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The Future Utilisation of Space:

Orbital Debris and the Space Security Agenda

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Abstract

The growth in orbital debris has been predicted since the dawn of the space age. Now the debris fields cascade through orbits and the risk of collision is on an infinite upward trajectory. This thesis will examine what impact a wider concept of space security can have our understanding of orbital debris and the space security agenda. The space security agenda is in a state a flux as it seeks the most effective way to deal with the threat posed by orbital debris. A traditionally narrow approach of security would see debris discarded as a security threat due to its limited threat to a state. However, a broader approach would see aspects of environmental security emerge, allowing both public and private sectors to act to solve this crisis. There is a sizeable void in the literature that links policy and science when analysing orbital debris. Therefore, when applying the theory, it is best to find consensus and collaboration. The Copenhagen and Welsh Schools of International Security offer opposing views initially. Nonetheless, when examined closely they reveal similarities that allow for a 'hybrid' theory to emerge. The international challenges to legal and policy changes are diverse and complex. Consequently, the significance of transparency and confidence-building measures to lead space policy and governance forward cannot be understated. This thesis argues that a broader concept of space security can support a greater understanding of space threats.

Contents

1 Introduction

'On June 29, 1961, the US Transit-4A satellite was launched from Kennedy Space Centre on a Thor-Ablestar rocket … [catalogued] as the 116th space object since the launch of Sputnik-1 on October 4, 1957. At 06:08:10 UTC on June 29, 77 minutes after the injection and separation of Transit-4A and two additional payloads, the Ablestar upper stage exploded, distributing its dry mass of 625 kg across at least 298 trackable fragments, of which nearly 200 were still on orbit 40 years later.'[1]

Two main categories that divide up the 'space junk' that surrounds and threatens our planet, Space Debris and Orbital Debris. Space Debris refers to both natural and artificial objects and particles, natural debris includes meteoroids that orbit the sun and occasionally pose a collision risk with Earth. Orbital Debris is any human-made object in Earth's orbit 'that no longer serves a useful function', and includes everything from abandoned satellites, disused rocket stages, misplaced tools and flecks of paint.[2] The definition of 'space debris' also includes objects that have re-entered Earth's atmosphere. It is estimated that '66% of all catalogued objects in space history have decayed, with most of these burning up due to aerothermal heating. Some objects,

[1] Klinkrad, Heiner. 2006. Space Debris - Models And Risk Analysis. Chichester, UK: Springer, Praxis Publishing Ltd.P.1

[2] Garcia, Mark. 2018. "Space Debris And Human Spacecraft". NASA. https://www.nasa.gov/mission_pages/station/news/orbital_debris.html.

however, can pose a risk either by surviving to ground impact or by releasing dangerous substances into the atmosphere.'[3] Another description often used is 'Space Junk' which is 'not just confined to redundant satellites, but to all other home-grown pieces of debris, either accidentally misplaced in space or intentionally set free.'[4] This includes maintenance equipment that has sometimes drifted away from astronauts during spacewalks and the unpleasant bags of frozen urine that has been jettisoned from spacecraft. However, this task no longer occurs today as astronauts can recycle urine into safe drinking water.

Approximations vary regarding the number of large objects considered orbital debris. However, NASA[5] believes there to be more than twenty thousand 'pieces of debris more substantial than a softball orbiting the Earth.[6] The illusion of space often gives the impression that it is a slow-moving environment, especially when we see astronauts conduct spacewalks on the outside of the International Space Station. However, pieces of debris can travel up to around 17,500mph which is approximately 7.8 kilometres per second (km/s).[7] Low-Earth orbit (LEO), which is between the altitudes of 200km and 2,000km, is the most congested orbit as telecommunications companies favour it. In LEO, the 'average relative speed of a piece of debris and a satellite in a collision in 10km/s', which is 22,369.4 mph. When considering that most

[3] Klinkrad, 2006. Space Debris - Models And Risk Analysis. P.3

[4] Powell, Jonathan. 2017. Cosmic Debris: What It Is And What We Can Do About It. Springer.P.176

[5] National Aeronautics and Space Administration

[6] Garcia, 2018. "Space Debris And Human Spacecraft"

[7] Ibid

satellites have no shielding, they do not stand a chance against an impact at these speeds.[8]

It is possible to track orbital debris from earth, yet the current technology struggles to track anything with a diameter smaller than 10cm due to the immense speed in which the debris is travelling. Therefore, it is estimated that millions of debris fragments are unaccounted for.[9] This poses a significant threat to the future of mega-constellations, which are large groups of satellites that number in the hundreds and even thousands as they will provide a larger target for all types of debris, both trackable and un-trackable debris, to collide with.

The increase in debris has coincided with humanity's increased utilisation of space, especially as the dependence on satellites has shaped the modern way of life for many across the globe. This increase cannot continue in its current fashion as it risks hindering future space exploration. Zenko wrote that 'it took forty years to produce the first 10,000 pieces of softball-sized space debris, it required less than a decade for the next 12,000'.[10]

[8] Chen, Shenyan. 2011. "The Space Debris Problem". Asian Perspective Special Issues: Avoiding An Arms Race In Space 35 (4): 537-558.

[9] Garcia, 2018. "Space Debris And Human Spacecraft"

[10] Zenko, Micah. 2011. "The Danger Of Space Debris". Council On Foreign Relations. https://www.cfr.org/blog/danger-space-debris.

1.1 Research Question

The question that will be being researched in this piece is **‘what impact can a wider concept of security have on our understanding of orbital debris and the space security agenda?'**

This question has been chosen as it highlights the main areas of focus for this research paper. Throughout, it will seek to advance the debates of the international and space security agendas through analysis of the narrowing versus widening debates. This will include discussions from the Copenhagen and Welsh Schools of International Security and the Human Security Agenda. As the primary emphasis of this paper will be focusing on the space debris problem, it was fitting to state this in the title and the research question. The research question will be referred to throughout this piece, and it is crucial, especially when dealing with international security theory, that the application of these theories will be applied to space-based examples.

As the question is developed a clear debate between different sides of the debate will emerge and allow for the appropriate application of examples that will acknowledge possible solutions for the future of space-based affairs regarding the mitigation of space debris. As will be expanded on during the methodology chapter, the analysis of academic and scientific sources will be coupled with first hand evidence obtained through interview that will help develop theories and ultimately seek to present a quantifiable answer to the proposed research question.

1.2 Purpose

The importance of researching the dangers posed by outer space activity is imperative to the future of humanity. Throughout this piece, many scientific research missions will be examined. Notably a ‘rigorous study by J.C. Liou and Nicolas Johnson, [which], indicated in 2006 that just the current amount of debris could generate a tripling of the space junk over the next 200 years.'[11] As research into the changing environment on Earth is increasingly acted upon, it is time that a similar progression from debate to action takes place in orbit around Earth.

As orbital debris is the chief security threat that it's put forward by this research paper. The space security agenda is intertwined with this topic area as it is in a constant state of flux as it seeks to find a coherent path for the future of outer space security affairs. The current governance system for space relies heavily on Treaties and International Agreements signed by states during the Cold War era. Consequently, many of the protocols are archaic and out of step with modern technological advances. This promotes the purpose of this research as a new way to ensure the peaceful utilisation of space is required. As will be discussed and analysed in detail throughout this piece, the historical governance systems, which are dominated by the United Nations, need to be updated, yet differing political divides between states hold this process back. There are divides between what security in space truly means. For this traditional view

[11] Pelton, Joseph N. 2013. Space Debris And Other Threats From Outer Space. New York: Springer.P.18

of security will be compared with a broader approach that includes the environment as a security issue. It is through this process that will emphases the difficulties that are prevalent in the currently proposed adaptions on an international scale to deal with the space debris problem.

It is a natural progression that all space treaties and agreements be revisited when they can no longer effectively govern modern space activities. Perhaps a new treaty is the future for space affairs and may be a path that could lead to solutions for the space debris problem. However, applying logic to the international political sphere is often misplaced and it will be scrutinised later in this piece whether it is more prudent to look towards a common set of goals and norms rather than a legally binding treaty. It will undoubtedly be essential to avoid a 'blame game' between space fairing nations when finding common ground. This is certainly the case for orbital debris as 'it is only a few spacefaring nations that were the prime cause of today's space junk. The primary countries in this regard are the United States, China and Russia.'[12] It will be noted throughout that space debris is of global concern and therefore will require a globally united response.

Through the analysis of literature, and interviews with experts in the space security and debris mitigation fields, the impacts of debris on current and future space affairs will be stressed. To give an effective application of the theoretical aspects of this research, it is required that a comprehensive examination of the history behind the

[12] Pelton, 2013. Space Debris And Other Threats From Outer Space.P.21

creation of human-made debris be undertaken. It is the hope of this piece that it may raise the profile of the imminent threat posed by humanity's pollution of our space environment and those who wish to tackle this problem in the future. The theoretical consideration in this piece takes examples from two opposite ends of a spectrum and seeks to show the consensus and compromise is often the best solution.

2 Methodology

2.1 Methods

This research paper will use both quantitative and qualitative approaches throughout the analysis. This is to broaden the research area and develop a deeper understanding of the complexities of the research questions and to meet the aims and objectives of the thesis. Many papers and journals have been published containing scientific data which will be a useful resource for quantitative data. Though, the limited research on qualitative data will require a wide range of sources that include academics, security experts, public sector agencies and private sector companies.

To begin, analysis of secondary source evidence surrounding the area of space debris will be the foremost section of research. Space security experts and academics papers and journals will allow for a more detailed explanation of the issues surrounding the debris problem and possible solutions. As well as this analysis will be the development and critical analysis of security theories that will seek to define the space security agenda while giving structure to the research through the expansion of an analytical framework.

The fundamental theories that will be tackled in this piece will be the so-called 'Copenhagen School', with key texts being written by Buzan, Waever and de Wilde and the so-called 'Welsh School' with crucial texts written by Booth and Wyn Jones. The thesis will also focus on the critiques of the Copenhagen School with texts by McSweeney and Hansen. The reasoning for these theories being selected is through the differing points of view that have been put forward by these schools. It opens debate for the widening and narrowing of the security agenda on Earth, and this can be applied to space when dealing with space debris. Consequently, the analysis of space debris leads to a question of how to define the problem, either as a security threat or an environmental issue.

The Copenhagen school has been chosen for theoretical analysis as it uses the traditional realist approach to security that focuses on the state as the referent object while adding societal security alongside. For the two critical thinkers behind this international security school, Buzan and Waever, they believe that the state should be the referent object for 'political, military, environmental and economic security, while society is the referent object for societal security.'[13]

It is through this view that security takes on a form of duality with the traditional view of the state be used to guard 'its sovereignty while {societal security] attempting to

[13] Hama, Hawre Hasan. 2017. "State Security, Societal Security, And Human Security". Jadavpur Journal Of International Relations 21 (1): 4

keep its identity.'[14] Through the examination of the Copenhagen School and its application to outer space security concerning space debris it will allow for a critique of the framework and follow this potential proposal for a more useful application to the space security agenda will be offered.

The Welsh school of international security has been selected for this research piece due to its initial opposition to the views held by the Copenhagen School. Whereas Buzan and Waever place the referent object of security as the state and then allow a section to be societal security, the Welsh schools see 'individuals as a core reference object of security instead of states.'[15] It is believed by the key thinkers Booth and Wyn Jones that the individual has the power and influence to change the security agenda depending on their views of what security is. It must be noted that the Welsh School 'does not look at the World as it is, but as it should be.'[16] Due to this, it is easy to critique when not being compared to other theories. However, for the purposes of this research piece, it is essential as it can highlight weaknesses in the Copenhagen School.

