AN ANALYTICAL OVERVIEW OF SPACE DEBRIS STARTUPS

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INTRODUCTION

1.1 Abstract

Once an expansive frontier of limitless possibilities, space now grapples with a tangible challenge - the proliferation of space debris. As humanity extends its footprint into the cosmos, our orbital activities leave behind a growing trail of non-functional satellites, spent rocket stages, and fragments resulting from celestial collisions. The implications of this debris, both immediate and potential, cast a shadow on the safety and sustainability of space activities.

In this analytical overview, we navigate the intricate landscape of startups committed to addressing the complexities of space debris. To comprehend the innovative solutions propelling this nascent industry, it is imperative to first grasp the underlying context of the space debris predicament and the diverse technologies applied to its management, monitoring, and removal.

1.2 Context

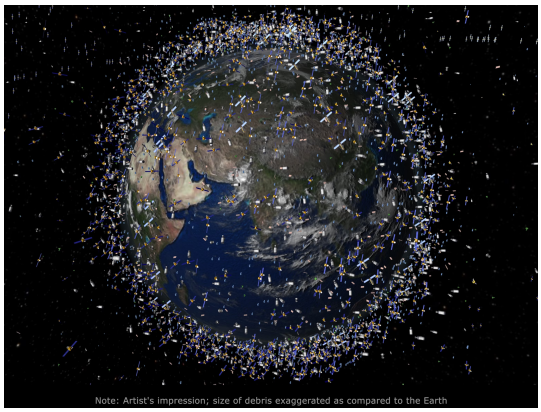
The challenge of space debris isn't just a result of past activities; it's a pressing concern for ongoing and future space missions. With low Earth orbit getting increasingly crowded with operational satellites, the risk of collisions with space debris is on the rise. The high-speed encounters between these celestial bodies pose a tangible threat to operational satellites, crewed missions, and the overall integrity of space infrastructure. To tackle this challenge head-on, both the scientific community and private enterprises are actively developing technologies. These advancements aim to monitor the debris population, predict potential collisions, and strategize for effective removal. The multifaceted approach includes ground-based radar and optical telescopes for tracking, as well as innovative spaceborne technologies such as nets, harpoons, and electrodynamic tethers for active debris removal.

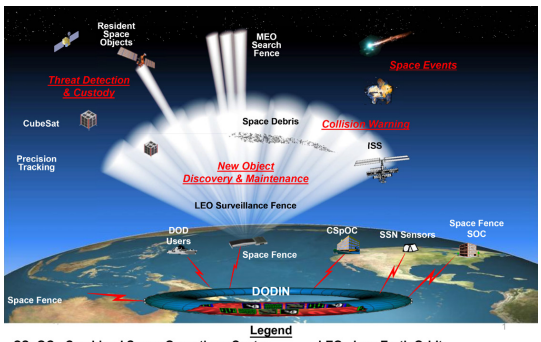
In the expansive realm of space exploration, startups are emerging as agents of change, injecting fresh ideas and technologies into the domain of space debris management. Their entrepreneurial drive aligns with the urgency posed by the space debris challenge, paving the way for innovative solutions that go beyond traditional governmental space agencies. In the following sections of this report, we'll provide a comprehensive overview of these startups, dissecting their missions, methodologies, and the economic viability that underlies their endeavors. As we closely examine their contributions, it becomes clear that these ventures are not only trailblazers in space debris mitigation but also heralds of a sustainable and secure future in Earth's orbit.

TECHNOLOGICAL OVERVIEW

2.1 Ground-Based Tracking and Monitoring

At the heart of space debris mitigation lies a network of ground-based radar and optical telescopes, functioning as the vigilant eyes of the cosmos. These instruments meticulously track the trajectories of space debris, providing crucial data for predictive collision avoidance maneuvers. By continuously monitoring the sky, these observatories contribute to the overarching goal of maintaining a clear celestial pathway.





Legend

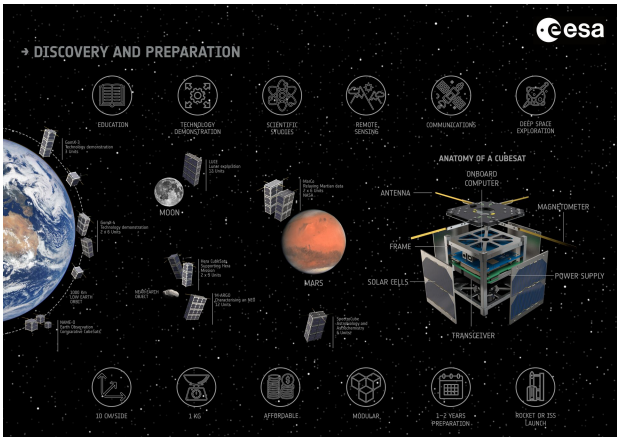
CSpOC - Combined Space Operations Center	LEO - Low Earth Orbit
DOD - Department of Defense	MEO - Medium Earth Orbit
DODIN - Department of Defense Information Network	SOC - Space Fence Operation Center
ISS - International Space Station	SSN - Space Surveillance Network

