

Development of global policy for active debris removal services

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ABSTRACT

Expected decreases in costs for launch services and satellite manufacturing is leading to a proliferation of new players in the space industry and a democratization of activities in low Earth orbit (LEO). This increase in the number of satellites will necessitate new and creative thinking to monitor and regulate an already congested, contested and competitive orbital environment.

Astroscale is one of the few companies in the world proposing to aid in the removal of orbital debris through the provision of two distinct service lines – End of Life (EOL) and Active Debris Removal (ADR) services. The EOL business line, which looks to mitigate the potential increase in future debris, addresses the commercial large constellation market by proposing to add a docking plate to satellites prior to launch, thus making rendezvous and capture easier to achieve. The Active Debris Removal (ADR) business line is focused on the removal of existing orbital debris, none of which have been prepared with a docking plate and thus are more difficult to capture. Most of this existing debris are the result of institutional missions and thus will be a market driven by governments and space agencies.

The End of Life Services by Astroscale – demonstration (ELSA-d) mission, which is in the assembly, integration and test (AIT) stages and due to launch in 2020, will prove the technologies that will support both of these business lines. Now that the possibility of debris removal and end-of-life services are closer to market, it is imperative we conduct this mission in a manner that follows basic tenants of best practices and standards whilst adhering to domestic regulation and international agreements.

While developing the technology on ELSA-d that will support these missions is of course essential, the creation of sustainable long-term market for orbital debris removal will not be realized without a clear global policy. As no single governmental entity has jurisdiction over the orbital environment, the creation of such standards is difficult at best and relies on the creation of widely-accepted norms and standards with which governments and commercial companies alike agree to abide. Developing these norms and standards relies significantly on both international organizations and national governments.

This paper examines Astroscale's efforts in actively discussing global standards and policy for orbital debris removal with a range of constituencies. We are contributing to discussions among policy makers in the U.S., Japan and Europe, as evidenced most recently by our leadership in coordinating a group response the U.S. FCC notice of proposed rule-making for orbital debris mitigation. Additionally, Astroscale is closely involved in conversations on best practices and norms of behavior in various formal and ad-hoc industry groups and international organizations, including: UN (UNISPACE-50), Interagency Debris Coordination Committee (IADC), Global VSAT Forum (GVF), the Consortium for Execution of Rendezvous and Servicing Operations (CONFERS), and the World Economic Forum (WEF).

A solution to the problem of orbital debris will rely on shaping policy as much as on developing technology. Astroscale is active in supporting the development of the norms, regulations and incentives that will contribute to the responsible use of space.

1 INTRODUCTION

To support the long term sustainability of space through Active Debris Removal (ADR), three efforts must come together: technical solutions to mitigate collisions in orbit and to remediate objects that are derelict, the creation of economic incentives for satellite operators to utilize services that support debris mitigation and remediation, and critically, the development of best practices, standards, and supportive policy and regulation to enable novel solutions and to drive responsible behavior in orbit. A prosperous space economy, including a wealth of services and downstream applications, rests upon all space actors working simultaneously towards the goals of long-term sustainability of space.

For domestic implementation of standards and best practices, nations tend to look to intergovernmental or international bodies to understand what norms are widely established for satellite operations and behavior. While there is unlikely to be a treaty-level agreement on an international level specifically for debris mitigation, these intergovernmental or international bodies are developing voluntary guidelines, practices, and standards that can be applied to ADR missions.

Domestically, nations are reviewing oversight authorities as it pertains to debris mitigation of private satellite operators through update of regulation or policy. Further, commercial satellite servicing, which can span from inspection to debris removal to life extension and more, are activities that may not have a straight-forward licensing process as most commercial activity in space until now involved communications, remote sensing, or launch. This paper will identify how debris mitigation and active debris removal policy is developing in several regions where Astroscale has a presence, where the company has contributed to the conversation.

Finally, many space policies and international operational practices were developed prior to the proliferation of satellite technology across the world when space was still relatively difficult to access. Today, privately owned and operated satellites account for over 50% of the active satellite population and this will grow drastically over the next decade with thousands of satellites being planned for launch and put into service in low-Earth orbit. Private space actors are taking the initiative to come together to establish industry standards and best practices for the long-term sustainability of space. Astroscale is engaged in several of these initiatives such as CONFERS, the Space Safety Coalition, and the World Economic Forum's Space Sustainability Rating.