As part of the debate that surrounds space debris focuses on its categorisation as a strategic security threat through the traditional view, or as an environmental problem, which is the view taken by a wider security stance. The Human Security Approach has been used to allow for a deeper understanding of what environmental security means

[14] Ibid. 4

[15] Ibid. 12

[16] Ibid. 12

for the security agenda. This is impactful as the current debris problem is seen by many as a governmental problem and therefore a strategic threat. In the future, through modern technological advancements, it may be thought of as an environmental problem as it will be possible to remove debris from orbit.

The use of this type of theoretical analysis will allow for a stable structure to aid in the narrowing down of the topic area. Space security has many possible avenues to explore. Therefore, it is vital that only the most necessary possibilities be developed that aid in the overall research of space debris and the future utilisation of space. The Copenhagen and Welsh schools can allow for comparative analysis that can help this piece seek out consensus, that would support the desired outcome that it may be useful to influence and advise policymakers on the future of the space security agenda when dealing with space debris.

The scientific complexities of monitoring, tracking and calculating space debris in several different orbits around Earth has led to the use of space agency figures as a source of secondary quantitative data. The reason for using government and private agencies is to give scientific backing to the debate. It would be impossible for an individual to research and gain the data required alone. Therefore, using already available and highly reliable data from several sources is needed. The primary sources for this piece have come from NASA, ESA and IADC. These space agencies and committees are consistent sources as they focus in the space arena, notably IADC, who concentrate on space debris coordination and mitigation measures. The United States currently has the most extensive available catalogue of space debris due to its constant tracking over several decades by NASA, this allows for greater dependability on the data used as it can be compared with other sources to make future projections regarding the cascade effect of space debris. Within ESA is the Space Debris Office, based in Germany. The work of the head of this space debris office, Heiner Klinkard, has been used throughout this piece as he has worked in developed technologies and other mitigation measures for space debris and followed the possible impact of human-made orbital debris on the future utilisation of space for humanity.

The primary source of qualitative data will come from semi-structured interviews with experts in the field of space debris and space security. Throughout this research piece, interviews have been held with Dr Bleddyn Bowen, at lecturer in International Relations at the University of Leicester, whose primary interests include the security of outer space. Another interview was conducted with Yuske Taguchi, an employee of Astroscale. Astroscale is a private company based in Singapore that is currently expanding its production of spacecraft that have the capability to remove debris from orbit following its end of life.

The interviews will allow for a broader discussion of the related fields and theory surrounding space debris. The fluidity of the interviews will probe a deeper understanding of different theories and practices that are currently in operation globally to address issues in space, being specific to the debris problem. The pre-arranged questions will be wide-ranging, and sub-questions will follow when necessary to maintain a topical trajectory. Follow-up question may be used when more information if need by the interviewee to elaborate a point of interest or develop a thought process.

2.2 Sources

The sources that have been used throughout this piece range from academics, national and international space agencies, international organisations and private space contractors and companies. All sources and points of reference can be found in full at the end of this research paper in a comprehensive bibliography.

The sources were chosen due to the expertise on the areas contained within this piece including; security theory and securitisation, outer space affairs, space theory, orbital debris mitigation measures, outer space policy and outer space law. Much of the secondary source data that has been collected and analysed has been obtained through the reading of articles and journals by academics in security theory or outer space affairs. This has led to scientifically backed information being intertwined with social science analysis.

When interviewing the selected candidates, an initial background on the person or company was required at the beginning. Following this, questions revolved around the possible gap between policy and science when dealing with outer space affairs, especially in direct regard to space debris. Current policy and legal challenges were addressed as an important topic area which led on to questions that expanded this point to conceivable advisory notes for future development of space policy and law. During the interview, all candidates were asked whether they believed orbital debris and the cascading effect should be defined as a security problem or an environmental problem. The reasoning for this line of question was to find if any academic or private sources had developed a hybrid-definition or naturally belonged to one side of the debate.

The interviews differed after this point between academics and private companies. For the academic interviews, an expansion of current security theory was needed to provide first-hand evidence of the developments made in this field. Depending on the personal view of the interviewee either pro-widening or pro-narrowing questions were used to play the role of a 'devil's advocate', this system allowed for the best theoretical elaborations as it challenged the thinking of the interviewee. In the information that was gained from this technique aided in the expansion of the theoretical framework which forms the backbone of this piece.

When interviewing members from the private companies, questions surrounding their current and future goals were asked. The insights into the possible solutions to the debris problem, especially in relation to debris mitigation guidelines became invaluable in the development of this research piece. The first-hand evidence obtained regarding the technical events that have been made to remove all future defunct spacecraft allowed for a more positive and hopeful section of the findings. Which, up until that development, had been limited to promoting solutions that were unfeasible in the current climate.

2.3 Ethics

Throughout the researching of this piece ethical values have been adhered to so that there is no compromise on the information and data retrieved. As mentioned above, interviews have been used in this research paper to provide unique and current developments within the public and private space security and debris mitigation fields. The interviewees were carefully selected and contacted via their publically available email addresses. In the initial email, a summary of the research topic was given as well as the reason for the candidate being selected. Consent forms were provided alongside a plain language statement which gave options to take part, and if so, remain anonymous if that is what the candidate wished for. The selected candidates were made aware that following the interview participation could be withdrawn at any time up until the point of publication.

As the interviews were designed to be semi-structured, this gave the candidates a platform to explain and expand on their research or their companies research. There was also a limited need for intervention the interviewer to prompt responses or return to the topic area.

Following the conclusion of the interview, it was highlighted that a copy of sections that would be assigned as quotes in the research piece would be sent to the interviewee before publication. This was most relevant to the private companies who did not wish for any adverse information be present as it would potentially damage the reputation of the company.

All contact information and data, including publically available email addresses, will be deleted following the submission of this research paper to the University of Glasgow. This will remove any possible conflict of interest and maintain the protection of the privacy of the interviewees.

2.4 Structure

This dissertation will be researched using both existing pieces of literature from experts in the field of space security and orbital debris. It will also utilise secondary source information when discussing and analysing the space security agenda. The primary source of information will be obtained through semi-structured interviews with space security scholars as well as private companies who are currently working to solve the debris problem that presently threatens our way of life.

Current and future trends in the space debris debate will be highlighted and give some data regarding the increase in the debris in specific orbits, notably LEO and some polar orbits. It will use data by space agencies around the world to identify and estimate the possible future growth of the debris problem. This will consider many stimuli, such as immediate cessation of space activities and some debris removal events to limit the growth.

The theory section will follow the close of the introduction and will outline that current theories that govern the space security agenda. The focus of this section will be the two main theoretical areas of this piece, the widening or narrowing of the security agenda. Following this, it will expand on the possible future adaptions and modifications that could change and improve the way in which space is governed, including changes that may arise from international agreements and treaties surrounding the threats from space that will impact humanity's future utilisation of space.

The literature review will place emphasis firstly on explaining how and why the space debris problem has escalated over the decades since man first entered space. It will then describe the specific actors and how they have contributed to the debris problem and how they are aiming to solve the cascading crisis which threatens our planet and humanity's future utilisation of space. This section will give the most significant insight into the orbital debris problem and provide a more in-depth analysis and explanation of specific events that have been discussed in the current and future trends section.

The methodology segment will explain how the research conducted to produce this work has been obtained and examined. It will also discuss the limitations of the work and highlight areas in which future research may wish to exploit.

The critical analysis will allow for many of the positions that have been taken by authors, professionals and academics to be critiqued by the author. This section will also allow for a discussion of the opinion by the author regarding the topics that have been discussed throughout this piece. The findings section will allow for reflection on what has been uncovered and what the personal opinions of the author are in relation to this topic area. This will allow for a collection of all the information that has been reviewed. Here it will be critically analysed, and theory will be imposed upon several differing views and ways of dealing with the debris crisis.

Finally, a concluding summary will highlight the main areas that have been examined throughout this piece. It will offer final remarks by the author that will bring together the entirety of the works and leave questions about the future research of orbital debris.

2.5 Limitations

The limitations of this piece begin with the theoretical framework which has been used. By comparing two differing schools of thought surrounding the broadening or narrowing of the space security agenda, this piece has highlighted the differences between both schools. Consequently, the similarities are areas of consensus have not been developed thoroughly, despite them being limited. There space security agenda is an incredibly complex notion, and to only research, two specific schools of thought do not allow for a total image to emerge of the current picture. In studies that may follow, this could be overcome by investigating all the possible avenues of research and seeking a consensus between them to best progress forward. This would take a great deal of work and would produce a substantial research piece, but it would allow for the most comprehensive understanding of the space security agenda.

In some cases, the secondary data that has been analysed has been written by government-run agencies that are open to influence by policymakers. With different governments holding slightly different policy stances on issues such as orbital debris, it is possible that discrepancies in the information could occur which may impact the overall analysis. It could be possible in future pieces that a section could be written to highlight these different policy dynamics to allow for a more celebrated analytical piece of research to emerge.

Following this, the reliance on data collected by external sources leaves the research piece open to criticism from the sources used. The dependence on NASA, ESA and IADC for scientific figures and projections has a Western bias and although these figures are reliable and from reputable sources, the predictions may differ with other space agencies around the world, such as Russia or China. The reason for using the above-noted agencies for collecting data is due to the long history of statistics being gathered by these agencies when focusing on the debris issue. Notably, NASA has been monitoring the growing debris fields in space for longer than any other space agency. Russian and Chinese space agency figures are not always readily available and are much for secretive generally in sharing compiled data. The impact of the failed 2007 Chinese ASAT test, which is mentioned throughout this research piece, is often reduced throughout Chinese space figures. The counter-argument for this is that Western space agencies may overcompensate for this in their figures surrounding the same debris creation event. With more public accountability, this would resolve a sceptical dispute. In future research, it may be possible to collect data from more source and compare them to give a global average, but this would rely on some of the more unwilling to share their space debris data.

Another limitation of this piece is the limited number of interviews conducted. Unfortunately, despite contacting a significant number of private companies, space agencies and academics very few wished to take part in the study. The reasoning for this is that this research piece is under time restrictions and therefore it was not possible to wait for all possible interviewees to respond before completion. It is also apparent that the researcher does not, yet, have the contacts necessary in this field of research and therefore a reliance on publically available contact information was required. If this research piece were completed again, it would be wise to set out to contact interviewees around one year before the publication of the research paper to allow more time for interviews to be conducted. Nonetheless, the interviews that were conducted have been of great help to the research and analytical data in this piece.

3 Theoretical Framework

Currently, the area of security theory is confined to a deadlock between two main groups, those who wish for a narrow approach to securitisation to be adopted globally, and those who argue for a wider concept that would consider a more significant number of ‘security threats'. An example of the wider approach is the human security agenda, where scholars and academics have engaged in ‘unresolved debates about the broad versus narrow definitions and the consequences of securitisation'.[17] Consequently, this has led to restricted academic work on exploring the links between the two leading schools of thought.

The differing schools of international security have all offered differing points of analysis and different referent points in which to focus when dealing with the question 'what is security?' Realism concentrates on the state and is unwilling to shift with the modern age in its expansion of the term 'security'. The Copenhagen School includes both societal and state security in its analysis. 'Consequently, the school could fill the gap that existed in realism.'[18] The Welsh School looked at individuals as the referent object of security and offered the emancipation strategy' this makes it complicated for scholars as it is somewhat abstract.[19] The Human Security Agenda and its many conflicting avenues leave it vulnerable to criticism. Yet, it is vital to the broader debate as it allows for a continued discussion on this topic and does not allow for traditional theoretical schools to dominate.

