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Towards a Future Debris Removal Service: Evolution of an ADR Business Model

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Abstract
The amount of orbital debris generated in low Earth orbit has been steadily increasing over the years. Recently, the rise of plans for large satellite constellations in low-Earth orbit (LEO) means that the number of satellites in key orbits will increase at a much higher rate than today, raising the likelihood of collision. This poses a risk to the sustainability of the entire orbital environment.

In-orbit collisions are low-probability, high-impact events which makes them difficult to risk-mitigate. The challenge of space debris can be considered as a tragedy of the commons, whereby individual actors damage the shared orbital environment through their contribution to space debris, even though it is not in their long-term interest to do so. Whilst governments and international frame-works may be able to shape the discussion, the missing enabler has been identifying commercial incentives that could address the problem.

The paper will describe the key components of a commercial active debris removal service including: customer identification, developing the business case, and quantifying the value of a debris removal service to end-users.

This paper will first evaluate and identify potential customers for a debris removal service. We identify satellite operators that plan to launch hundreds of satellites into LEO as prime customers given their potential contribution to future space debris and their aligned incentives in maintaining their orbital environment. There are also many other actors in the satellite value chain that have a vested interest in maintaining the orbital environment. In this paper we will also consider the small satellite operators, national agencies and the insurance market as possible users of active debris removal services, and articulate why the incentives might be aligned for them to do so. This paper will present quantitative analysis justifying action to remove failed satellites to maintain the orbital environment. We will evaluate the financial value of a debris removal service including quantifying: lost revenue from satellite failures, reputational risk of creating space debris, cost of collision avoidance manoeuvres, and other relevant factors.

Keywords: end-of-life, active debris removal, business case, space sustainability

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Acronyms/Abbreviations

ADR – active debris removal
CAM – collision avoidance manoeuvre
LEO – low Earth orbit
PMD – post mission disposal
TAM – total addressable market
SAM – serviceable addressable market
SOM – serviceable obtainable market

1. Introduction

Though it is still nascent, the market for debris monitoring and removal is predicted to grow significantly in the next decade. The increasing number of launch vehicle providers and decreasing costs for satellite development leads to a rise in the number of operators in orbit. The deployment of unprecedented number of satellites in the next 5-15 years will contribute to more crowded and dangerous orbits. Anomalies in orbit, as a result of strong particle radiation from the Van Allen Belts or generic malfunctions, will contribute to, and result in the failure of a certain percentage of satellites. Active debris removal (ADR) services can provide the backstop for the tail-end of the failed satellite distribution to ensure a sustainable orbital environment.

As the technology for debris removal matures, so must the business case for these services. Customers are currently reluctant to pay for debris removal services until either there is stricter regulation in place mandating ADR or a clearer economic case for such services. The objective of this activity is to identify viable commercial business models for debris removal services. The successful development of the ADR market requires 3 core components: viable technology solutions, effective regulatory policy, and a strong business case for satellite operators to act. There can be no successful market without these components. In this paper, Astroscale seeks to complete the final piece of the puzzle in maturing the ADR market.

This paper begins in Section 2 by identifying three types of potential customer for debris removal services: Satellite operators (Section 3), Insurers (Section 4), National Agencies (Section 5). For each type of customer, this paper provides an assessment to the potential market, identifies specific customer needs and presents the tailored value proposition. The main findings of this paper are summarised in the Conclusion (Section 6).

2. Customer Identification

A recurring question posed to ADR service providers is, '*who will pay for your service*?' In this section we will assess three different types of customer for debris removal services, and explain the value of debris removal services to each of them. Potential customers for ADR services include satellite operators (primarily large constellation operators), national agencies and the insurance market. The market for ADR services includes all of these potential customers; whilst the services for each may be complimentary, each have different objectives and needs for debris removal services, meaning that a tailored value proposition is required. Satellite operators seek to mitigate mitigating future debris to protect the provision of services, national agencies look to remove existing debris to protect the orbital environment, whilst the insurance market may wish to mitigate exposure to collision risks associated with debris.

For each type of customer, this paper provides an assessment to the potential market, identifies specific customer needs and presents the tailored value proposition.

3. Satellite Operators

Satellite operators have a direct interest in maintaining a sustainable orbital environment. This section assesses the market of future satellite operators and identifies the value proposition for commercial satellite operators of debris removal services.

