

# Agnirva Project Report

**Project Report Topic: The Role of Space Robotics in Space  
Debris Mitigation**

**Internship Organisation : The Agnirva Space Internship program**

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## Introduction

- Background on Space Debris

Space debris, which includes defunct satellites, spent rocket stages, and collision fragments, poses a major risk to space operations. The accumulation of debris increases the likelihood of collisions, threatening operational satellites and the future of space exploration.

- Importance of Space Robotics in Debris Mitigation

Space robotics have emerged as a powerful tool in addressing space debris challenges. Through various techniques, robots can capture, monitor, and mitigate space debris, contributing to a safer and more sustainable space environment.

- Objectives of the Report

This report explores the contributions of space robotics to space debris mitigation, detailing key strategies, case studies, and future directions for robotic involvement in debris reduction.

## Overview of Space Debris and Its Impact

- Definition and Types of Space Debris

Space debris consists of any human-made object in orbit that no longer serves a useful purpose. It can include defunct satellites, spent rocket stages, and fragments from collisions or explosions.

- Impact of Space Debris on Space Operations

Debris poses collision risks to active satellites and spacecraft, endangering space missions and resulting in substantial economic losses.

- The Need for Debris Mitigation

The growing amount of space debris necessitates effective mitigation strategies to prevent collisions and ensure the safety of future space operations.

## Key Strategies of Space Robotics in Debris Mitigation

- Active Debris Removal (ADR)
- Capture Mechanisms: Nets, Harpoons, and Manipulators

Robotic spacecraft can capture large debris objects using advanced capture mechanisms like nets, harpoons, and robotic arms.

- Case Study: ESA's RemoveDEBRIS Mission

The RemoveDEBRIS mission successfully demonstrated net and harpoon technology to capture simulated debris, marking a significant step forward in ADR.

- Robotic Servicing Missions
- Extending Satellite Lifespan and Controlled Disposal

Robotic servicing missions attach to defunct satellites, providing propulsion for controlled disposal or moving them to a safe orbit.

- Case Study: Northrop Grumman's Mission Extension Vehicle (MEV)

The MEV has successfully extended satellite life, showcasing the potential of robotic servicing in debris reduction.

- In-Space Assembly and Manufacturing
- Benefits of On-Orbit Assembly for Reducing Launch Debris

By building structures directly in space, the need for multiple launches is reduced, decreasing debris associated with rocket stages.

- Case Study: NASA's Archinaut Project

NASA's Archinaut project aims to develop robotic manufacturing capabilities in space, offering a sustainable approach to large-scale assembly.

# Role of Robotics in Debris Tracking and Monitoring

- Importance of Accurate Debris Mapping

Mapping debris helps avoid collisions and aids in developing comprehensive debris mitigation strategies.

- Robotic Platforms with Advanced Sensors and Imaging

Robotic platforms equipped with sensors and imaging systems gather valuable data on debris, improving debris monitoring accuracy.

- Data Collection for Collision Avoidance and Risk Assessment

This data is critical for collision avoidance maneuvers and assessing debris-related risks.

## Preventative Maintenance Through Robotic Servicing

- Role of Robotics in Satellite Inspection and Maintenance

Robots can inspect, refuel, and repair satellites, preventing in-orbit failures that could generate debris.

- Example: NASA's Restore-L Mission for Satellite Refueling and Repair

Restore-L aims to demonstrate robotic satellite servicing, reducing the need to replace malfunctioning satellites with new launches.

- Benefits for Preventing In-Orbit Failures and Reducing Potential Debris

Robotic maintenance extends satellite lifespans, lowering the chances of debris generation.

# Testing and Development of New Mitigation Technologies Using Robotics

- Overview of New Mitigation Technologies: Drag Sails and Tethers

Drag sails and tethers are designed to increase drag on debris, facilitating its deorbit.

- Role of Robotic Platforms in Testing and Validation

Robotic platforms deploy and test these technologies in space, proving their feasibility and effectiveness.

- Future Applications and Benefits for Debris Reduction

These technologies, once proven, can help accelerate debris mitigation efforts.

## International Collaboration and Best Practices in Robotic Debris Mitigation

- Overview of International Initiatives (e.g., ESA's Clean Space Program)

ESA's Clean Space program and similar international efforts aim to establish shared standards and promote cooperation.

- Importance of Collaboration and Standardization in Debris Mitigation

Coordinated efforts allow for more effective debris management and promote sustainable practices.

- Role of Robotics in Fostering International Coordination

Robotic technologies are central to collaborative mitigation strategies, supporting a unified approach to space debris.

# Challenges and Future Directions in Robotic Debris Mitigation

- Technical and Operational Challenges

Challenges include technological limitations, high costs, and operational difficulties in debris capture.

- Future Research Areas for Robotic Debris Mitigation

Further research is needed to improve robotic capabilities, capture mechanisms, and mission efficiency.

- Potential for Growth in Space Robotics Technology

As technology advances, space robotics will play an increasingly prominent role in maintaining orbital sustainability.

## Conclusion

- Summary of Key Findings

Space robotics provide numerous effective methods for mitigating space debris, from removal to servicing and monitoring.

### 9.2 The Role of Robotics in Ensuring Sustainable Space Operations

Robotics is essential in preserving the orbital environment for future missions and ensuring operational safety.

### 9.3 Final Thoughts on the Future of Space Robotics in Debris Mitigation

With ongoing advancements, space robotics will continue to enhance debris mitigation efforts and support sustainable space exploration.

## 10. References

- [NASA's Space Robotics Program](#)
- ESA Clean Space Initiative
- [Journal of Space Robotics](#)