[17] Security Dialogue, Special Section: What is Human Security? Various authors, 35:3 (2004), pp.345-72; Taylor Owen, 'Human Security – Conflict, Critique and Consensus: Colloquium Remarks and a Proposal for a Threshold-Based Definition', Security Dialogue, 35:3 (2004), pp. 373-87; Nicholas Thomas and William T. Tow, 'The Utility of Human Security: Sovereignty and Human Intervention', Security Dialogue, 33:2 (2002), pp. 177-92; Alex J. Bellamy and Matt McDonald, '"The Utility of Human Security": Which Humans? What Security? A reply to Thomas and Tow', Security Dialogue, 33:3 (2002), pp. 373-7; Grayson, 'The Biopolitics of Human Security'.

[18] Hama, 2017. "State Security, Societal Security, And Human Security. 16

[19] Hama, 2017. "State Security, Societal Security, And Human Security" 16

Within these different approaches towards security studies, there have been attempts to bridge the gap between the narrow securitisation approach associated with the Copenhagen School and the so-called 'Welsh School', who favour the wider approach to security theory. The more optimistic view taken by the Welsh School is often discordant with its opposing and more pessimistic view associated with the Copenhagen school, championed by the works of Waever, Buzan and de Wilde.[20] It could be argued that the Copenhagen School may be a prominent theory for the future of space security as the notion of securitisation has developed out of this school of thought through the constructivist routes of some of its leading proponents, notably Buzan. However, it is through the critique of the Copenhagen School that an enhanced theory can be developed to address the threats of orbital debris. It is often the case that one specific theory cannot solve all the issues related to any topic, in this case, space debris. Consequently, new theories develop through the influences of multiple stimuli and conflicting theories. Space Security should be no different as it arguably poses the most complex set of challenges humanity has ever faced. The Welsh School, also known as the Aberystwyth School due to its links with scholars at Aberystwyth University, is led by Booth and Wyn Jones. This expansion of 'critical security studies', coined by Booth, has focused on the normative development of the world and the challenges that are constantly arising through fluctuating and continual

[20] Floyd, Rita. 2007. "Towards A Consequentialist Evaluation Of Security: Bringing Together The Copenhagen And The Welsh Schools Of Security Studies". Review Of International Studies 33 (02): 327. doi:10.1017/s026021050700753x.

global development. Booth expresses his thoughts on human security as having 'taken on the image of the velvet glove on the iron hand of hard power'.[21]

Moltz has engaged in the theoretical literature to tackle the space environment and the threats posed by dismissing the dangers of polluting Earth's orbit. It is Moltz that argues the most comprehensive way to understand the current space environment is to apply an 'environmental security' approach.[22] By securitising the environment, and with it the space environment, this theory would allow for a deepening of the space security agenda, which allows for space weather, space debris (including comets and asteroids) being considered security threats and would necessitate a need to be dealt with as such. This is an extreme widening of the security agenda and Moltz describes space security as being 'the ability to place and operate assets outside the Earth's atmosphere without external interference, damage or destruction.'[23] Taking this view of Moltz and giving in a workable, practical example in space highlights many issues with this extreme widening of the space security agenda. Any object, human-made or natural, would be considered a security threat as it can potentially disrupt, damage or destroy a spacecraft or satellite, which, in theory, initially seems logical. However, the technological developments of active debris removal systems (ADR) and the current

[21] Booth, Ken. 2007. Theory Of World Security. Cambridge: Cambridge University Press.

[22] Moltz, James. 2007. "The Past, Present, And Future Of Space Security | Journal Of World Affairs". Brown.Edu. https://www.brown.edu/initiatives/journal-world-affairs/141/past-present-and-future-space-security.

[23] Bowen, Bleddyn E. 2013. "James Clay Moltz, The Politics Of Space Security: Strategic Restraint And The Pursuit Of National Interests". Intelligence And National Security 28 (2): 288-291. doi:10.1080/02684527.2012.727071.

development of dual-use satellites throws doubt of the workable nature of this view. It is possible to argue that as Moltz has attempted to widen the security agenda to combat the space debris problem and improve the environment in space, he has developed a theory that would condemn the ADR systems and other systems that would clean up the orbits around Earth to be defined as security threats themselves. This view, when applied to a practical example, would lead to the weaponisation the entirety of space surrounding Earth.

3.1 Traditional Security

The space security agenda is being dominated by the 'widening vs narrowing' debate. The traditionally narrow view would firstly ask 'what is meant by security?' Secondly, 'what is to be secured?' It is through the development of these questions that the principal question can be answered, should space debris be a security issue?

From a traditional security view, it is argued that 'framing a problem as a security issue usually means that a threat could escalate into an issue of survival.'[24] The current debate between scholars reaching this area seeks to find an answer, or at least an explanation, between the 'true' threat posed by space debris. For many scholars that argue against space debris being categorised as a security issue, it is claimed that it 'may be difficult to escalate the issue of debris to one of survival'.[25] The reasoning for

[24] Bowen, Bleddyn E. 2014. "Cascading Crises: Orbital Debris And The Widening Of Space Security". Astropolitics 12 (1): 52

[25] Ibid. 52

this is view is that compared to nuclear war, which is a highly intense escalation, the debris issue cannot cause the same sudden loss.

For Waever, the history of security binds the concept to defence and the state. Therefore, he argues that 'addressing an issue in security terms still evokes an image of threat-defence, allocating to the state an important role in addressing it.'[26] The traditional view of security was developed heavily out of Cold War thinking, and it is often hard to release the shackles of state on state warfare. If, however, an even older development of security is discussed, Clausewitz argued that war is not limited to the state. The state is involved directly in all security matters may not be a positive outcome.

The Copenhagen School, which is dominated by Buzan and Weaver, has attempted to create a more comprehensive backbone to the theory by defining some cornerstones. It is argued by Buzan and Weaver that a 'speech act' philosophy is prevalent in this theory. This develops out of 'triology' which includes the speech act, the actor and the audience. Yet the connection between the actor and audience is not developed clearly throughout the theory and is therefore left vague. For the Copenhagen School, the articulation of the word or phrase 'security' 'entails the claim that something is held to pose a threat to a valued referent object that is so existential that it is legitimate to move the issue beyond the established games of 'normal' politics to deal with it by

[26] Lipschutz, Ronnie D. 1998. On Security. New York: Columbia University Press. 42

exceptional'.[27] It is this development out of the traditional security view that allows Weaver to put forward the point that 'security' is still dominated out of a fight for national survival. Therefore, speaking the word 'security' creates an issue through its traditional realist definitions. Furthermore, 'the authority to speak is constituted by the performative power of the speech act itself which constitutes actors and their social relations retroactively.'[28]

It must be noted that although the is an emphasis on the linguistics involved in security theory, which is developed from a post-structural influence, Buzan and Weaver 'do not follow radical poststructuralists who would only concentrate on the power structure of the linguistic features of a speech act'.[29]

For the Copenhagen School, society is at the centre of security. However, before an issue can become securitised, it must be politicised, according to Weaver and Buzan.[30] It could be argued, that politicisation of an issue could be used by the elites for their own gain. However, with society being at the centre of this school it is based on a democratic model and would, therefore, in theory, the elites would be unable to do this as they would be held accountable by society. This allows for the question of 'how does a security threat emerge?' For Buzan and Waever 'a security issue emerges not

[27] Stritzel, Holger. 2007. "Towards A Theory Of Securitization: Copenhagen And Beyond". European Journal Of International Relations 13 (3): 360

[28] Ibid. 362

[29] Buzan, Barry, Ole Wæver, and Jaap de Wilde. 1998. Security. London: Lynn Rienner Publishers. 46

[30] Hama, 2017. "State Security, Societal Security, And Human Security". 6

necessarily because there is a real existential threat but rather because the issue is presented as a threat, and therefore security is a self-referential practice.'[31] From this point, a successful 'speech act' is required 'whereby the members within a community develop meaning in terms of a threat to something to which they collectively attribute value and demand an effective response, however drastic'.[32]

3.2 Widening Security Approaches

The widening of the space security agenda has similarities to the human security agenda on Earth. It can be highlighted that 'the main threats to space security of all actors come not from enemies, but from the environment and the pollution of human activity is depositing there.[33] Thus, by adopting a wider framework to define security threats, it is possible to include space debris as a security issue.

Moltz is one thinker that has been extremely generous in his expansion of the term 'security', especially when dealing with space security. Moltz claims that due to 'the interaction of technology and politics in the realm of outer space [rarely being] a linear process' it is often hard for consensus to emerge between actors.[34] However, as will be explained he does believe that there are four main schools that define the

[31] Hama, 2017. "State Security, Societal Security, And Human Security". 7

[32] Hama, 2017. "State Security, Societal Security, And Human Security". 7

[33] Zhong Jing, "China and Space Security," in John M. Logsdon and James Clay Moltz, eds., Collective Security in Space: Asian Perspectives (Washington, DC: Space Policy Institute, 2008), 77–83.

[34] Kearn, David W. 2010. "The Politics Of Space Security: Strategic Restraint And The Pursuit Of National Interest - By James Clay Moltz". Review Of Policy Research 27 (4): 530-532.

utilisation of space, some of which rely on the development of actor's views alongside technology to form a consensus on pressing space security issues.

The first school of thought is ‘space nationalism [and he argues that this] seeks to acquire control over outer space in order to maximize its potential for military purposes.'[35] This school can be seen at the dawn of the space age, as the United States and the Soviet Union entered a technological battle to secure the domination of space. It was an essence of space nationalism that led the Soviets to put the first man in space, and the same ideal that led to the United States putting men on the moon.

Following this, the second school is ‘global institutionalism, [Moltz believes this] emerged as a response to the early military exploits in space and has sought to use formal diplomatic agreements to avert potentially dangerous arms races in space by creating a sanctuary.'[36] Subsequently, after the start of the space race, it became clear that governance was needed to prevent space becoming a war zone. As explained in the legal and policy sections of this piece, treaties such as OST where required to limit what could happen in the space domain and hold states accountable for their actions. Thirdly, the technological determinist school ‘focuses on the emergence of new technologies that could drive states to compete in outer space, but questions the politically driven rationales of space nationalists for the need to move aggressively to

[35] Kearn, 2010. "The Politics Of Space Security: 530-532.

[36] Ibid

close off the prospects of potential competitors before there are technical means to do so.'[37] The focus on technology is undoubtedly a driver for outer space affairs.

'Finally, the social interaction school views political outcomes as contingent and often imperfect, but over time, as actors learn, consensus can emerge, and norms and tacit agreements can contribute to fairly stable expectations.'[38] Moltz does align himself with this school of thought. However, he acknowledges that due to the complicated technological advancements and deployments of new technology, alongside fluctuating political relationships this is a school that is easily critiqued.