Altogether, the ongoing international efforts, domestic regulatory and policy environments, and voluntary measures by industry add up to a sea-change in how space actors are moving forward in this new era of congestion and competition in orbit, and how ADR is increasingly an option. By being part of the dialogue in all these efforts, Astroscale's activities are contributing to setting rules of the road for good space behavior thus ensuring the long-term sustainability of space.

2 ASTROSCALE SUMMARY

Founded in 2013, Astroscale's mission is to secure long-term spaceflight safety by becoming a provider of reliable and cost-efficient spacecraft retrieval. The company comprises of nearly 100 people with offices in Singapore, Tokyo, Harwell (UK) and Denver, CO. In addition to developing the technology for debris capture and removal, Astroscale is deeply involved in the global conversation on enhancing policy that supports long-term space sustainability and is developing the business case and economic arguments for use of debris removal services. From the technology point-of-view, Astroscale plans to help in the removal of orbital debris through the provision of two services: end-of-life (EOL) targeting LEO constellations, and active debris removal (ADR) targeting existing larger space debris:

- EOL – To provide this service, satellites will be prepared with a docking mechanism before launch that will allow for eventual removal from orbit. This “semi-cooperative” solution allows for a simpler capture mechanism and will ensure that all satellites have a means of de-orbiting by a third party, improving long-term orbital sustainability and safety of future satellite operations. The primary customers for this service will be the commercial satellite operators.
- ADR – Removing debris that is currently in orbit requires a “non-cooperative” solution as this debris was not prepared for deorbit before launch. Astroscale will partner with governments and international organizations to research and develop missions that incorporate innovative solutions for capture and removal of environmental critical debris, such as rocket upper stages and defunct satellites that are already in orbit. The primary customers for this service will be governments.

For both business lines, Astroscale is focused on providing an end-to-end service, addressing mission licensing, spectrum acquisition, insurance, and operations for debris removal.

2.1 End of Life Service by Astroscale Demonstration (ELSA-d)

The ELSA-d Technology Demonstration Mission will be launched in 2020. It will be the first commercial end-to-end demonstration mission to rendezvous and capture a satellite designed for semi-cooperative spacecraft retrieval mission. The mission will consist of two satellites, a servicer satellite and a client satellite, launched together. The servicer satellite is equipped with proximity rendezvous technologies and a magnetic capture mechanism, whereas the client satellite has a docking plate which enables it to be captured magnetically. Through a series of release and capture activities, ELSA-d will demonstrate a range of key technologies proving capabilities for a full customer mission, including target search, target inspection, target approach and rendezvous, and target capture. More background on Astroscale's ELSA-d mission and technology solution can be found on the company's website or a recent IAC paper on the topic [1, 2].

3 UN COPUOS LONG-TERM SUSTAINABILITY GUIDELINES

The recently adopted United Nations Committee on the Peaceful Uses of Outer Space (UN COPUOS) 21 Long-term Sustainability Guidelines (21 LTS) do not address debris removal itself but bring forward some key behaviors which will result in a safer space environment for all operators [3]. The overall objectives of the LTS Guidelines are very much in line with those of Astroscale's mission to "secure long-term spaceflight safety and orbital sustainability for the benefit of future generations" and encourage the development national and international practices and safety frameworks to advance norms of behavior in space, creating a more sustainable environment [4].

Several guidelines can be implemented immediately by the commercial space community, particularly those that deal with communication and information sharing practices, as well as design and behavior in orbit.

3.1 Better Communication and Transparency

Communication is essential, particularly for active debris removal services in order to avoid misperceptions, to build trust, and to make it easier to communicate with other orbital operators. The commercial space community, including Astroscale, is very active in developing practices that enhance communication across all space actors. The below specific examples drawn from the 21 LTS Guidelines show how voluntary practices can support debris removal activities.