2.2 Active Debris Removal (ADR) Technologies

In the pursuit of actively mitigating space debris, innovative technologies have emerged. Harpoon systems, resembling celestial spears, aim to physically capture defunct satellites and space debris. This involves deploying a harpoon from a servicing spacecraft, securing the target, and orchestrating a controlled deorbit. Nets and snares, akin to cosmic fishermen, utilize deployable devices to ensnare debris, allowing for its secure removal and eventual descent. Electrodynamic tethers, a technological marvel, leverage the interaction with Earth's magnetic field to generate electrical currents, providing propulsion for controlled deorbit maneuvers.

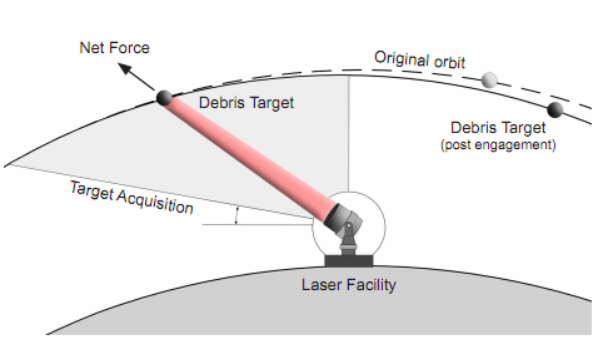
2.3 CubeSats for Debris Monitoring

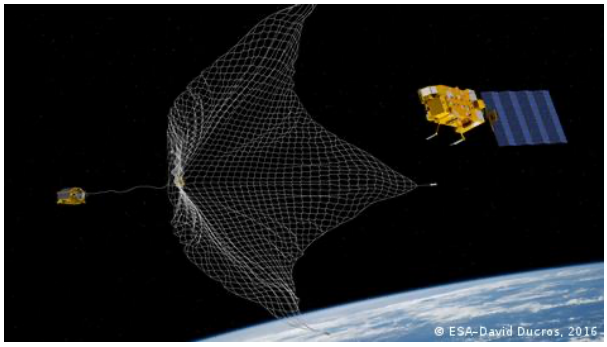
In the burgeoning era of miniaturized satellites, CubeSats serve as indispensable scouts navigating the cluttered trails of space debris. Deployed with the purpose of monitoring and gathering data on the density and distribution of debris, these small but mighty satellites contribute significantly to our understanding of the orbital environment.



2.4 Laser Systems for Deorbiting

Laser systems, whether ground-based or mounted on spacecraft, propose a unique approach to space debris mitigation. By directing laser beams toward targeted debris, these systems can induce a change in the debris' trajectory, facilitating a controlled descent toward Earth. This technology offers a precise and non-contact method for altering the orbits of space debris.





2.5 Spacecraft Design Improvements

In the ongoing quest for sustainable space activities, spacecraft design plays a pivotal role. Future satellites are crafted with deliberate considerations for controlled deorbiting at the end of their missions. The goal is to ensure that spacecraft gracefully re-enter Earth's atmosphere, minimizing the creation of additional debris.

2.6 International Guidelines and Policies

Beyond the realm of technology, the orchestration of space debris mitigation demands a harmonized international effort. Establishing guidelines and policies is paramount to regulating space activities, ensuring responsible practices, and mitigating the risks associated with the proliferation of space debris.

OVERVIEW OF STARTUPS

3.1 Astroscale

Astroscale, founded in 2013 by Nobu Okada, is a pioneering Japanese company headquartered in Tokyo. The company's flagship product is the ELSA-d (End-of-Life Services by Astroscale demonstration) spacecraft, designed to capture and de-orbit defunct satellites. Astroscale focuses on active debris removal (ADR) using innovative technologies, such as a magnetic capture mechanism that attaches to defunct satellites or spent rocket stages. The ELSA-d mission involves deploying a client satellite and a servicer satellite, equipped with magnetic plates. The servicer then approaches the client satellite, attaches magnetically, and safely guides it into Earth's atmosphere, where both satellites burn up upon reentry. Astroscale's mission is to demonstrate the viability of their debris removal technology, showcasing the potential for scalable and sustainable solutions.

In terms of financial backing, Astroscale has secured significant funding from both public and private sources. They have received support from the Japan Bank for International Cooperation, demonstrating the government's commitment to fostering space sustainability. Additionally, private investors, including venture capital firms and strategic partners, have recognized Astroscale's potential, contributing to the company's robust financial foundation.