For Moltz, the 'referent object in space security should be the space environment itself.'[39] The use of the environment to govern space and dictate its path leaves it out of the control of singular actors, such as states. It requires a united response from all space fairing nations, and arguably those who do not currently have the capabilities to develop and launch their own satellites and spacecraft. Moltz goes further and expands the term 'space security' to include human-made and natural threats. Therefore, space weather, natural space debris, as well as human-made space debris, are all contained by this definition. It is Moltz belief that 'space security [is] the ability to place and operate assets outside the Earth's atmosphere without external interference, damage or destruction.'[40]

[37] Ibid

[38] Ibid

[39] Bowen, 2014. "Cascading Crises: Orbital Debris And The Widening Of Space Security". 53

[40] James Clay Moltz, The Politics of Space Security: Strategic Restraint and the Pursuit of National Interests (Stanford, CA: Stanford University Press, 2008), 11

The environmentalist links between Moltz and environmental security are obvious. As with the environment, a security threat can be defined as anything that threatens the future ability to sustain life. The impact of modern technology, especially satellites on Earth has been so profound that without them humanity's very way of life would certainly stall and possibly falter. The threat to these satellites posed by orbital debris is profound and growing, the companies and states that operate them are currently unable to effectively deal with the threat, placing them on the back foot in the 'battle'. Therefore, it is easy to conclude that a broadening of the space security agenda is required as 'space is part of [the] critical infrastructure and a vital security issue.'[41]

The Welsh School of security studies, 'which developed out of Critical Theory, has defined itself by critiquing 'the modernist meta-narrative of rational social [and] political theory.'[42] Using this theoretical framework, it can be used in direct opposition to the traditional and narrow views associated with the Copenhagen School. It is put forward by the Welsh School that the 'realist understanding of security as 'power' and 'order' can never lead to 'true' security'.[43] The reasoning for this is that through its analysis of the traditional views of security, the Welsh Schools sees that a new world has emerged where theories need to adapt and change. The Welsh School 'sets out from a criticism of conventional studies, particularly realist theories of security. The Welsh School begins their critique by arguing that in the changed post-Cold War world

[41] Bowen, 2014. "Cascading Crises: Orbital Debris And The Widening Of Space Security". 54

[42] Floyd, 2007. "Towards A Consequentialist Evaluation Of Security: 330

[43] Ibid 332

state-centric realism longer satisfactorily explain the complex web of world politics'.[44] The days of Cold War politics and its black vs white approach are now long gone, and the diverse nature of challenges in security have risen, alongside the shifting of ideology and alliances across the globe.

For the Welsh School the recent develops in global security, and the rise of ecological issues being considered as security threats using the Human Security Agenda, have left traditional views behind. This is not to say that these theoretical schools of international security are ‘wrong' or totally flawed, just unwilling to see that the world they are analysing is no longer black and white. The main evidence for this point comes from realism's inability ‘to draw a comprehensive picture of current security issues; in many parts of the world today threats against states are internal rather than external, and state security is not the only consideration.'[45]

Whereas the traditional security approaches have the state as their referent object, the human security agenda shares the view of the Welsh school that the people should be the referent object as they have the ability to influence what security is. However, within human security there are several different routes that the theory takes, some are broader than others and include the environment, right to self-determination and health all forming security issues. Ultimately some strands securitise the clear majority of issues that impact daily life. This leads to the main criticism of this school, which outlines that if everything is a security issue, they cannot be dealt with effectively. The

[44] Ibid 332

[45] Hama, 2017. "State Security, Societal Security, And Human Security".2

domination of several types of security problem would lead to a rating system that would in turn progress into a tier system of security threats. This evolution would complicate and therefore slow down, the reactiveness to deal with a security threat.[46]

The human security approach does not totally reject the idea of the state being somewhat involved in security; it argues that ‘states are providers of security for individuals in ideal conditions, with a recognition that sometimes states endanger human security. Furthermore, the approach as a challenge to state-centric approach changes the sovereignty of the state from absolute sovereignty to conditional sovereignty.'[47]

The main argument for the development of the human security agenda when dealing with outer space affairs and security issues is that it allows for non-military threats to the general peace and security of space to be highlighted. It is put forward by Moorthi, that by applying human security concepts to space security, it allows for an encompassing of a diverse number of threats. For Moorthi, this adaption also emphasises that humanity needs to ‘deepen the concept of security from the state down to the individual level and up to the regional and international level.[48]

[46] Hama, 2017. "State Security, Societal Security, And Human Security".14-15

[47] Ibid. 15

[48] D. Narayana Moorthi, "What ‘Space Security' Means to an Emerging Space Power," Astropolitics 2 (2004): 263.

With a wider concept of space security being adopted, it is possible that more cooperation between national space agencies would be a result. Gallagher argues that a cooperative approach regarding space debris would increase cooperative ventures between governments in space.[49] Though Gallagher's interpretation, the widening of the space security agenda to include orbital debris will not allow the issues to be forgotten. Although this is a valid point and highlights the need for action on space threats, there is no guarantee that defining issues in space as security threats would lead to a quicker solution than if it remained de-securitised.

Another thinker who focuses on the environment when dealing with the definition of space security is Zhong Jing. Jing is critical of the current security concept for space and believes that the zero-sum model that is currently used is outdated and based on Cold War thinking that is dominated by the United States. Jing believes that through this concept being deployed it negatively impacts cooperation and confidence-building measures in space. Currently, the space security agenda is constrained into the belief that an enemy is required for a space issue to be considered a space security threat and too much focus is placed on what other states intentions are in space. However, Jing believes that ‘the main threats to the space security of all actors come not from enemies, but from the environment and the pollution of human activity is depositing there.'[50]

[49] Nancy Gallagher, "Towards a Reconsideration of the Rules for Space Security," in John M. Logsdon and Audrey M. Schaffer, eds., Perspectives on Space Security (Washington, DC: Space Policy Institute, 2005), 1–3, 27, 33, 38.

[50] Zhong, "China and Space Security," 77–83.

The most influential part of the space security agenda, for those who seek a wider scope of the term, is the environment. As argued by Moltz, one the most prolific security 'broadeners' in this field, that 'the nature of the space environment itself is influential, if not decisive, in shaping outcomes.'[51]

3.3 Widening vs Narrowing of the Space Security Agenda

It is argued by Bowen, that 'it may be difficult to escalate the issue of debris to one of survival, as opposed to general high-intensity conventional and nuclear war.'[52] The reasoning for this is that such a state of total war would lead to extreme and sudden loss, in comparison to debris, which may 'neutralise individual satellites in a staggered and long-term fashion.'[53]

However, with the cascading crisis in space, debris will, if no measures are taken, reach a point where the staggered effect becomes one of consistent and prolonged catastrophe. Nuclear capabilities, in the modern era, rely heavily on satellites for launch and guidance. Therefore, should a satellite be damaged by debris, it can no longer function and will have become part of the debris problem as sections orbit Earth in an unpredictable, dangerous fashion.

[51] Kearn, 2010. "The Politics Of Space Security. 530-532.

[52] Bowen, 2014. "Cascading Crises: Orbital Debris And The Widening Of Space Security". 52

[53] Bowen, 2014. "Cascading Crises: Orbital Debris And The Widening Of Space Security". 52

As seen in both 2007 and 2009, it does not take more than one major incident to transcend certain orbits into chaos for centuries. As the argument above states, sudden loss of space assets in a conventional war is certainly a possibility and with modern tracking technology, it is possible to avoid large debris in space. Therefore, allowing for debris to be categorised as a 'long-term threat'. Yet, it ignores the capability of debris to cause a continual catastrophic loss because of conventional war. Should the sudden loss of space assets be the first stage, it is ultimately a self-defeating notion due to the inherent and unavoidable risks to all states space assets. The only possible defence to maintaining a presence in space following such an action would be comprehensive, and currently unavailable, orbital debris defences such as ADR technology.

The points argued by Weaver and Buzan's Copenhagen School regarding the 'speech act' in securitisation does not truly aid in the expansion of the theoretical expansion of the topic. A singular speech act does not account for much of the develops that are so often involved in security issues. Therefore, it cannot account for the diverse nature of security threats, especially the social processes that are involved. It can be deduced that in 'most cases a security scholar will rather be confronted with a process of articulations creating sequentially a threat text which turns sequentially into a securitization.'[54] When discussing space security, it often takes away from a national threat, thus allowing the arguments against matter, such as orbital debris, to be defined as a security threat. However, when policymakers refer to debris fields as an

[54] Stritzel, 2007. "Towards A Theory Of Securitization. 377

issue that can potentially impact their assets in orbit, this allows for a potential speech act to occur, leaving the Copenhagen School vulnerable in this way is due to its confused sectors between the social realm and its postmodernist linguistic ideas.

It is stated by Weaver and Buzan that ‘by uttering "security," a state-representative moves a particular development into a specific area, and thereby claims a special right to use whatever means are necessary to block it'.[55] This idea of security has merit and can be easily associated with historical examples of states using language to influence the people, such as during the Cold War and Hitler's rise to power in Germany during the 1920's and 1930's. It is precisely this reasoning that this particular definition of security may be flawed. The use of language to define a security threat, such as orbital debris, can be sued as a self-serving approach to influence others for a political or economic gain of person or persons who wield power. As with all problems concerning security, human nature is a variable that is ever changing, and so often this leads to misuse of the practices that may have been developed with the interests of society at its core.

Discussed in the above section on widening the security agenda, Gallagher put forward the idea that more cooperatives ventures would flourish between national space agencies to solve issues, such as the debris problem in orbit around Earth. This view is argued by Nair, who believes that widening the security agenda ‘would

[55] Lipschutz, 1998. On Security

increase military sensitivities outside of Earth's atmosphere.[56] It is these conflicting views that lead to many scholars unable to find common ground as they are blinded by their personal philosophy. The differing views on the space security agenda and lack of consensus leave the problem open, especially in the public sector. There are companies in the private sector that are attempting to solve the debris problem. However, the issue with this model is that private companies must make a profit to exist. This topic will be disused in more detail throughout this piece.

It is possible that due to the differing positions of the Copenhagen School and the Welsh School they may complement each other in several ways. It is put forward by Floyd that ‘the more unified the critical schools of security are, the stronger an alternative they can offer to the mainstream of security studies'.[57] This emphasizes that the use of critical schools, from opposite sides of a debate, can influence the mainstream theory into a consensus that is still impactful. Following this, Floyd believes that ‘the more united the academy, the more adaptable are its ideas to policymakers'.[58] This would include examples such as the European Union, which when related to space is currently growing in influence alongside the European Space Agency, in promoting and steering international policy on the future of space exploration and the impacts humans have had on the space environment.

[56] Kiran K. Nair, "Space Security: Reassessing the Situation and Exploring Options," in John M. Logsdon and James Clay Moltz, eds., Collective Security in Space: Asian Perspectives (Washington, DC: Space Policy Institute, 2008), 85.

[57] Floyd, 2007. "Towards A Consequentialist Evaluation Of Security: 336

[58] Ibid. 336

Floyd finishes with describing how ‘a combination of the two schools into a larger approach paves the way for a more critical engagement with security on the part of the security analyst, allowing for normative, but denying infinite conceptualizations of security'.[59] From this idea, it is clear that Floyd believes that by finding common ground between two opposing theories, it opens up a new dimension for scholars and analysts to create almost ‘hybrid' theories that essentially combine complimentary ideas that are believed to address the problem and issues that are prevalent in a topic area.