- **B1: *Provide updated contact information and share information on space objects and orbital events.***
Astroscale agrees that information sharing and transparency is essential to the understanding of orbital activities. Astroscale will proactively supply contact information to its orbital neighbors and will consistently provide publicly available information on any active debris removal mission.
- **B2: *Improve accuracy of orbital data on space objects and enhance the practice and utility of sharing orbital information on space objects.***
This guideline encourages States and International and Intergovernmental Organizations to improve the accuracy of orbital data by using, for example, geographic distribution of sensor networks, on-orbit tracking aids, and a variety of sources of information. For active debris removal, accurate and on-going SSA data is essential, particularly for the rendezvous and capture phase of the mission. The servicer and collected debris will need to transit through both active space operations while avoiding debris. Accuracy in conjunctions, especially among large constellation fields, is essential.
- **C2: *Share experience related to the long-term sustainability of outer space activities and develop new procedures, as appropriate, for information exchange.***
This guideline encourages involvement of non-governmental entities in sharing experiences and expertise in space activities that contribute to the long-term sustainability of space. Astroscale, as member of the practices and standards group Consortium for Execution of Rendezvous and Servicing Operations (CONFERS - see section 5.1), has adopted a practice of sharing experiences of anomalies in order to reinforce safe practices for on-orbit servicing, including debris removal. Anomaly sharing is common in the aviation industry, which has led it to be the safest mode of transportation available.

- *C4: Raise awareness of space activities.*
The commercial space community is eager to increase awareness of the innovative technologies and activities occurring in space as well as end user benefits. Astroscale is an active participant in many fora and groups around the world that promote the education of the value of space activities and in particular, on-orbit servicing, debris removal and the long-term sustainability of space.

Astroscale recognizes that governments have similarly supported dialogue surrounding commercial debris removal. Astroscale's founder and CEO Nobu Okada was invited by the Government of Japan to provide a technical presentation of debris removal activities during the UN COPUOS plenary in June 2019. The U.S. Government similarly invited Astroscale U.S. President and Managing Director, Ron Lopez, to address the Space Enterprise Forum, co-hosted by the Department of State and Department of Commerce in July 2019 to discuss this new mission as an element of a growing space economy.

3.2 Behavior and Technology

Ultimately, global understanding surrounding norms of behavior in space is necessary for the development of debris removal missions. The following guidelines focus on technologies and behaviors of space operators for the purpose of creating a safe space flight environment, and when adopted, highlight the value of debris removal.

- *B8: Design and operation of space objects regardless of their physical and operational characteristics*
This guideline encourages the trackability of space objects as well as consideration of end-of-life disposal according to international or national debris mitigation guidelines. Astroscale has been vocal in recommending specific behavior and technology in industry groups for the trackability, identification, and end-of-life procedures including adoption of a 95% post-mission disposal reliability and ensuring a back-up disposal method is available to the satellite operator.
- *D2: Investigate and consider new measures to manage the space debris population in the long term*
This guideline encourages the development of new measures including technological solutions to manage space debris including extension of lifetime, prevention of collision, passivation techniques, and post-mission disposal options such as active debris removal.

4 POLICY AND PROGRAMMATIC DEVELOPMENTS FOR ADR IN SELECTED REGIONS

More than ever, governments and agencies are recognizing the risks posed by space debris and are considering policy and programmatic solutions. Japan, the UK, ESA (European Space Agency), EU (European Union) and the US are all increasing activities to support monitoring and removal of potentially harmful debris.

4.1 Japan

Japan is in the forefront of the discussion on space debris remediation. The home of Astroscale's R&D and manufacturing center, Japan has taken several concrete steps, at various political levels, to address the policy concerns for orbital debris removal. In June 2017 the Space Policy Committee (SPC), the leading advisory body reporting to the Prime Minister, released its interim report for Space Basic Plan revision for fiscal year 2018. This was the start of several tangible and effective steps on space policy which address the orbital environment. Key among these efforts is a "Task Force for Space Debris", established by the Minister of State for Space Policy. The Task Force is comprised of State Ministers and the President of JAXA and has convened twice in 2019.

The Government of Japan is also supporting space debris removal through funding of missions. The JAXA KITE mission in 2017 attempted to remove debris using an electrodynamic tether. CRD2 (Commercial Removal of Debris Demonstration) is the latest project to study and develop technologies related to ADR. In October 2019, JAXA released a request for proposal for phase 1 of a potential ADR mission, which looks to 1) approach a Japanese spent rocket body, 2) perform proximity operations, and 3) capture images to understand the status and motion of the debris.