From a business perspective, Astroscale has positioned itself as a pioneer in the space debris removal industry. While profitability in the short term may' be influenced by the high research and development costs, the increasing global awareness of space sustainability is likely to drive demand for their services. Astroscale's business model, focused on providing essential orbital debris removal services, holds promise for long-term viability and success.

3.2 ClearSpace

ClearSpace, founded in 2018 as a spin-off from the École polytechnique fédérale de Lausanne (EPFL) in Switzerland, has its headquarters in Switzerland. The company aims to provide end-to-end solutions for the removal of space debris. ClearSpace focuses on developing mission-specific robotic systems capable of capturing and de-orbiting debris, starting with the ClearSpace-1 mission. ClearSpace's ClearSpace-1 mission, scheduled for the mid-2020s, targets the removal of the VESPA (Vega Secondary Payload Adapter) upper stage from orbit. The capture mechanism involves a four-armed robotic system that firmly grasps the target object. This pioneering approach demonstrates ClearSpace's commitment to addressing the specific challenges posed by individual items of space debris.

ClearSpace has secured substantial funding from the European Space Agency (ESA), providing both financial support and a strong endorsement of their capabilities. Private investors have also contributed to ClearSpace's funding, reflecting confidence in the company's innovative approach to space debris removal.

In terms of the business landscape, ClearSpace operates with a focus on providing tailored solutions for space debris removal. While initial costs may be significant, ClearSpace's long-term viability is strengthened by its commitment to addressing the specific challenges posed by individual items of space debris.

3.3 D-Orbit

D-Orbit, founded in 2011 by Luca Rossettini, is an Italian company headquartered in Milan. D-Orbit provides end-to-end satellite launch and deployment services, and it also focuses on innovative solutions for debris removal. The company's flagship product is the ION Satellite Carrier, a versatile platform designed for satellite deployment and hosting of payloads, including technology for debris removal. D-Orbit's approach to debris removal involves attaching propulsion modules to defunct satellites, allowing them

to be safely deorbited. This approach aligns with their commitment to addressing the challenges of space debris while offering comprehensive satellite deployment services. D-Orbit's financial backing comes from a mix of public and private support. Securing contracts from space agencies for satellite deployment services and establishing partnerships with commercial entities showcase D-Orbit's robust financial position. Private investments further contribute to the company's ability to advance its technologies and expand its market presence.

From a business perspective, D-Orbit's dual focus on satellite deployment and debris removal enhances its overall sustainability. The revenue generated from commercial satellite deployment services supports the development of space debris removal technologies. D-Orbit's integrated approach positions it favorably for long-term success in a market increasingly prioritizing responsible space practices.

3.4 Effective Space Solutions

Effective Space Solutions, founded in 2013 by Arie Halsband, is headquartered in Israel. The company focuses on developing solutions for space sustainability. The DeOrbiter, Effective Space Solutions' flagship product, is a satellite servicing spacecraft designed for various missions, including debris removal and satellite life extension. The DeOrbiter spacecraft is equipped with advanced technologies, including a robotic arm for capturing and de-orbiting defunct satellites.

Financially, Effective Space Solutions has attracted support from both public and private sectors. Government contracts for space debris removal missions and strategic partnerships with private investors showcase the confidence in the company's capabilities.

The company's emphasis on providing satellite servicing solutions, including debris removal, positions it as a key player in the emerging market of on-orbit services. This, coupled with strategic partnerships and contracts, contributes to the company's financial viability and long-term prospects.

3.5 Rocket Lab

Rocket Lab was founded in 2006 and headquartered in Long Beach, California, it is a Company that provides launch services, spacecraft, satellite, components and on-orbit management.

They started with a small, industry-defining launch device, the Electron, the second most frequently launched rocket, with around a 90% success launch rate. They didn’t stop there however, and are currently developing the next generation large launch vehicle, called The Neutron, which will help launch large spacecraft missions of the future that will provide vital data and services to the Earth. They are also a premier supplier of flight-proven satellites, subsystems and spacecraft components.

They house various mission profiles for commercial, defence and civil markets. Rocket Lab space systems technology has enabled more than 1,700 missions globally.
The financial situation of Rocket Lab till 2023:

Rocket Lab also ventured into the field of Space debris removal in 2021. It signed a launch contract with Astroscale Japan Inc. The Electron Rocket is scheduled to soon launch the , which the Japanese Aerospace Exploration Agency selected as the first phase of Phase I of its Commercial Removal of Debris Demonstration Project.