This investigation focuses on satellite operators with numerous satellites, since satellite constellations are expected to dominate the number of satellites in orbit in the future. That said, operators of single satellites may still have need of debris removal services. A single satellite might cause a specific threat to other satellites in orbit, depending on the nature of a potential failure, pose a reputational risk to the operator if left in an irresponsible orbit, or require removal in order to comply with future regulations.

Astroscale's ELSA-d mission, that will launch next year, will demonstrate the technology capabilities required to safely remove failed satellites from orbit [1]. The magnetic capture mechanism requires a docking plate to be fixed on satellites before they launch. Incorporating such a docking mechanism on satellites before launch, future-proofs an operator's satellite and enables easier removal if the craft becomes defunct through the use of active debris removal (ADR) services.

As part of the Sunrise Project, a Public-Private Partnership led by the European Space Agency (ESA) and OneWeb, Astroscale is working to develop its next-generation ELSA-OW. ELSA-OW will be a debris-removal vehicle designed with OneWeb as a representative customer, but suitable for a range of constellation customers [2].

3.1 Market Assessment

There are currently approximately 1,300 operational satellites [3] in low Earth orbit. This number is expected to grow dramatically with the development of upcoming satellite constellations. Future satellite constellations are expected to dominate the total number of satellites in orbit going forward. Constellations are likely more favourable for cost effective debris removal given the large number of satellites operating within a close environment. In such circumstances, the failure to remove failed satellites from such an operational orbit poses a direct threat to the rest of the constellation, meaning that debris removal presents a clear benefit to a constellation operator.

Several commercial systems aim to provide affordable internet services globally at very high latency, whilst some focus on target markets. Though it is expected that some will not proceed, as many depend on venture capital and partner contributions, the increased reliance on high-speed internet access will lead to support of multiple constellations. The following graph indicates the potential growth in the number of satellites over the next 5 and 10 years.

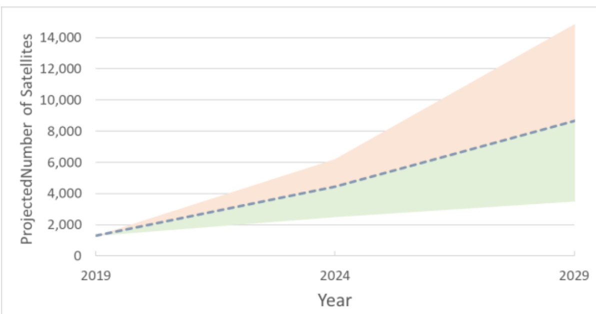

Figure 1 – The projected number of LEO satellites in the next 10 years

The expected growth in the number of satellites within constellations (the black dashed line in Figure 1) accounts for the likelihood of success of each satellite constellation, the number of satellites launched to date, licencing approvals from respective agencies, and the satellite operator's heritage. The upper limit (the orange fan) assumes all satellite constellations that have been publicly announced are successful with a further mark-up to account for potential satellite constellations that have not yet been announced. The lower limit (green fan) assumes a much more conservative assumption that the large constellations are not successful. It is important to note that this projection is highly sensitive to the success of SpaceX, who have announced plans to launch ~12,000 satellites (the first 4,425 of which are captured in this 10-year projection). Figure 1 only considers active satellites. As such, we assume that satellite constellations are replenished with new satellites when old ones fail. The number of satellites in this analysis remains constant once the constellation is complete although the amount of failed satellites, and therefore debris, will increase.

Within the next 10 years, we expect the number of satellites in low earth orbit to increase to over 10,000 satellites. We define this projection of the entire population of satellites in LEO as the total addressable market (TAM) for ADR services.

However, not all of these satellites will be serviceable by the first commercial debris removal vehicles being developed by Astroscale. The serviceable addressable market (SAM) is defined at portion of the total market that Astroscale can serve. To identify the SAM, we performed a series of filters on the satellite population to consider:

- **Low altitude**: Removing all satellites below 500km altitude whereby they are compliant with international guidelines for satellites to decay within 25 years.
- **Country of Origin**: Removing satellites from China and Russia whereby legal considerations may exclude satellites from these jurisdictions.
- **Mass threshold**: Removing CubeSats and all satellites under 40kg where we expect third-party active debris removal services will not be economically viable.
- **Capture Mechanism Compatibility**: Removing existing satellite constellations that do not have capture mechanisms on board and therefore not serviceable with the current mission design. Astroscale are willing to work with constellation customers even if they don't have a magnetic docking plate, although these customers are not considered in this preliminary analysis.