The concern over space debris is a key issue for the Abe Government. Ahead of the June 2019 G20 meetings, the SPC developed a proposal on measures against space debris [5]. Prime Minister Abe went on to include these measures in his talking points at the G20 meeting and Astroscale had a display on the topic at the Osaka meetings.

Finally, licensing of space objects from Japan requires a debris mitigation plan. The requirements for debris mitigation plans are weighed against international guidelines. The Cabinet Office will conduct periodic reviews to ensure Japanese satellite licensing continues to adhere to international guidelines.

4.2 United Kingdom

Over the previous several years the UK Space Agency (UKSA) has become a prominent global player in supporting space commerce generally, and in-orbit services and debris mitigation activities specifically. The UKSA is addressing in-orbit servicing missions, including active debris removal via a mission licensing concept. With the RemoveDebris program having been led through Surrey Space Center, the UK government has experience in assessing this new type of in-orbit activity from a lens of safety, international agreement, and national security.

Changes have been made in UK national space policy to support the growing space industry and changing dynamic of in-orbit space activity and a Space Strategy was developed with a focus on topics including in-space robotics. In 2018, the UK announced the Prosperity from Space proposal and a space sector deal in the UK for which in-orbit robotics and IOS is one of four highlighted priority sectors. In support of this strategy Astroscale is working in conjunction with the Satellite Applications Catapult to promote activities related to space debris removal.

Additionally, through funding from InnovateUK, Astroscale is leading the development of the National In-orbit Servicing Control Centre, hosted at the Satellite Applications Catapult. The UKSA has taken an active role to ensure there is an international level of agreement on debris mitigation solutions, through UN COPUOS Space Debris Guidelines and the IADC Space Debris Mitigation Guidelines. This includes updates based on debris population modelling and simulation work undertaken on behalf of UKSA.

4.3 Europe

ESA has been an influential participant in the subject of debris policy and research through activities in various centers. The European Commission (EC) has also been engaged in the effort.

- ESA's CleanSpace at ESTEC has been a major contributor to space debris sustainability. ESA funded several studies focused on debris removal as well as programs such as Service Oriented ADR (SOADR) in 2013, the phase-0 to e.Deorbit. The ESA e.Deorbit programme worked towards a mission to remove Envisat and reached roughly a Phase B level, before the programme was superseded. In SOADR there was consideration of both the technology and commercial aspects of ADR.
- The ESA Space Debris office has also been working on many aspects of debris tracking and are fully involved with the tracking / simulation community through activities at European Space Operations Centre (ESOC).
- ESA has recently issued a Request for an Outline Concept for the removal of an ESA-owned VESPA adapter to demonstrate the commercial in-orbit services, called ADRIOS for Active Debris Removal/In-Orbit Servicing. If successful, this initiative could trigger other Agencies to fund removal of their spacecraft and rocket upper stages.
- The ESA ARTES programme was created to develop technologies for future generation telecommunication satellite missions however there is an element of space debris mitigation through OneWeb Sunrise, a project that was established under the ARTES program as a public-private partnership between ESA and OneWeb to mature technologies necessary for orbital debris removal. Astroscale, along with several parallel industrial partners, is working towards maturing ADR capabilities and will improve upon the heritage capabilities currently being developed for its ELSA-d mission.
- The EU funded the RemoveDebris mission, a demonstration of ADR capture technologies consisting of a consortium of European industry and coordinated by Surrey Space Centre. The EU and ESA also signed a space strategy deal in 2015 that covered many areas including the new EU SSA Service.

4.4 United States

The organizational and regulatory environment in the US is shifting towards actions that help all space entities operate in a safe and sustainable environment.

The National Space Policy of 2010 remains in effect with a goal to strengthen stability in space which including strengthening measures to mitigate orbital debris. The National Space Policy includes mention to "mitigate and

remove on-orbit debris, reduce hazards, and increase understanding of the current and future debris environment.” [6]

Space Policy Directive-3 was issued in June 2018 and is the first presidential policy of its kind in the US to address space situational awareness (SSA) and space traffic management (STM) [7]. Some key features are: commitment to reviewing debris mitigation guidelines and assess what regulatory changes are required, the promotion of space safety standards and development of best practices that enhance space sustainability, and the provision of free basic SSA data and STM services that can be enhanced by external sources. Importantly, the policy indicates that “The United States should pursue active debris removal as a necessary long-term approach to ensure the safety of flight operations in key orbital regimes.” Overall, SPD-3 recognizes that space safety is a global issue and the US will pursue agreement on best practices and standards for orbital debris mitigation through international and intergovernmental organizations.