3.4 Application to the Research

Space security, when being applied to space debris should certainly have a focus on the state. Having the state as an influence and not the referent object, in this case, makes sense as it was state-run space operations that entered space and caused human-made debris to spiral out of control. Yet, for this argued to be applied to space security then ‘space' must be the referent object. Therefore, a state-based view is required to find a solution to the historic problems of space debris. By placing the state as the referent object it the danger is that a Cold War-era approach would be implied as the best path. As has been examined above, the end of the Cold War led many International Security Schools to critique the narrow realist views that had governed and guided international security for decades. The survival of the state is critical to this international security approach, however, will the growing influence on multi-

[59] Floyd, 2007. "Towards A Consequentialist Evaluation Of Security: 336

state organisations when dealing with space affairs, it is conceivable that this referent object could change to accommodate a new global political order if it was required.

As the issue of space debris is growing, it will soon become unavoidable for governments to state the level of the threat. As Buzan and Waever have argued, this would consist of a ‘speech act', following this the cascading debris crisis would no longer be able to be ignored as a ‘potential' security issue. The securitisation of space debris has arguably already taken place, and therefore it poses an existential threat to our way of life.

Although having the state as the referent object may be an effective way of dealing with historic debris, it does not tackle the future advances in technology. Therefore, as security studies have seen, through the development of individual security, the environment has become more important when dealing with security on Earth. The future of debris mitigation requires the influence of environmental security to assess and deal with the problems associated with outer space affairs, in this case, orbital debris.

Through the application of an environmental approach, while still acknowledging that a state is a referent object, it is possible that a complementary way forward could emerge. Therefore, it is proposed in this research that influences of the traditional state security framework, alongside the broader environmental and social theories be applied to tackle historic and future space debris issues. This ‘triology' would allow for a solid theoretical base whilst permitting the diverse nature of outer space security to be adapted when necessary.

4 Literature Review and Historical Background

4.1 Causes of Debris

It is highlighted by Chen, that space debris can be placed into five main categories: 'payloads, rocket bodies, anomalous debris, mission-related debris and breakup debris'.[60] It could be argued that breakup debris is the most important when studying space debris and its related impact on human space activity. This is because, as seen in Figure 1, it accounts for over half of all in-orbit debris. Breakup debris, by definition, is the 'destructive disassociation of an orbital payload, rocket body or structure.'[61] Breakup debris can also be split into sub-categories that allow us to understand what is contained within the larger term. These categories are deliberate creation, accidental collision, propulsion, battery and unknown. The larger of these categories is 'deliberate creation', which, is the primary cause of breakups in space. This may come as no surprise as many people are accustom to seeing the spent rocket stages of a spacecraft being detached, yet few ever wonder where these large structures end up. However, included within the category of deliberate creation is the use of ASATs

[60] Chen,. 2011. "The Space Debris Problem". 540

[61] Ibid 540

and as detailed throughout this piece, the 2007 Chinese ASAT test led to a unique contribution to dangerous debris in LEO.

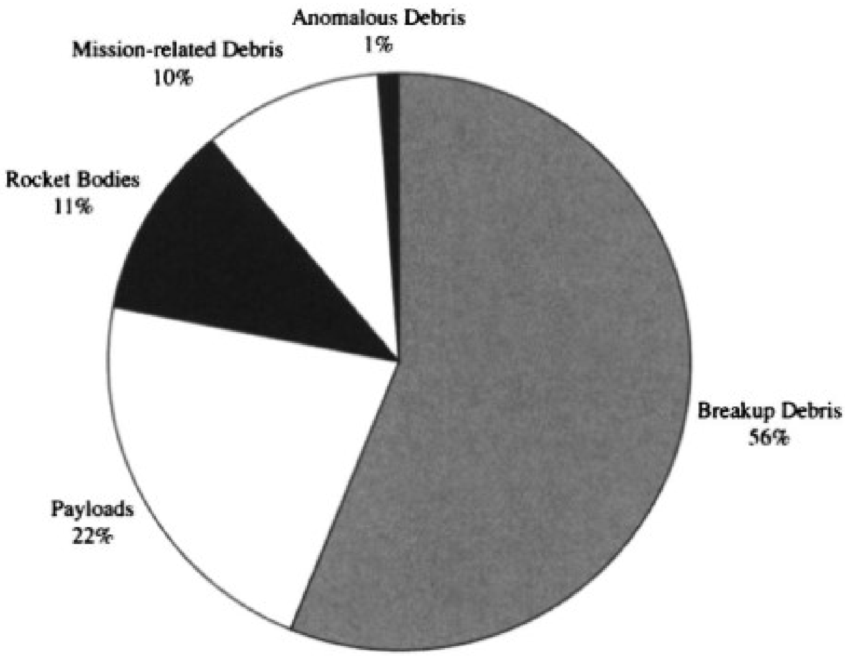

Figure 1 Relative Segments of the Catalogued In-Orbit Earth Object Population
Source: Technical Research on Space Debris and Other Risks to Spacecraft and Satellites, Beihang University, 2006-2009, funded by the MacArthur Foundation.

4.2 Kessler Syndrome

As explained earlier in the current and future trends section, it is often the case that fragments of debris created by collisions are more likely to have an extended orbital life in comparison to deliberately created debris. The repercussions of this have dominated the space security agenda for decades, and currently, there are debates over whether some regions of space around Earth are now too unstable to allow any other satellites. This is due to the extremely high risk of collisions, which will only increase over coming decades. This cascading crisis, first identified by Donald Kessler in the 1970's, warned of a chain reaction that would see 'collisions take over as the dominant debris generation mechanism.'[62] The findings of Kessler's research have led to many space agency's working to prevent 'Kessler Syndrome', however, it is now the case that this cascading effect has already taken hold in many orbits around Earth. J.C Liou concluded in 2010 that,

> *'model analyses already indicated that the debris population (for those larger than 10 cm) in LEO had reached a point where the population would continue to increase, due to collisions among existing objects, even without any future launches. The conclusion implies that as satellites continue to be launched and unexpected breakup events continue to occur, commonly-adopted mitigation measures will not be able to stop the collision-driven population growth. To remediate the debris environment in LEO, active debris removal must be considered.'*[63]

Seen below in Figure 2 if the findings by Liou and Johnson, who achieved this drastic result with data that effectively prevented any launches into space since 2006.

[62] Chen,. 2011. "The Space Debris Problem". 551

[63] Liou, J.C. 2010. "An Assessment Of The Current LEO Debris Environment And The Need For Active Debris Removal". Ntrs.Nasa.Gov. https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20100017146.pdf.

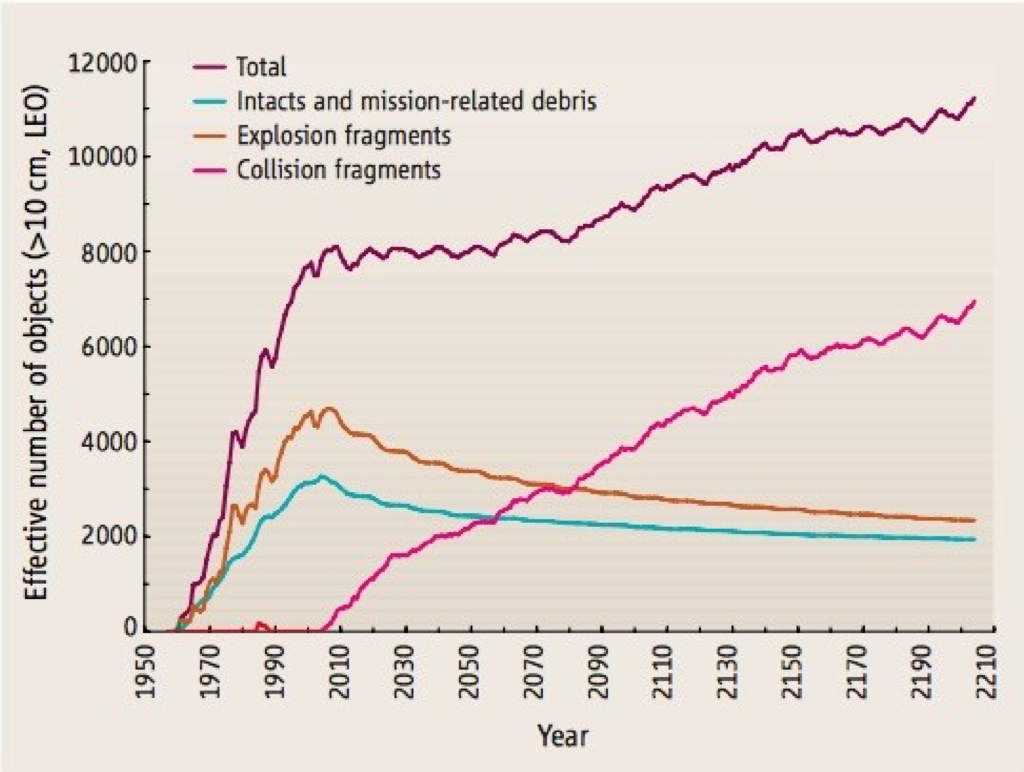

Figure 2 Source: Liou, J.-C., and N.L Johnson. 2006. "PLANETARY SCIENCE: Risks In Space From Orbiting Debris". Science 311 (5759): 340-341. doi:10.1126/science.1121337.

It has been argued that Kessler Syndrome has already begun and that immediate action is required. However, if we focus on the forecasts completed by Liou and Johnson, we can see that in the very near future governments and international organisations are going to see 'a runaway [of] growth in the number of collisions and debris in LEO. The increase in debris will cause space to become an even more dangerous environment and as the debris collisions increase the debris problem will come into direct conflict with national security strategies. Unfortunately, if the history of humanity is to be used as a guide for a response, it is likely that the cascade of debris through Kessler Syndrome will be at an advanced stage before a united international response is adopted. Furthermore, this highlights the need for action by all parties, public and private, on this threat.

Dr Bleddyn Bowen, whose work on space security and orbital debris has been used and analysed throughout this research piece, was able to give an interview on his thoughts regarding the widening of the space security agenda and it impactions for the debris crisis. Regarding Kessler Syndrome, Bowen believes that without the 2007 failed Chinese ASAT test and the 2009 Iridium-Kosmos collision both occurring in quick succession, the topic of orbital debris would not be being discussed as it is today without them. These two major debris creation events crystallised a lot of attention and activity into the development of space policy and related security issues. Bowen compares the orbital debris problem to climate change, which Bowen argues will be a massive issue in the generations to come. Whereas orbital debris is a problem for this generation to solve, yet governments, historically, do not tend to act until a problem has grown big enough in size to force them to act.[64]

One company that has seen the dangers of Kessler Syndrome and decided to act is Astroscale. The company is currently developing technology that can remove defunct spacecraft from orbit before they have a chance to cause a collision. This private company has seen a gap in a market that will allow them to create a solid business model, generate profit all while cleaning Earths orbits of human-made debris.