The CEO and founder of Astroscale had said the following about the Electron rocket: "Reliable and commercially viable launch vehicles like Rocket Lab's Electron rocket enable frequent and flexible access to space, allowing us to advance our on-orbit services which are fundamental to the growth of the space infrastructure and economy". The Astroscale mission was ready to launch in September 2023, however, a launch failure was detected and the mission has been grounded for the time being until the issue is resolved.

As of November 21st, the company is valued at a $2.03 billion market cap. Rocket Lab has raised a total funding of $288M over 4 rounds. Its first funding round was on Oct 01, 2013. As of Quarter 3 of the financial year 2023, the company has a backlog of $582 million. Quarter 3 was one of their best quarters of the year, with an increase of 9% in revenue.

3.6 LeoLabs

Founded in 2016 as a venture-funded spinout of Silicon Valley research pioneer, SRI International, and Scientists and Space Industry veterans, LeoLabs is a startup committed to securing the LEO(low earth orbit). The company is built on 30+ years of R&D along with its ever-expanding global radar network and Data services to help satellite operators deploy their services safely and to empower governmental space agencies with detailed visibility in the LEO ecosystem.
Before LeoLabs, military and government organisations collected data on orbital object tracking. Their key aim is to fill the 'data deficit' that exists in orbital object tracking. It is now one of the largest and most accurate providers of data on object tracking in the LEO ecosystem. Their most popular product LeoSafe uses their existing state-of-the-art tracking technology to provide live updated images of different kinds of space debris. It is the only commercially available service that provides critical conjunction alerts and risk metrics in real-time.

Their Last round of seed funding was in 2021 June, when they secured $65 million worth of funding. There are no exact figures for their current net worth, however, estimates say their net worth is approximately 290-350 million. They had a 77% growth in revenue and have earned $29.8 million this year in revenues. The future is certainly bright for this

company as space debris removal gains more awareness, and the use of the tracking technology and data provided by LeoLabs will become more and more valuable.

3.7 Aurora Propulsion Technologies

A Finnish space startup founded in 2018, Aurora Propulsion Technologies is a company that provides satellite manufacturers with reliable mass-produced components for altitude and orbit control. Their main mission is the sustainable use of space. They focus on providing solutions for Collision avoidance, and Deorbiting and also provide custom solutions. Their motivation to focus on solutions for these areas is that its technology is invaluable due to the increasing amount of space debris in the atmosphere. Solving collision risks and deorbiting enables the satellite and its company to comply with tightening legislation and reduce risks in the future, integrate the smallest propulsion system in the world easily due to its plug-and-play design, become sustainable & gain public acceptance.

Collision Avoidance:
Aurora uses The Aurora Resistojet Module for Collision avoidance as its main product. The ARMC is a small propulsion system, almost as small as a Swiss knife. It utilizes water-based propellants for the safety of CubeSats and SmallSats.The ARM-C generates 1 mN of thrust on command with a single resistojet thruster. The device is built for serial production, making the system affordable and available on demand.
The economic benefits from collision avoidance are massive since it prolongs the time period a satellite can stay in space without collision. Furthermore, Aurora claims its solution is light and cost-effective.

Deorbiting:
Aurora Plasma Brake is their main product to tackle the problem of Deorbiting. It is a small and reliable device weighing about 0.2 kg. It is autonomous, requires minimal power and can deploy automatically.
Plasma Brake uses Coulomb drag to interact with the upper atmosphere plasma, slowing a spacecraft down. The plasma brake deploys a negatively charged 0,5…5 km micro tether to create the drag.
The cost and Economic benefits of the Plasma breaker are immense. The plasma brake can prolong missions by 1-3 years since it helps save propellant for station keeping. Furthermore, since it is so light, their estimates say the plasma break saves 15-25 kg for paying customers, which amounts to 400-500 Thousand euros of extra revenue per flight.

Their last round of funding with publicly available data secured 1.7 million Euros in 2021 December. They attracted investment from venture capital firms such as Practica Capital and Tesi (Finnish Industry Investment Ltd.) and The Flying Object, a Fund from Kluz Ventures. The 2022 financial year estimates say the company made around $6.5 million in revenue.

CONCLUSION

In conclusion, space debris startups are at the forefront of addressing the challenges in Earth's orbit. Their innovative solutions not only tackle immediate threats but also set the stage for sustainable space practices. The success of these startups depends on navigating a delicate balance between profitability and responsible space activities, requiring collaboration with industry players and adherence to regulatory frameworks.

These startups play a crucial role in advancing technologies that ensure a safe and secure future in space. As they pioneer new approaches to space debris mitigation, their impact reaches beyond economic interests, emphasizing the importance of preserving our orbital environment. In essence, these startups represent a forward-looking vision where technological innovation aligns with the long-term health of Earth's celestial frontier.

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