Finally, the serviceable obtainable market (SOM) identifies the portion of the market that Astroscale expects to capture. Here we make a conservative assumption that Astroscale captures 50% of the future satellite market. Astroscale is currently the market leader due to its financial stability (US$140M raised to date) and key technology developments from ELSA-d[1]. As such, we expect a higher market share in the short term that may gradually slow down as new competition enter the market.

These three metrics: the TAM, TOM, and SOM are illustrated below in Figure 2.

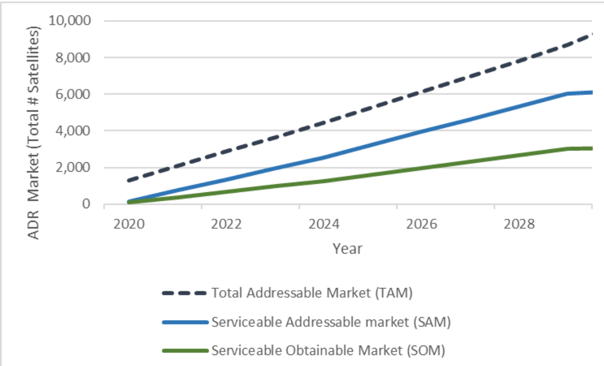

Figure 2 – The projected market for ADR services

Figure 2, above, shows the project market for ADR services without accounting for the failure rate of such satellites. We assume that third-party ADR services are only required for satellites that fail on-orbit. Satellites that remain operational should be brought down and removed by the satellite operator itself. Astroscale has conducted a thorough internal analysis of satellite failure rates using known historical data which yielded a lower bound of 4.3% and an upper bound of 15.6%. This range is consistent with other studies of satellite failure rates [4],[5],[6]. Based on these failure rates, we predict the number of failed satellites that may require third party ADR services in the future.

We use the SOM as our benchmark and assume a fixed percentage of these satellites fail evenly across the next five years. The results are shown below in Figure 3. We consider two cases:

- Low failure rate: All satellites are removed from orbit at the end of their operational lifetime and satellites fail at a low failure rate of 4.3% for their design life. The estimated number of removals in this case is shown with the dark green bars.
- High failure rate: Satellites fail at a higher rate of 15.6% which assumes that satellites remain in operation beyond their specified design life. The estimated number of removals in this higher case is shown with the light green bars.

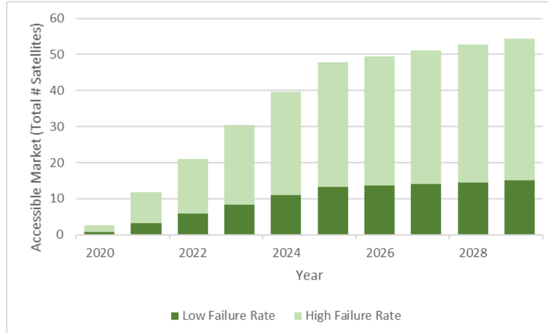

Figure 3 – The Projected Market Demand for ADR Services

Whilst the uncertainties in these estimates are large, we expect that there will be 10-50 satellites per year that could be removed from orbit by end-of-life services by Astroscale. These estimates can be considered an upper limit as they do not currently consider the following factors:

- Figure 3 does not address the replenishment of satellite constellations. As new satellites are launched to maintain constellations, we expect the market demand to flatten to ~15-50 satellite removals per year.
- The demand for debris removal services may be reduced depending on a satellite operator's deployment strategy. So called 'dead-on-arrival' satellites may be considered out of scope of debris removal services if satellites are launched to a lower altitude before raising to their operational orbit.
- This estimate assumes that customers will want to bring down all failed satellites that they are unable to remove themselves. However, satellite operators might be prepared to leave a small percentage of failed satellites in orbit. If instead, a satellite operator is targeting a 95% post mission disposal (PMD) rate, there may be less demand for debris removal services.