[64] Bowen, Bleddyn. Interview by Author. Tape Recording via Skype. United Kingdom. May 25th 2018

When Astroscale began, it faced three significant challenges. Firstly, the technological difficulties in tackling the debris problem are vast. The complexities of developing a satellite that can track, intercept and remove debris from orbit cannot be underestimated. Following this, policy issues remain a problem when dealing with space debris. It has been highlighted through the interview that not one single country is to blame for the increasing amount of orbital debris cascading out of control around our planet. It is true that the clear majority has been created by the United States, Russia and China. However, Yuske makes the valid point that the whole population has benefitted from launches made by these countries, for example, telecommunication and global navigation. Consequently, the response needs to come from several areas and not merely from these larger space fairing nations. The final challenge was the business model. Governments are apprehensive about dealing with space debris as it currently requires a significant amount of economic expense. Nonetheless, Astroscale has created a business model that encompasses future debris creation. With the increase in reliance on satellites, companies are looking towards ‘mega-constellations' as the answer. These groups of satellites are planned to number in the hundreds and even thousands, leaving them extremely vulnerable to possible collisions and subsequently, large debris creation events. The danger of a collision with a mega-constellation is that it would speed up the cascade effect, known as Kessler Syndrome, and leave many orbits inacceptable for generations. What makes this apparent noble quest profitable is that between 5-10% of satellites that are sent into orbit become defunct before their EOL. With an increase in launches in the future and with it an increase in satellites around Earth, Astroscale is in a prime location to reap the rewards the solutions to the space debris crisis has to offer.[65]

Astroscale has a close relationship with many space agencies around the world, such as NASA and ESA. These space agencies are also attempting to figure out the most effective and efficient way to remove debris from orbit. However, for national space agencies, the problem of historical debris provides the most considerable headache. The example given by Yuske was of the Envisat which was operated by ESA and launched in 2002 on a sun-synchronous polar orbit. However, 'the Envisat mission ended on 08 April 2012, following the unexpected loss of contact with the satellite.'[66] The Envisat remains one of the largest defunct Earth observations satellites in orbit. Since its unexpected EOL, ESA has been unable to work out any possible way to remove the Envisat from orbit. With a mass of over eight tones, it is an extremely hazardous piece of orbital debris. The potential of a vast debris event is growing, and Astroscale is one of the few companies that are actively attempting to limit the effects of Kessler Syndrome.[67]

The way in which Astroscale proposes to remove future debris from orbit is why using a special metal plate that would be attached to a client's satellite before launch.

[65] Taguchi, Yuske. Interview by Author. Tape Recording via Skype. United Kingdom and Japan. June 21st 2018

[66] "Envisat - Earth Online - ESA". 2018. Earth.Esa.Int. Accessed July 20. https://earth.esa.int/web/guest/missions/esa-operational-eo-missions/envisat.

[67] Taguchi, Yuske. Interview by Author. Tape Recording via Skype. United Kingdom and Japan. June 21st 2018

Following the EOL of the satellite Astroscale spacecraft will track the defunct debris and intercept. As the customers have installed the docking plate, it can identify and monitor the tumble of the debris that is so often erratic, and this limits the risk of collision and debris creations when the interception takes place. The chancer satellite that is operated by Astroscale is a reusable satellite that has a docking mechanism to retrieve debris and lower the defunct satellite into a lower orbit where it can quickly burn up in the atmosphere as it returns the Earth. This will be aided by future regulations on spacecraft that will limit the number of heat-resistant materials used that have the potential to survive re-entry and strike Earth. A more in-depth analysis of the future debris removal techniques is given later in this research piece.[68]

As stated above, Astroscale is a private company who is seeking to reduce future debris, and due to its methods of capture in orbit, it cannot remove historic debris due to it not having a docking plate. There is also no financial gain that has been found as of yet form the removal of historic debris. This leaves it firmly in the hands of the national space agency who are funded through taxes. This does not mean that companies, such as Astroscale, cannot aid the development with national space agencies and other companies by sharing technology to speed up developments in debris removal and other mitigation measures. The primary focus for dealing with historic debris is currently the advancement of ADR technology and dual-use satellites. However, as examined throughout this research piece, this method has presently

[68] Taguchi, Yuske. Interview by Author. Tape Recording via Skype. United Kingdom and Japan. June 21st 2018

some political and legal issue to overcome before it can be embarrassed by any space agency or company.[69]

One of the central ideas throughout this research piece has been a focus on theory and with it, space policy through the space security agenda. The debates behind what orbital debris classification should orbital debris be given in the realm of security studies have been analysed thoroughly throughout this piece. It is interesting to see what a private company believe orbital debris is, concerning security. For Astroscale, they know the debris problem as both an environmental issue and a security issue. As Yuske explains, for defence ministries the question of debris is a strategic threat that involves planning and monitoring. For companies like Astroscale who are not a security company, they must deal with debris from an environmental perspective. As the clear majority of the debris in orbit around Earth is human-made, it is the role of humans to deal with this issue.[70]

When the interview looked towards the future of outer space affairs, it was clear that Yuske believes that the future debris creation will be dominated by private companies, such as telecommunication networks, launching satellites into space. For Astroscale, this development of the market will lead to a continual replacement of defunct satellites that will need to be removed due to space restrictions. This is undoubtedly

[69] Taguchi, Yuske. Interview by Author. Tape Recording via Skype. United Kingdom and Japan. June 21st 2018

[70] Taguchi, Yuske. Interview by Author. Tape Recording via Skype. United Kingdom and Japan. June 21st 2018

a private sector development that will only involve national space agencies as clients or aids in technological advancements. The future of outer space affairs that deal with space debris will see a close relationship between private companies and international organisations, such as UNCOPUS and UNOOSA, as their input in future space policy and legal will be valued. One example of this possible progress can be seen through what Yuske describes as a 'rating system' for space launches and mission in the future. This system works by giving a space mission a score which decided by the EOL capabilities of the spacecraft, the use of a green propellant and amount of heat-resistant materials used. The rating given to mission must meet a threshold before the UN allows a launch to take place. Through advancements, such as this proposal, it is clear that Astroscale cares for the space environment and seeks to influence and guide the decision-making process in the future. Yuske finished the interview by comparing the space debris problem to the greenhouse effect on Earth and rising amount of CO_2. However, the big distinction between the two issues is that the creation of orbital debris has been done by human-kind and therefore it is up to humans alone to tackle and solve these problems.[71]

[71] Taguchi, Yuske. Interview by Author. Tape Recording via Skype. United Kingdom and Japan. June 21st 2018

4.3 Policy Issues

One of the complexities of the debris problem is that the number of possible collisions is directly correspondent to the number of launches. Unfortunately, the 'launch rate fluctuates from year to year and is extremely difficult to predict, because launches are dictated by political, economic, and technological considerations.'[72] However, an increase in launches is extremely likely due to the reliance of modern technological advances on satellites. Therefore, this trend would significantly increase the amount of debris across all orbits, especially LEO and Polar Orbits. Consequently, the likelihood of catastrophic collisions between larger spacecraft and satellites, such as mega constellations, resulting in larger fragments orbiting Earth and once again increase the chances of collisions with other debris or space objects. In summary, 'an increase in the on-orbit mass would exacerbate the feedback effect, and act as a reservoir for fuelling a collision cascading process.'[73]

Presently there is a gulf, by and large, between the science and policy communities. Bowen highlights that there is still a lot of political and strategic naivety amongst the science community. For some scientists working in this field, they still believe space is somewhere that science happens. They are not wrong to hold this view, as scientific advancements and experimentation are constantly conducted in space. However, for Bowen, the main reason why 'man' went into space was for the military advantage,

[72] Klinkrad, 2006. Space Debris - Models And Risk Analysis P.146

[73] Ibid P.145

and therefore the military industrial complex has poured so much money into rocket and satellite technology. The science, which is an extremely integral part of this process, developed out of the military strategy in space. Science has since been used to legitimise the processes of rocket development and the need for spy satellites.[74]

Currently, all major long-term projection models of the environment surrounding Earth have led to the same conclusions regarding the most efficient debris mitigation measures. These models have been developed with the inclusion of technical, economic and operational achievability when comparing them to the most effective way to improve environmental stability in orbit. The following points have been outlined by Heiner Klinkrad, who is the head of the European Space Agency's Space Debris Office, as the main categories that impact the orbital debris problem and best impact zones to focus attention on to limit future growth.

- ‘Reduction of mission-related objects
- Prevention of on-orbit explosions
- Prevention of non-explosive release events
- Collision avoidance between trackable objects

[74] Bowen, Bleddyn. Interview by Author. Tape Recording via Skype. United Kingdom. May 25th 2018

- Post-mission disposal of space systems
- Removal of passive on-orbit objects'[75]

The reduction of mission-related objects (MROs) is related to the increasing amount of debris that detaches in orbit following the successful launch of any spacecraft. Also, these mission-related objects refer to misplaced items such as work tools that drift away from astronauts when they are conducting maintenance or other tasks outside of their space station. It is estimated that MROs contribute to '10.5% of the trackable catalogue population, [with an estimated] 60% of these related to launch systems, and 40% related to payloads.'[76]

The prevention of on-orbit explosions is extremely important as the debris caused by a spacecraft being destroyed in this manner is very hard to track and spreads over a large section of the orbit. It is also possible that the debris moves into different orbits depending on the size of the explosion and size of the debris created. End-of-life (EOL) passivation became a requirement in the early 1980's, EOL would allow spent rocket stages and boosters to move into a graveyard orbit or lower themselves in an orbit that would speed up the time taken to burn up in Earth's atmosphere. The majority of all rocket stages sent into space before this became a requirement are still in orbit and pose a considerable risk to other spacecraft. Another danger became apparent in 1994

[75] Klinkrad, 2006. Space Debris - Models And Risk Analysis. P.165

[76] Ibid P.166

when ‘a Titan III-C, [which had been] launched in 1967 exploded after 27 years in orbit.'[77] It was estimated in 2004 than 50% of all rocket bodies launched before 1990 where still in orbit, ‘hence, there is a significant number of latent explosion sources still on orbit.'[78]

Non-explosive release events refer to the slag that is distributed as fuel is burnt during the launch of a rocket stage. During the launch slag is created that form into small fragments that and does not degrade quickly and can its diameter can be measured in centimetres. Therefore, as it remains in orbit, it travels at speeds more than 6km/s making them extremely dangerous to other spacecraft before they burn up in Earth's atmosphere.

Collision avoidance between trackable objects is continually being improved by technological advancements. This has become necessary due to the increase in orbital debris alongside the increase in satellite use. To operate an effective collision avoidance program, both spacecraft must have reserve fuel to consider for possible avoidance measures. Unfortunately, much of the defunct debris that has been launch before the turn of the century did not have any reserve fuel. Therefore, when its operational life ended it could not move out of the way of other spacecraft.

Post-mission disposal of space systems is the most effective way of dealing with the debris environment as disposal of systems following their end of mission life will

[77] Ibid P.168

[78] Ibid P.168

reduce the mass of debris in all orbits, especially LEO as it is the most congested. The main difficulty of post-mission disposal is that orbits at LEO are influenced by several factors, including 'non-spherical geopotential, by luni-solar attraction, by solar radiation pressure, and by aerodynamic forces. Of these, only air drag, acting opposite to the direction of motion, is a non-conservative, energy dissipating perturbation.[79] Therefore, the purpose of an EOL manoeuvre is to 'lower the altitude and increase the air drag to the maximum possible extent for the given propulsion system, propellant efficiency, and fuel capacity.'[80]

Removal of passive on-orbit objects has often been linked with the use of ground or space-based lasers. The common thinking on this technique is to fire a laser at a piece of debris, which will heat up and destabilise the debris object until a plasma blowout occurs. The plasma blowout would act as propulsion for the debris and can be calculated to change the orbit of a piece of debris, so it returns to Earth much faster.

