space mission (DFSM):

India intends to Debris free space missions (DFSM). This initiative was declared by Shri Somanath S., Chairman, ISRO/Secretary, DOS during the inaugural opening plenary of the 42nd Annual Meet of Inter-Agency Space Debris Co-ordination Committee (IADC) held at Bengaluru on April 16, 2024.

“This initiative aims to achieve debris-free space missions by all Indian space actors, governmental and non-governmental by 2030. India also encourages all other state space actors to follow this initiative for the long-term sustainability of Outer Space”. The initiative includes avoiding debris generation and on-orbit collisions. It also involves actively de-orbiting spacecraft, controlled re-entry of spent rocket stages, and passivation. Implementation of DFSM is scheduled to begin in early 2025.³³

ISRO System for Safe & Sustainable Operations Management (IS4OM)³⁴:

IS4OM is ISRO’s holistic approach to ensure the safety of our space assets and thus, sustains the utilization of outer space for national development. The system safeguards all Indian Space assets by mitigating the collisional threats from space objects through specific orbit maneuvers and complying with international guidelines on post mission disposal and satellite’s end-of-life operations.

³² The Editors, “Space Trash Threatens the Global Economy” (Scientific American, May 17, 2024) <<https://www.scientificamerican.com/article/there-is-too-much-trash-in-space/>> accessed November 2, 2024

³³ “India’s Intent on Debris-Free Space Missions” (Explained) <https://www.isro.gov.in/Debris_Free_Space_Missions.html#> accessed November 2, 2024

³⁴ “Dedication of ISRO System for Safe & Sustainable Operations Management (IS4OM) to the Nation” <<https://www.isro.gov.in/IS4OM.html>> accessed November 2, 2024

Project NETRA³⁵:

Project NETRA represents the initial endeavor by India to develop a timely warning system for space debris and associated threats that its satellites encounter in space. The project demonstrates India's desire to be prepared for any threats to its space operations, which are growing more congested and contentious every year. In addition to supporting global efforts to increase awareness of space events and promote responsible behavior among all countries utilizing it, such activities will help India bolster its own space capabilities.

Space Situational Awareness Control Centre (SSACC)³⁶:

India's space domain is managed and protected by the Space Situational Awareness Control Centre (SSACC). It is the cornerstone of India's larger plan for space sustainability and resilience, reaffirming its proactive stance in addressing the growing challenges of carrying out operations in space brought on by debris propagation and orbital crowding. Furthermore, this multipurpose facility reflects global efforts to advance understanding of space events and foster international collaboration in the preservation of Earth's space resources.

Mission Shakti, India's Anti-Satellite Missile test:

On March 27, 2019, India tested its anti-satellite (ASAT) missile, known as Mission Shakti. The Defence Research and Development Organization (DRDO) was in charge of it. India successfully destroyed one of its own defunct satellites, Microsat-R, in low Earth orbit (LEO) at a height of roughly 283 kilometers during the test using a ground-based missile. The objective was to boost India's strategic defense capabilities by showcasing its ability to destroy satellites in orbit. Although space debris was created during the test, most of it returned to Earth's atmosphere and burnt away in a matter of weeks to months since the target satellite was at a relatively low altitude. India was the fourth nation to display ASAT capabilities with this mission, following the United States, Russia, and China.

Though the missile test was a great achievement for India, it lagged in clearing defunct satellites without creating more debris. In addition to this missile test, there are certain space debris management programs have been taken as an initiative by India which have been mentioned in earlier part is for the sustainability and safety of space operations. These

³⁵“ISRO SSAControl Centre Inaugurated by Dr. K. Sivan, Chairman, ISRO/ Secretary, DOS” <<https://www.isro.gov.in/ISRO%20SSAControl%20Centre.html>> accessed November 2, 2024

³⁶“Foundation Stone of Space Situational Awareness Control Centre by Chairman, ISRO” <<https://www.isro.gov.in/Foundation%20stone%20of%20Space.html>> accessed November 2, 2024

programs generally address about the debris management in outer space but it does not specifically mention anything about the clearance of defunct satellites without causing space environmental damage.³⁷

4.2 Other states initiatives (Research and Testing Missions):

ESA's Clean Space initiative:

ESA launched this initiative to focus on reducing space debris and improving sustainable space practices which mainly fall into three main areas viz., reducing environmental impacts and fostering green technologies, minimizing the production of space debris and removing space craft from orbit and demonstrating in-orbit servicing of spacecraft.³⁸ It includes missions like *ClearSpace-1*, *CleanSat* and research into various ADR technologies.

NASA's Orbital Debris program office:

NASA has been conducting research into tracking and modeling space debris, as well as exploring methods for debris removal, such as laser-based concepts and spacecraft designed for ADR missions. Mitigation measures can take the form of curtailing or preventing the creation of new debris, designing satellites to withstand impacts by small debris, and implementing operational procedures such as using orbital regimes with less debris, adopting specific spacecraft attitudes and even maneuvering to avoid collisions with debris.³⁹

The *ClearSpace-1* mission from the European Space Agency (ESA) demonstrates how they have developed *robotic arms* and *manipulators* for trash capture. In order to demonstrate *nets* and *harpoons* for debris collection, the University of Surrey and its collaborators created the Remove DEBRIS mission. NASA and ESA have investigated *ion beams* and *laser ablation* for non-contact trajectory changes, while Japan's JAXA has tested tethers to deorbit extinct satellites. To demonstrate autonomous satellite swarms and capture technology, Astroscale launched ELSA-d, and researchers are working on *magnetic devices* for trapping debris. ESA and NASA are working on *AI-based debris tracking* systems. Additionally, to guarantee that