3.2 Customer Needs

The key to the ADR services business is providing a reliable, low-cost service closely linked to the customer's business. Time to market is a key factor and is partly driven by customers. The following considerations have been identified as priorities for satellite operators:

- **Cost**: Some satellite operators are most sensitive to the price of debris removal services. The price of the debris removal service may also act as a feedback mechanism: high failure rates beyond design life combined with a cost-effective de-orbiting service could help to incentivise satellite operators to retain satellites in orbit longer.
- **Trade-Offs**: Other customers are considering the trade-off between increasing the reliability of satellites against outsourcing debris removal for failed satellites.
- **Timing**: Some satellite operators can tolerate many failed satellites in their constellation for a long duration. As such they would prefer to wait until Astroscale can provide the cheapest service (e.g. wait for multiple satellites to fail in the same plane for a multi-target servicer).

3.3 Value Proposition

The debris removal in-orbit servicing market is a large commercial opportunity with several large constellations planning to launch a combined number of >10,000 satellites. Debris removal and in-orbit servicing will open a new market with enormous potential, driven by the various planned large constellations requiring third-party providers to de-orbit failed spacecraft. The follow arguments demonstrate the business case for an affordable ADR service for large LEO constellations. Different arguments will resonate more strongly with different satellite operators, depending on their business strategy. Some arguments are more quantifiable, whilst others are softer, more subjective incentives.

3.3.1 Ensure Operational Service

End of life services are fundamental to ensure operational service of satellite constellations, limit collision avoidance manoeuvre (CAM) operations and mitigate collision events. Satellites are exposed to external collision risks due to other satellites and existing debris. The risk of collision for a satellite operator is increased due to the presence of their own additional satellites, particularly those that have failed without any manoeuvring capability. This marginal increase in the collision risk with failed satellites will result in more catastrophic collisions and the requirement of more collision avoidance manoeuvres. This risk can then be quantified as an additional cost to the satellite operator through increased loss of service, increased operational costs and additional fuel required for satellites.

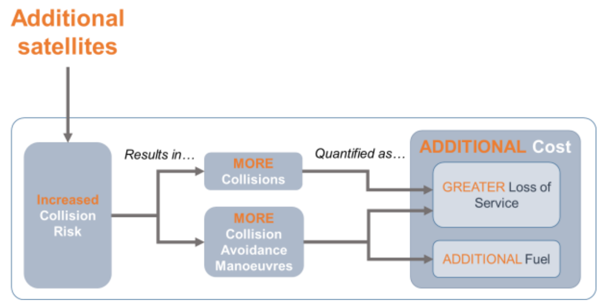

Figure 4 – In the absence of ADR service provision, satellite operational service is compromised.

As such, there is a financial incentive to remove failed satellites from orbit. Measuring the PMD rate is an effective way to assess the proportion of satellites that have been de-orbited sustainably. For a given constellation, the PMD rate is defined as the percentage of satellites that are removed from Earth's orbit within a reasonable time period (currently less than 25 years).

Multiple NASA and ESA studies in recent years have shown that the *achieved* reliability of post-mission disposal operations is one of the most critical factors in the growth of the LEO debris environment. For large LEO constellations, it is recognised by satellite operators [7], [8] that a high PMD rate is necessary to ensure that non-functional spacecraft do not unnecessarily jeopardize the orbital environment. For constellations with numerous satellites, a high PMD rate protects the immediate orbital environment which is synonymous with protecting and maintaining the operational service of their own constellation.

Based on a NASA Orbital Debris Program Office (ODPO) study [9], for large constellations, the *achieved* post-mission disposal reliability needs to be in the >95-99% reliability region to avoid an unsustainable increase in the quantity of debris in LEO, and therefore maintain the operational service of a satellite constellation. High PMD rates could be met through:

- Passive measures – if satellites are at sufficiently low altitudes, atmospheric drag will allow them to decay naturally,
- Active de-orbiting by the operator at end of life, assuming that the satellite has such capabilities, or;
- Through the provision of third-party ADR services such as Astroscale.

It should be noted that the achieved post-mission disposal reliability to-date since the establishment of the existing orbital debris mitigation guidelines is well below 90%, so achieving this much higher rate of post-mission disposal reliability will almost certainly require a different approach than what has been used to-date.