4.4 Legal Issues

Under current legal precedents, it appears that without any changes to the legally bindings treaties that 'individual countries will need to utilise technology currently developed to remove the largest and most dangerous space debris in low earth orbit on a one at a time basis.'[81] This is a consequence of the principle that only a launching

[79] Klinkrad, 2006. Space Debris - Models And Risk Analysis. P.170-171

[80] Ibid P.172

[81] Pelton, Joseph N. 2015. New Solutions For The Space Debris Problem. New York: Springer. P.36

state is able to remove its own defunct satellites from space. The only way in which another state could do this would be an act of war under current space law. International space law has a rather narrow focus, 'especially when it comes to the subject of space objects and space debris. The formal international space law that exists in this area was drafted over a relatively short period between 1963 and 1972 and as such does not [consider] much that has changed about outer space activities over the last four decades.'[82]

The first steps towards a Space Treaty were the Declaration of Legal Principles in 1963. 'This was followed with the 1967 Outer Space Treaty that evolved from the consensus discussions within the UN Committee on the Peaceful Uses of Outer Space (COPUOS).'[83] Regarding space debris, there is also 'the Inter-Agency Space Debris Coordination Committee (IADC) that has developed consensus guidelines to minimise the creation of additional space debris.'[84] IADC is a multi-agency committee and contains the major space-faring nations alongside other smaller space fairing nations as well as ESA.

ADR is one of the most promising ways in which to tackle the current debris problem as well as maintain the environment in the future. However, there are currently several issues that need to be addressed to enable ADR technology 'or for activities

[82] Ibid. P.70

[83] Ibid. P.71

[84] Ibid. P.71-72

that would impact the orbits of space objects in attempts to prevent orbital collisions or minimise the likelihood of such collisions.'[85]

Firstly, the international definition of space debris, orbital debris and space objects would need to be unanimously agreed upon, and codified into law through an amendment to a current space law treaty, such as OST, or the creation of a new treaty. The debate between what constitutes a ‘space object' and what is ‘space debris' goes back to the original space treaties. Article VIII of the Outer Space Treaty states that:

> *"A State Party to the Treaty on whose registry an object launched into outer space is carried shall retain jurisdiction and control over such object, and over any personnel thereof, while in outer space or on a celestial body".*[86]

The IADC has defined space debris as ‘all man-made objects including fragments and elements thereof, in Earth orbit or re-entering the atmosphere, that is non-functional.'[87] This definition was subsequently adopted by the UN COPUOS. However, the European Space Agency defines space debris as: ‘all non-functional, man-made objects, including fragments and elements thereof, in Earth orbit or re-entering into

[85] Ibid. P.69

[86] "The Outer Space Treaty". 2018. Unoosa.Org. Accessed July 3. http://www.unoosa.org/oosa/en/ourwork/spacelaw/treaties/introouterspacetreaty.html.

[87] "Inter-Agency Space Debris Coordination Committee (IADC): Documents". 2013. Iadc-Online.Org. https://www.iadc-online.org/index.cgi?item=docs_pub.

Earth atmosphere.'[88] There is no section in the '1963 Declaration of Legal Principles, the 1967 Outer Space Treaty, or the 1972 Liability Convention, however, [that explains] any distinction made between functional and non-functional space objects.'[89]

The definitions of space debris and a space object are essential when dealing with new technology as 'one of the reasons for a differentiation of a "space debris element" from a "space object" would be the presumed ability to transfer jurisdiction and control of a launched space object to another entity [for] removal'.[90] This would constitute of lowering the object's orbit to aid in the increase of orbital decay or possibly changing the orbital parameter to avoid a collision. It is incredibly important here to acknowledge the difference, especially in legal terms between 'jurisdiction' and 'control'. It is within the deeper meanings of these words that causes controversy and disagreement when developing any legal precedent for space.

The next issue is the liability; currently, it cannot be transferred between states. This poses issues as states have launching farcicalities are no longer the sole users as private companies have emerged, such as SpaceX, who is capable of building, launching and maintaining a presence in space. These new developments were not foreseen when the original space treaties where ratified, as space was believed to be

[88] "ESA Clean Space". 2013. ESA. http://www.esa.int/Our_Activities/Space_Engineering_Technology/Clean_Space/What_is_space_debris.

[89] Ibid. P.73-74

[90] Pelton, 2015. New Solutions For The Space Debris Problem. P.74

a military and scientific realm and would only be inhabited by state-owned and state built products.

Under existing space law there is currently no apparatus to facilitate the transfer of jurisdiction, control or liability of a space object. This is the case for both functional and non-functional spacecraft. It could, therefore, be 'argued that such a condition creates exactly the wrong incentives to address the orbital debris problem and reduce orbital debris congestion and thereby reduce the threat of orbital collisions that would create yet more orbital debris.'[91] As highlighted above, the dated treaties that have helped humanity govern space affairs for decades are now struggling to cope with the rate of technological advancements.

Thirdly, a clear and unambiguous update is required for the definition of fault. This would be required before any real progressive steps can be taken to deploy ADR technology in space.

The point is undoubtedly clear that there are many complicated and diverse challenges to be over when finding 'cost-effective, safe, and technically efficient ways to remove space debris from orbit or even to find effective ways to manoeuvre spacecraft to avoid collisions. But, there are likewise [many] problems and challenges to establishing space law and regulations that allow the cleaning up of space to

[91] Ibid P.74

proceed in an efficient manner without creating political, strategic, or liability claim problems as the removal of space junk take place.'[92]

Bowen highlights in an interview that there is a disconnect in terms of politics and morality of space security. The practitioners who deal with space security every day and the scientists who are called in as experts on space are both leaders in their respective fields but rarely combine effectively. For example, scientists who are brought in by governments and space agencies due to their expertise in rocket design, are unlikely to know the complexities of nuclear strategy and arms control. This can be seen on the international stage as China and Russia proposed an amendment to space law that bans space weapons. This, in the eyes of Bowen, is an entirely illiterate piece of space law as taken at face value it seems to be an important improvement. However, it fails to address Earth-based ASATs which, as highlighted throughout this paper, China used in 2007 and caused one of the largest debris creation events. Russia too has comprehensive ASAT weapons, it not merely the Chinese, many states have this capability. It is argued by Bowen that the international community is running scared of space weapons and many international bodies that monitor and govern space believe that should these weapons be placed in space that it will lead to a space conflict. When in fact the damage can already be done from Earth. Bowen brings a summary of this point by emphasising that there are disconnects between policy and science for two main reasons. Firstly, the naivety of the science community to ignore the importance of policy and space security. Secondly, because there are few security

[92] Pelton, 2015. New Solutions For The Space Debris Problem. P.72-73

experts and civil servants that know about space security and space governance. He criticised the United Kingdom in this regard as currently, they have almost no public servants that have or have had any focus on space affairs.[93]

4.5 Confidence Building Measures

One of the significant diplomatic tools that govern all areas of security when dealing with inter-state problems is confidence building measures (CBMs). In recent time this notion has developed into Transparency and Confidence Building Measures (TCBMs). These measures were used extensively between the Soviet Union and the United States during the Cold War, along with their allies. Therefore, as Space Treaties where developed during this time, provisions were made for their use on the decisions of major declarations. The definition of 'transparency' when dealing with issues of security and CBMs is often subjected to critique. However, for the purposes of this research piece, the definition offered by Carolyn Ball will be used. Ball defines transparency as 'the degree of openness in conveying information and a device of strategic negotiations signalling the trustworthiness of the actor in negotiations.'[94]

Confidence building measures do not refer to one singular act; there are many different types, Dr Jana Robinson recognises: 'informational measures; consultative modalities; notification requirements; constraint mechanisms; and access

[93] Bowen, Bleddyn. Interview by Author. Tape Recording via Skype. United Kingdom. May 25th 2018

[94] Ball, Carolyn. 2009. "What Is Transparency?". *Public Integrity* 11 (4): 297

measures.'[95] Many of these CBMs are self-explanatory, but others require a short definition of what they entail. Informational measures 'involve making public … information about a governments national security policies, military capabilities, arms imports and exports [and] defence budget.'[96] Consultative modalities encourage discussion and dialogue between two nations to reduce tensions. The notification requirements are normally used to notify other states about upcoming military exercises in a region and this links with constraint mechanisms which limit certain activity, such as military personnel being present in de-militarised zones. Finally, access measures 'allow states to monitor each other's actions as well as to verify compliance with constraint-oriented CBMs'.[97]

Since the end of the Cold War, ICBMs came under scrutiny as without the high levels of a nuclear apocalypse the concessions being made by states in return for perceived gains became unpopular on the worlds diplomatic stage. However, when dealing with space security, as outlined throughout this piece, the policy and legal issues surrounding the creation of new legally binding treaties has led to a unique set of circumstances. Consequently, there has been an increase in the willingness 'to forge achievable and pragmatic TCBMs'.[98]

[95] Robinson, Jana. 2016. "Transparency And Confidence-Building Measures For Space Security". *Space Policy* 37: 134

[96] Ibid 135

[97] Ibid: 135

[98] Ibid 135

As space is becoming an environment that is seeing an increase in traffic, and this trend only projected to increase in coming years, issues such as space debris will continue to plague space affairs. The dynamic threats that the space environment poses to spacecraft will demand policy responses and the 'political will to make tough decisions, both at multilateral and national levels.'[99] One example of Space TCBMs in action came in February 2009, when the Russian Kosmos and the United States Iridium satellites collided. Immediately, Russia and the United States maintained contact to establish what had occurred and shared information that could allow each side to discount that this event was a calculated and planned attack, thus reducing tension. Following the immediate action and tracking of the debris, 'four months after the collision, experts from both countries met in Vienna to discuss the incident and identify opportunities for bilateral space TCBMs.'[100] These develop between old enemies can be used as evidence for the promotion of TCBMs, another example can highlight the need for TCBMs in space as it undoubtedly influenced the reaction of Russia and the United States in 2009. In 2007, following China's failed ASAT test and following lack of transparency led to alarm around the world. Europe took a stand against this and a 'document entitled "Food for Thought on a Possible Comprehensive Code of Conduct for Space Objects" was introduced by Italy in the Conference on Disarmament in March 2007'.[101]

[99] Ibid 134

[100] Robinson, 2016. "Transparency And Confidence-Building Measures For Space Security". 140

[101] Ibid 141

For Robinson, TCBMs for space are here to stay and will only increase in the future if the unwillingness to sign legally binding treaties remains. TCBMs are not a perfect solution, but they are currently the only viable option to influence the rules that govern space. Therefore, Robinson includes in her articles some recommendations that may improve TCBMs in the future. Firstly, an increase in awareness for all space security concerns would see quicker and more practical solutions to space debris through the increased knowledge of policymakers. Following this, building TCBMs with like-minded partners, this would allow countries to focus on issues that they see as the more substantial threats. For example, some space fairing nations may wish to focus on banning weapons from space while others wish to reduce the amount of collision avoidance measures taken by satellites. Also, Robinson would like to see an increase in information exchange and sharing regarding debris tracking. However, as highlighted in this piece, the likelihood of countries sharing more information is limited.

5 Current Issues

The orbital debris issue is not new, and it has always been prevalent and almost certainly would have been foreseen by many space agencies at the beginning of the space age. It is approximated that over '17,000 human-made objects have re-entered Earth's atmosphere since 1957, and many incinerated during the passage. However, a proportion [have] managed to survive re-entry, making landfall across the globe.'[102]

[102] Powell, 2017. Cosmic Debris. P.152

Debris making landfall is only one of many dangers that out of control debris poses, all of which will be explored further and in more detail throughout this piece. During the 1990's it was known that ‘only one in 10 satellites [would still be] operational by the end of 1990, [and become] a mounting problem that would only escalate in time.'[103]

The problem of ‘space junk' is not a new one, with every launch into space debris has been created. However, it was not until the 1980's that space agencies and governments actively worked to reduce the amount of debris created with each launch. Nonetheless, all the efforts to reduce the debris, especially in LEO, was undone by two major debris creation events. These events are the 2007 failed Chinese Anti-Satellite Weapon (ASAT) test and 2009 Iridium-Cosmos collision.