SPD-3 also directs a review of NASA’s Orbital Debris Mitigation Standard Practices (ODMSP). These standard practices are meant for US Government entities to adopt in the pursuit of space sustainability regarding government missions. The update, expected fall of 2019, will set the tone for commercial and international space sustainability efforts.

Space Policy Directive-2, issued in May 2018, is also instrumental in encouraging safe and effective active debris removal services [8]. The Directive looks to conduct sweeping reviews of current regulation that inhibit growth in the space industry. For example, Commercial Remote Sensing regulation is undergoing an update that would affect non-earth imaging (NEI) capability. NEI is likely to become common on active debris removal missions as the servicing satellite approaches its client.

The Federal Communication Commission (FCC) is in the process of conducting its own Orbital Debris Mitigation regulatory update [9]. The previous rules for commercial satellite debris mitigation plans were established in 2004. This update is addressing the need for trackability, maneuverability, de-orbit plans, and active debris removal, amongst other topics.

5 INDUSTRY BEST PRACTICES AND STANDARDS

Several industry initiatives have formed that are developing best practices and standards which support debris removal activities. Astroscale is actively engaged in the below groups that develop these safe practices for rendezvous and proximity operations (RPO) and debris removal.

5.1 CONFERS

The Consortium for Execution of Rendezvous and Servicing Operations (CONFERS) is an industry-led initiative seeking to establish best practices and operations standards for rendezvous and proximity operations (RPO) and On-Orbit Servicing (OOS). While aimed at industry best practices, there is government, academic, and non-governmental organization representation through observer status. Astroscale is an executive member, having worked with other members to develop a set of Guiding Principles in 2018 and Recommended Design and Operational Practices in 2019 [10, 11]. Both documents are intended to be updated in order to reflect the changing nature of On-Orbit Servicing operations.

5.2 SPACE SAFETY COALITION (SSC)

SSC is an ad hoc coalition of companies, organizations, and other government and industry stakeholders that actively promote responsible space safety through the adoption of relevant international standards, guidelines and practices, and the development of more effective space safety guidelines and best practices. Astroscale has endorsed SSC’s recent Best Practices for the Sustainability of Space Operations [12].

The key elements of the SSC Best Practices for the Sustainability of Space Operations are:

- Encouraging information relevant to safety-of-flight and collision avoidance
- Consider the sustainability of the space environment when selecting launch service providers
- Making safety a priority when designing architectures and operations concepts
- Designing spacecraft that adhere to specific operations practices
- Adopting space operations concepts that enhance the sustainability of the space environment

5.3 WORLD ECONOMIC FORUM SPACE SUSTAINABILITY RATING (WEF SSR)

The WEF SSR is being led by the MIT Media Lab and ESA with support from Bryce Space Technologies and the University of Texas at Austin. It is envisioned as a tool to incentivize space operators to drive towards higher standards of debris mitigation. Although the rating is still being designed, there has been multiple opportunities for industry to contribute to the elements that would make up the rating. Astroscale's founder and CEO, Nobu Okada, is a member of the WEF Global Future Council on Space Technology who helped develop the mandate for a WEF SSR. Astroscale continues to provide inputs into the process, which is expected to be finalized in 2020. [13]

6 CONCLUSION

Altogether, practices, guidelines, programs, and incremental policy changes are trending towards support of debris removal services in multiple regions. Whether in international and intergovernmental fora, like the UN COPUOS 21 LTS Guidelines adoption, or domestic and regional efforts to develop technologies, debris removal is becoming an established element of long-term sustainability. Additionally, industry best practices are forming that open the door for safe and effective de-orbiting techniques, on a timeline that mitigates the increasing congestion of orbits. There is no one straight path towards an era of long-term space sustainability. It is a complex issue involving multiple actors from various regions around the world. However, with creative technology solutions, commitment to improving policy and best practices, clear licensing paths, and the growing realization of the economic and safety imperative, active debris removal services as an element of space sustainability are emerging as an essential concept to ensure all space actors continue to access space and leverage the benefits coming from Earth's orbits.

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