3.3.2 Optimise Satellite Design

When designing and building satellites, operators face a number of cost-related trade-offs including:

- Optimizing satellite design for operations versus additional functionality to de-orbit
- Increasing reliability of satellite versus outsourcing end-of-life servicing

Astroscale can provide the backstop for the tail-end of failed satellite distribution enabling satellite operators to optimise their design (and therefore streamline costs) for operational service.

With no external action, satellite reliability, is correlated with post mission disposal (PMD) as demonstrated in Figure 5. Assuming that all operational satellites can be de-orbited themselves and all failed satellites must be removed by external action, the PMD disposal rate is simply one minus the failure rate]. As such, reaching a target PMD requires more reliable satellites and therefore higher cost of production. Alternatively, Astroscale services can be employed to reach a target PMD rate at a lower cost (without step change increase in satellite cost from higher reliability requirements).

As illustrated in the example in Figure 5, a satellite constellation with a 15% satellite failure rate cannot meet a 95% PMD rate target without either:

1. Increasing costs to ensure the inherent satellite reliability is higher (and therefore the failure rate is reduced from 15% to 5%)
2. Outsource the removal of the tail-end of the failure distribution to a third party such as Astroscale which will remove 10% of satellites in the constellation from orbit.

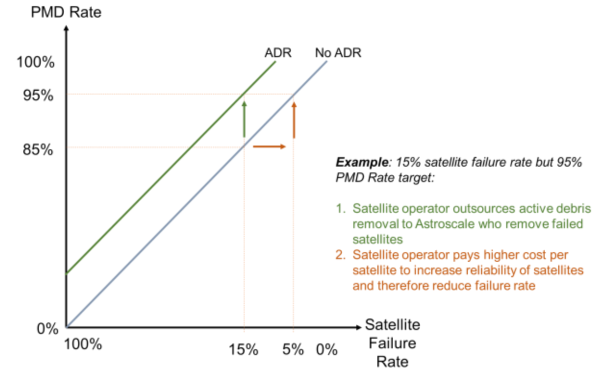

Figure 5 – The relationship between PMD rate and satellite failures

Increasing costs for greater reliability though enhanced design processes, higher quality components and more extensive assembly, integration and testing will eventually have diminishing returns as higher reliability is targeted. As shown in Figure 6, cost optimisation balances satellite cost with the number of satellites required for high quality of service (QoS) to a reliability level below 100%.

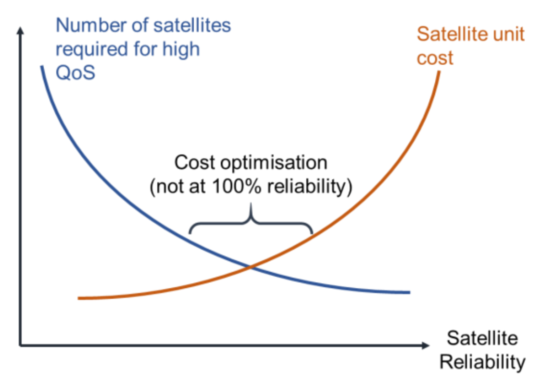

Figure 6 – Cost optimisation for satellite operators

Astroscale suggests that a combination of robust satellite design and back-up disposal capability can help operators achieve a high PMD rate.

3.3.3 Mitigate Risk of Extended Satellite Lifetimes

It is common practice for operators to keep their satellites in orbit for as long as they are operational, often extending beyond their original design life. However, this poses a risk to the orbital environment, as the longer satellites continue to operate, the more likely it is that they fail and remain in orbit. If left in orbit, such satellites can degrade, risking fragmentation events that cause further damage to the orbital environment.

For example, in the summer of 2018, four geostationary satellites failed, all of which had reached or exceeded their design life. ESA's Envisat had a design life of 5 years but remained operational for 10 years before unexpectantly failing. At over 8000kg and orbiting in a 790km sun-synchronous polar orbit, it now represents one of the most critical space debris objects in LEO. Employing ADR services provides a way to de-orbit satellites at the end of their life, even if they have failed or run out of fuel.