³⁷ "Mission Shakti" (Defence Research and Development Organisation - DRDO, Ministry of Defence, Government of India) <<https://drdo.gov.in/drdo/mission-shakti>> accessed November 2, 2024

³⁸ "Clean and Eco-Friendly Space" <https://www.esa.int/Enabling_Support/Preparing_for_the_Future/Discovery_and_Preparation/Clean_and_eco-friendly_space> accessed November 2, 2024

³⁹ Douglas S, "NASA Seeks Solutions to Detect, Track, Clean Up Small Space Debris" (NASA, September 25, 2023) <<https://www.nasa.gov/directorates/stmd/prizes-challenges-crowdsourcing-program/center-of-excellence-for-collaborative-innovation-coeci/coeci-news/nasa-seeks-solutions-to-detect-track-clean-up-small-space-debris/>> accessed November 2, 2024

satellites safely deorbit after their operations, satellite constellations such as OneWeb are implementing end-of-life disposal systems and self-destruction mechanisms.

CHAPTER V

SUGGESTION AND CONCLUSION

5.1 Suggestion:

For the purpose of active space debris removal and clearance of defunct satellites from the outer space there should be a proper regulatory framework which should consist of state responsibility and liability for such damages. Here's an outline of a comprehensive framework for managing the removal of defunct satellites addressing state responsibility, liability, operational requirements and international collaboration. This structured approach could help to achieve a safer, more sustainable space environment, ensuring that future generations can continue to benefit from space activities.

International Framework for Orbital Debris and Satellite Disposal (IFODSD):

Article 1: State Responsibility for Mitigating Space Debris

Each state is responsible for ensuring that its space activities, including those of its private sector, do not contribute to harmful debris in orbit. This includes mandating that states enact laws and regulations to control the generation of space debris and to monitor satellite activities. States are expected to enforce compliance with internationally recognized guidelines for debris mitigation during the design, launch, operation, and end-of-life phases of satellites.

Article 2: Obligation for End-of-Life Satellite Disposal

All satellite operators have a clearly defined end-of-life disposal plan before launch. Operators must specify whether their satellite will de-orbit, re-enter the atmosphere, or relocate to a designated "graveyard orbit." States are responsible for ensuring that all satellites under their jurisdiction are equipped with disposal mechanisms, such as propulsion systems for de-orbiting or alternative disposal technologies, to avoid becoming defunct debris.

Article 3: Mandatory Reporting and Tracking of Satellite Status

States and satellite operators regularly report on the operational status of their satellites. If a satellite becomes non-functional or risks becoming defunct, operators must immediately notify relevant international organizations. A centralized tracking system is to be maintained, supported by data-sharing among states, to monitor and predict satellite movements, track

defunct objects, and minimize collision risks.

Article 4: Liability for Damages Caused by Defunct Satellites

States hold liability for any damage caused by their defunct satellites under the Convention on International Liability for Damage Caused by Space Objects. This article enforces the principle of no-fault liability, meaning that a state is responsible for damages caused by its satellites, regardless of intent or fault. It further requires that states establish compensation mechanisms or insurance to cover potential liabilities from defunct satellite incidents.

Article 5: Implementation of “Polluter Pay” Principle for Satellite Operators

“Polluter Pay” Principle, imposing fees on satellite operators based on their contribution to space debris. The fee structure incentivizes satellite operators to invest in debris mitigation and removal technologies, as fees would be reduced for operators who demonstrate responsible disposal practices.

Article 6: International Cooperation in Defunct Satellite Removal

States should work collaboratively through international treaties and organizations to address shared challenges in debris management and defunct satellite removal. This includes data-sharing, joint research on debris removal technologies, and multilateral agreements on space traffic management to reduce collision risks in shared orbits, especially low Earth orbit (LEO).

Article 7: Support for Active Debris Removal (ADR) Technologies

It encourages states to invest in and support the development of active debris removal (ADR) technologies, such as satellite “tugs” or robotic arms capable of capturing and de-orbiting defunct satellites. By funding research and partnering with private companies, states can contribute to innovative solutions that directly address the growing issue of space debris.

Article 8: International Standardization of Satellite Disposal Protocols

It requires the creation of standardized protocols for satellite disposal, aligning practices across countries. This includes universal standards for deorbiting altitude, disposal maneuvers, and end-of-life strategies, ensuring consistency in debris mitigation efforts worldwide. States would collaborate through an international regulatory body to develop and enforce these protocols.

Article 9: Annual Assessment and Reporting on Debris Mitigation Efforts

It requires that each state publish an annual report detailing its progress in debris mitigation, defunct satellite removal efforts, and compliance with international debris management standards. Reports would cover both government and private sector activities, improving transparency and accountability.

Article 10: Humanitarian and Environmental Standards for Satellite Disposal

It requires that satellite disposal methods adhere to humanitarian and environmental standards, minimizing harm to human health and ecosystems. This includes using controlled deorbiting methods that prevent satellite parts from reaching populated areas and developing materials that degrade upon re-entry, reducing the environmental impact.

5.2 Conclusion:

As proving of the hypothesis, there is no proper regulatory framework for the clearance of defunct satellites from the orbit and even the existing framework in international law does not provide any particular provisions regarding who (which state) and how the responsibility for such clearance would take place. Though if there are some initiatives which have been taken by India and also by other countries, it is not adequate for handling the present heating issue. The rapid growth of the concerned issue may affect the future exploration of space. To tackle these issues it would be better to have a separate regulation for the clearance of defunct satellites as well as the space debris to safeguard the space environment.