3.3.4 Manage Regulatory Risk

With regulations moving towards debris mitigation plans and the future enforcement of space sustainability, satellite operators should consider how debris removal services, such as Astroscale, can support their compliance with future policy. Satellite operators can manage the following regulatory risks through proactive action and engaging with debris removal services such as Astroscale:

- **Fines due to regulatory non-compliance** – whilst no fines have been reported directly regarding space debris, the FCC has issued fines in the past for regulatory non-compliance. In 2018, Swarm Technologies who were fined $900,000 by the FCC [10] due to non-compliance on the issuance of a license ahead of launch. Whilst Swarm were fined for not having a license, rather than being non-compliant with a license, the value of this fine provides a first order indication of potential financial ramifications.
- **Regulatory Delays** - There is a risk that licences are not approved without a post mission disposal plan and ineffective debris mitigation plans result in delays. In 2017, the FCC requested additional information with respect to SpaceX's application to operate their satellite constellation. This included further collision risk analysis to ensure a debris-free space environment.
- **Cost of Compliance** – As debris mitigation policies and regulations evolve, satellite operators will need to comply with a greater understanding of the environment with which they will operate, and deeper technical understanding of debris mitigation measures such as design features and robust operational plans and manoeuvres.

There is benefit to the sound regulation of space activities, especially in this new era of increased activity, growing debris and congestion [11]. Governments must have oversight and continuing supervision of its domestic space activities, include those conducted by private industry, according to the Outer Space Treaty, Article VI. Additionally, approval by a government of the space mission will bring certainty and legitimacy to investors, who are weighing the risk of a costly space project. Also, regulation ensures all licence applicants are playing by the same rules and are being vetted similarly, at least under a single national authority. The actions of satellite operators today will drive best practice going forward. As best practices evolve into future regulations, satellite operators should be preparing to address the debris mitigation regulatory needs of tomorrow, today. In essence, operators should be proactive in adopting responsible space behaviours that include third-party ADR services.

Astroscale ensures it is at the forefront of global discussions in driving stricter norms and standards and defining "best practice", through numerous discussion forums including the Interagency Debris Coordination Committee (IADC), the Consortium for Execution of Rendezvous and Servicing Operations (CONFERS), and the United Nations [12].

3.3.5 Become a Responsible Space Actor

Through engaging with debris removal services such as Astroscale, satellite operators are demonstrating that they are responsible space actor committed to sustainable practices, that are reducing the overall collision risk in orbit, benefiting both themselves and other space users.

Whilst the importance of space sustainability is yet to be fully embraced by the space industry, examples can be drawn and lessons learnt from other industries to demonstrate the value of being a responsible space actor.

<u>Deepwater Horizon Oil Spill</u>

Environmental disasters can cause major financial and reputational repercussions. One example, the Deepwater Horizon oil spill in 2010, resulted in the largest marine oil spill in the history of the petroleum industry. An explosion at the Deepwater Horizon drilling rig, chartered to BP, resulted in approximately

4.9 million barrels of oil leaking into the North-Central Gulf of Mexico [13]. It is difficult to underestimate the damage caused to the environment and to BP as a company. The oil spill had a devastating effect on marine life; waters contained forty times more hazardous polycyclic aromatic hydrocarbons (PAHs), than were measured before the spill [14] as well as affecting over 2100km of shoreline. The Deepwater Horizon oil spill resulted in BP being fined a $4.5bn fine by the US Department of Justice [15], a further $18.7bn in corporate fines [16], and a total cost to BP, including clean-up costs, charges, and penalties, of ~$65bn [16].

Given the importance of satellites to everyday life, a collision in orbit that compromised critical satellite services could result in a similar catastrophic event, both for the orbital environment and for the company responsible. Satellite operators should not wait for satellite collisions to occur, or for the Kessler syndrome to manifest, before taking action.

Overall, there is a clear incentive for satellite operators to manage reputational risk by leading the way in space sustainability. Sustainable actions in space include the responsible removal of satellites from operational orbits and the mitigation of space debris. Active debris removal services, including those provided by Astroscale, can support satellite operators in maintaining a sustainable orbital environment.

3.3.6 Reduce Insurance Premiums

Space insurance is available to mitigate the risk from launch, post separation and in-orbit operations. Premium rates for space insurance are linked to the inherent risk associated with the service being covered. Collision risk is currently an insignificant element in pricing on-orbit insurance [17] although the emerging threat of space debris and collision risk have caused insurers [18] to examine the orbital debris risk more closely.

In the future, insurance premiums may have to rise to reflect the increasing risk of collision. The insurance industry can be a supporting force in driving responsible behaviour in space. End-of-life services by Astroscale will reduce the number of failed satellites in orbit, therefore reducing the collision risk of operational satellites in orbit. As a result, Astroscale is reducing insurance companies' exposure to third party liability and, as such, insurance premiums for the satellite operator could reduce.

4. Insurance Industry

Satellite insurance is a specialized branch of aviation insurance in which about 20 insurers worldwide participate directly [19]. Existing insurance products include launch and in-orbit insurance - that covers the risk of damage or breakdown of a satellite during and after launch – and third-party liability insurance – that provides protection for third party property damage (and disability) due to the possession, use and management of satellite.

4.1 Market Assessment

The space insurance industry is facing challenging times, with very low premiums due to overcapacity in the market, and losses exceeded premiums again in 2019. From 2011 to 2019, space insurance exposures have increased 60%, whilst premiums are down 40% [20]. The insurance industry needs to understand new risk profiles, simplify products and address issues of sustainability such as space debris in order to meet these challenges.

As of January 2019, 43% of GEO satellites are insured on orbit, whilst only 6% of LEO satellites are insured on orbit [21]. From 2011 to 2019, there has been an increase in the number of LEO satellites that are insured from 21 to 95, with the total insured value in LEO increasing from $1bn to $5bn. The Iridium constellation makes up 70% of insured LEO market, indicating that the expected growth of LEO constellations within the next decade will present growing opportunities for the insurance market also.

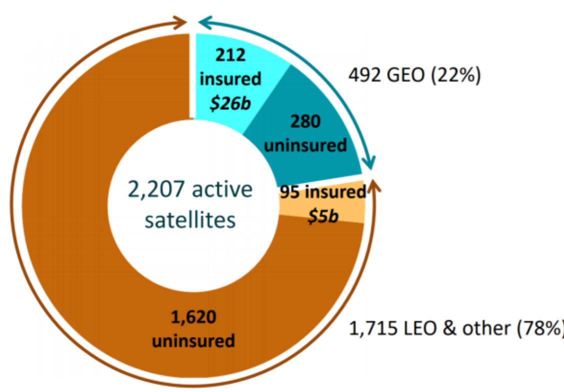

Figure 7 – The Insured vs. Uninsured satellites as of 2019 [22]

4.2 Customer Needs

Space insurance is a relatively complex and volatile niche market [22]. Space insurance is market-driven, meaning that insurers are limited in their ability to incentivise new practices within their customers. Following the recent failed Vega launch, insurance premiums are expected to increase significantly. In addition, with major players such as Swiss Re leaving the space insurance market, market dynamics now put insurers in a better position to incentivise favourable ADR services that benefit all players.

4.3 Value Proposition

Debris removal services present an opportunity for insurers to mitigate their exposure to collision risk. In the case of providing third-party liability insurance, the insurer pays out for any third-party damage due to the possession, use and management of satellite. Without an ADR service agreement, the insurer is potentially liable for the damage caused by a satellite that remains on orbit (see Scenario 1 in Figure 8 on the following page). Employing debris removal services to remove such a satellite from orbit at the end of its operations reduces the risk that the insurance company is exposed to. Removing failed satellites from orbit mitigates the risk of such an event and therefore provides value to the insurer providing such coverage.

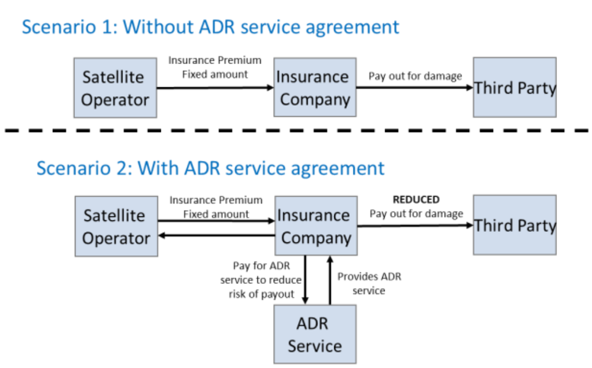

Figure 8 – Third-Party Liability Coverage without (Scenario 1) and with (Scenario 2) an ADR service agreement.

Given that there has never been a claim on third party liability insurance in orbit, such an event could lead to a market failure within this sector. Debris removal services present an opportunity to mitigate such risk.

5. National Agencies

The number of space-faring nations have grown dramatically since the dawn of the space age. According to the UN's Online Index of Objects, 79 countries have launched satellites into outer space [23]. Close to 50 nations have government space budgets, nine over $1 billon, and nearly 20 under $100 million [24].

5.1 Market Assessment

The United Nation's Committee on the Peaceful Uses of Outer Space (COPUOS) – that includes 92 member states – recently published 21 long-term sustainability guidelines [25] that encourage space actors to investigate and consider new measures to manage the space debris population in the long term. A number of national agencies have announced debris removal missions, indicating the emerging institutional market for ADR services.

The European Space Agency's Clean Space initiative includes three branches [26]: (1) Eco-design, (2) CleanSat, (3) In-orbit servicing/Active Debris removal: removing spacecraft from orbit and demonstrating in-orbit servicing of spacecraft. In addition, the European Space Agency is currently considering a Service Offer Request for the removal of an ESA-owned satellite.

Japanese Prime Minister Shinzo Abe recently announced Japan will conduct space debris removal missions: a first inspection satellite will be launched in 2022, followed by a second mission to remove debris from orbit [27]. The goal is to commercialize the technology by 2025.

5.2 Customer Needs

The institutional market requires a highly reliable ADR service that can remove debris from that is already in orbit. Most large debris in LEO is between 600-1400 km in altitude [28]. Critical objects (failed satellites, rocket bodies and other large pieces of debris) already in orbit could destroy operating satellites. As a result, capture mechanisms must be developed that are capable of docking with a non-cooperative target.

5.3 Value Proposition

Utilization of data from space has become a fundamental part of daily life in developed economies and will soon be more intrenched in global society. The risk of collision between an active satellite and a piece of space debris has the potential to inflict significant consequences on multiple high-value industries, including transport, agriculture, environmental monitoring, military and more.

The increasing number of launch vehicle providers and decreasing costs for satellite development will lead to a rise in the number of operators in orbit. Government launch strategies, including multiple spaceports, will increase the number of satellites in orbit for which a government is the launching state, and therefore leaving that government liable for damage that such satellites may cause on Earth or in space.

The amount of orbital debris generated in low Earth orbit has been steadily increasing over the years. Recently, the rise of plans for large satellite constellations in low-Earth orbit (LEO) means that the number of satellites in key orbits will increase at a much higher rate than today, raising the likelihood of collision. The deployment of unprecedented number of satellites in the next 5-10 years will contribute to more crowded and dangerous orbits. This poses a persistent threat to government and industry space assets, as well as a growing risk to the sustainability of the entire orbital environment.

The threat of space debris is a global environmental challenge, much like climate change and ocean plastic. The challenge of space debris can be considered as a tragedy of the commons, whereby individual actors damage the shared orbital environment through their contribution to space debris, even though it is not in their long-term interest to do so. Removing failed satellites from key operational orbits is an effective way to mitigate collision risk and prevent the growth of dangerous space debris in orbit.

Whilst there are financial incentives for large satellite constellations to remove debris from their orbits and protect the operations of their functioning satellites, the institutional market can help to stimulate commercial ADR market. Furthermore, the demand for commercial ADR is greatly enhanced by regulatory enforcement of sustainable practices, which in turn makes the ADR market more commercially viable.

6. Conclusions

This business case analysis evaluates the economics of ADR servicing. Under current space practices, space debris will become an ever-growing problem with thousands of satellites scheduled to launch in the coming years. As a result, there is growing market demand for debris removal services. Whilst estimates are somewhat uncertain, Astroscale expects that there will be demand for 10-50 satellites removals per year by the late 2020’s. Although ADR benefits all users of space, this paper demonstrates the value of debris removal missions to three types of potential customer. Demand from satellite operators is driven by the need for risk reduction, in maintaining business continuity and limiting liability exposure, as well as regulatory compliance. Demand from governments and national agencies is driven by the need to protect the overall orbital environment, whilst insurers are incentivised to mitigate their exposure to collision risk.

Astroscale has a viable solution to address the space debris problem through the development of ELSA-d and future debris removal missions. Furthermore, Astroscale’s first-mover advantage, global footprint including offices in Japan, the US, and the UK, and well-funded business mean that we are well positioned to address this growing market. Through this paper, Astroscale seeks to demonstrate how we can add value to the marketplace, whilst also doing good for the orbital environment.

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