The first large orbital debris creation events occurred on January 11th, 2007, ‘this event was the intentional launch of a Chinese missile to destroy an obsolete polar-orbiting Chinese weather satellite, the Fen Yun 1C. A missile using an ASAT system was launched from near China's Xichang Space Centre.'[104] The ASAT destroyed the satellite but failed to expel the debris out of Earth's orbit; thus it created an estimated 3,000 pieces of trackable debris. The event also occurred at an altitude where the debris will remain in orbit around Earth for hundreds, and in some cases, thousands of years.

Following this event, on February 10th, 2009, the American ‘Iridium 33 mobile communications spacecraft and the Russian Kosmos 2251 defunct weather satellite

[103] Powell, 2017. Cosmic Debris. P.152

[104] Pelton,. 2015. New Solutions For The Space Debris Problem. p.3

collided at an altitude of 789 km.'[105] Similar to the 2007 creation event this 'collision occurred at a sufficiently high velocity to create nearly 3,000 new debris elements in low earth orbit. Thus, [because of] the Chinese anti-satellite missile firing and the Kosmos-Iridium collision, the amount of tracked debris elements increased by almost 30%.'[106] It is important to stress that although some debris is defined as 'trackable', it is not always 'predictable'. For example, following the failed Chinese ASAT test in 2007, much of the debris that was created and more substantial enough to be tracked was not in a specific orbit. The force that created the debris had blown the debris through several different orbits, and it wasn't for some time that predictions could be made regarding their continued orbit around Earth. It is in these situations where it becomes incredibly complex for space agencies around the world to issue emergency warnings to spacecraft that may be on a collision course without of control debris.

5.1 Outer Space Treaties

Outer space is not without governance, and there are many internationally ratified treaties that oversee and manage outer space affairs. In total, there are five treaties, and they deal with a variety of issues that will be explained below. It is also the purpose of these treaties to stress 'the notion that outer space, the activities carried

[105] Ibid.P3

[106] Pelton, 2015. New Solutions For The Space Debris Problem..P.4

out in outer space and whatever benefits might be accrued from outer space should be devoted to enhancing the well-being of all countries and humankind'.[107]

The first legally binding treaty was the 'Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies', this treaty is commonly known as the 'Outer Space Treaty' or 'OST'. The Outer Space Treaty came into force in October 1967 after it was signed by three depository countries, these being the USSR, USA and UK. This treaty set the precedent for how the modern world interacts with outer space. The treaty states that all states are free to explore space and no nuclear weapons of weapons of mass destruction can be placed in space. OST also does not allow for 'national appropriation by claim of sovereignty, by means of use or occupation, or by any other means'.[108] The treaty additionally places states in a place of responsibility for their space activities even if it is carried out by a non-governmental organisation, ultimately making a state liable for any damage or infringement of outer space law. This will be discussed further within this piece as it poses many questions for the future of space tourism and private companies such as SpaceX launching spacecraft. Also noted is that the shortcomings of the OST became apparently immediately and it seemed to contradict itself. 'Article one emphasises the right of the free use of space for peaceful purposes, the treaty's

[107] "Space Law Treaties And Principles". 2018. Unoosa.Org. Accessed July 3. http://www.unoosa.org/oosa/en/ourwork/spacelaw/treaties.html.

[108] "The Outer Space Treaty". 2018. Unoosa.Org. Accessed July 3. http://www.unoosa.org/oosa/en/ourwork/spacelaw/treaties/introouterspacetreaty.html.

preamble commits signatories to promote the “common interest of all mankind” and “friendly relations”’.[109]

In December 1968, the second space treaty came into force. The ‘Agreement on the Rescue of Astronauts, the Return of Astronauts and the Return of Objects Launched into Outer Space' is commonly known as ‘The Rescue Agreement'. The reason for this treaty to be signed was due to the Cold War politics that dominated the globe. It was also likely that when astronauts and spacecraft re-entered Earth's atmosphere that they would land in territory belonging to a state that was not the launching state. This would give rise to further tensions between nuclear superpowers which needed to be avoided at all costs, and as this agreement benefitted all sides, it was quickly ratified. The third treaty governing space was not signed until 1972 and became binding in September of the same year. The ‘Convention on International Liability for Damage Caused by Space Objects' or the Liability Convention codified that ‘a launching State shall be absolutely liable to pay compensation for damage caused by its space objects on the surface of the Earth or to aircraft, and liable for damage due to its faults in space.'[110]

[109] Robinson, Jana. 2016. "Transparency And Confidence-Building Measures For Space Security". *Space Policy* 37: 140

[110] "Liability Convention". 2018. Unoosa.Org. Accessed July 3. http://www.unoosa.org/oosa/en/ourwork/spacelaw/treaties/introliability-convention.html.

The penultimate legally binding treaty to be adopted was in 1976 with the Convention on Registration of Objects Launched into Outer Space, commonly referred to as the Registration Convention. The 'Registration Convention expanded the scope of the United Nations Register of Objects Launched into Outer Space and addressed issues relating to States Parties responsibilities concerning their space objects.'[111] This built upon other sections of previous treaties and clarified more ambiguous sections surrounding the cataloguing of all spacecraft that was being launched into space.

The final Treaty did not come into force until 1984, despite being in UN Legal Subcommittee since 1972 and being adopted by the UN General Assembly in 1979. The 'Agreement Governing the Activities of States on the Moon and Other Celestial Bodies' or simply 'The Moon Agreement', elaborated on the OST when referencing celestial bodies and the Moon and emphasised that these areas could only be used for peaceful purposes. Alongside these elaborations, this agreement states 'that the Moon and its natural resources are the common heritage of mankind and that an international regime should be established to govern the exploitation of such resources when such exploitation is about to become feasible.'[112] This brings with it many questions about what the future holds for humanity's utilisation of space in the future, especially regarding space mining.

[111] "Registration Convention". 2018. Unoosa.Org. Accessed July 3. http://www.unoosa.org/oosa/en/ourwork/spacelaw/treaties/introregistration-convention.html.

[112] "Moon Agreement". 2018. Unoosa.Org. Accessed July 3. http://www.unoosa.org/oosa/en/ourwork/spacelaw/treaties/intromoon-agreement.html.

There is a global consensus that the current policy for dealing with current and future space security challenges are insufficient. However, no agreement can be reached on what the best way to move forward is. Many space 'superpowers', such as the United States and Russia, are more concerned about the possibility of space weapons. However, many smaller space-faring nations demand action on orbital debris 'due to its indiscriminate nature and immediacy of the threat.'[113] This is not to say that there is not 'widespread international concern with the sustainability of space activities', as Active Debris Removal Systems (ADR) are becoming ever more commonplace in research and testing departments of many space agencies.[114] However, as stated above, the focus remains on space weapons as the hard hitters of space exploration fight for influence over amendments of current treaties. Notably, the United States has in recent years called the 'Treaty on the Prevention of the Placement of Weapons in Outer Space, the Threat or Use of Force Against Outer Space Objects' (PPWT) fundamentally flawed, especially after Russia and China proposed a revised version of their draft. This was because there was, among other things, no 'agreed-upon definition of what constitutes a space weapon.'[115] The revised draft also did not deal with regulations regarding ground-based space weapons, such as anti-satellite weapons (ASATs), which was particularly concerning for many who would be bound by this treaty, following the Chinese ASAT disaster of 2007.

[113] Jaramillo, Cesar. 2015. "The Multifaceted Nature Of Space Security Challenges". Space Policy 33: 63-66. doi:10.1016/j.spacepol.2015.02.007.

[114] Pace, Scott. 2015. "Security In Space". Space Policy 33: 51-55. doi:10.1016/j.spacepol.2015.02.004.

[115] Ibid

5.2 Growth of Debris

The growth of orbital debris is often mentioned; therefore, it must be addressed how this occurs. 'The increment in the amount of debris is affected by the elimination rate as well as the creation rate.'[116] As can be seen in Figure 3 the increase was slowly climbing until the beginning of the 1990's. At this point, the levels of growth slowed as space agencies developed technologies that limited the amount of debris created per launch. It must be highlighted that 'orbital debris is not evenly distributed around Earth's orbit. There are bands where this orbital debris [is] currently concentrated. The worst congestion is in the LEO region and particularly the Sun-synchronous polar orbits.'[117]

However, in 2007 and 2009 respectively there is a clear and highly irregular jump. This data highlights the impact of the failed Chinese ASAT test in 2007 and the first major orbital collision in 2009 between the Russian Cosmos 2251 and the US Iridium 33. Since those events, the largest increase has come in the form of payload fragmentation debris, which is usually un-trackable due to its size. Therefore, the fragments are more likely to have further impacts and create more debris. It is possible that it is this increase in fragmentation debris that has caused the increase in 'unknown' debris as small collisions are becoming more commonplace, especially in LEO. It is this 'cascade effect [that is now] the largest source of new debris elements

[116] Chen, 2011. "The Space Debris Problem". 540

[117] Pelton, 2013. Space Debris And Other Threats From Outer Space.P.19

as the number of micro-debris elements that are less than 1 mm in size has climbed into the millions.'[118]

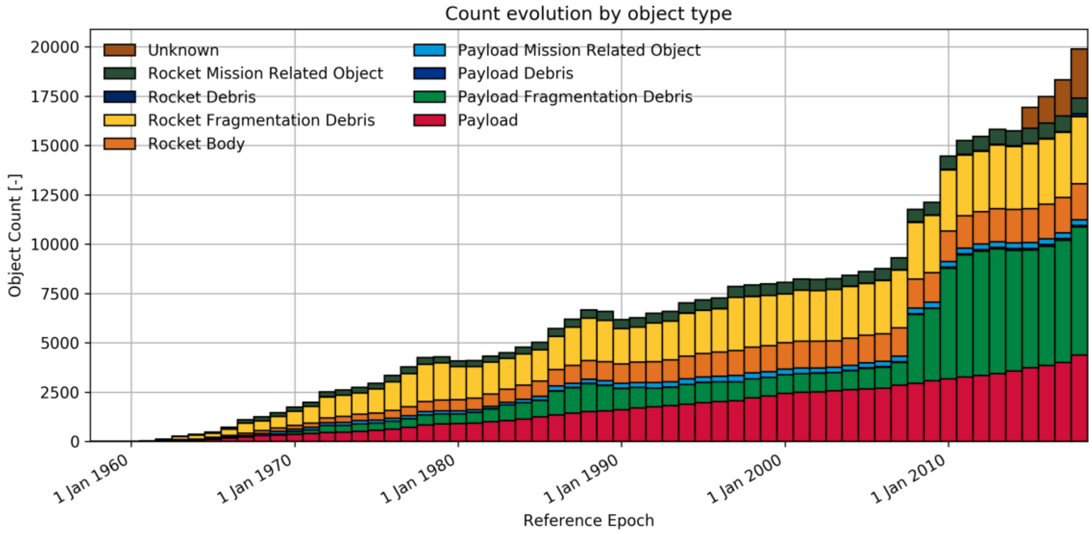

Figure 3 Source: About Space Debris. 2018. European Space Agency. https://www.esa.int/Our_Activities/Operations/Space_Debris/About_space_debris.

Another factor in the increase of orbital debris is the lifetime of the debris itself. Space agencies can calculate how long a particular object, for example, a spent rocket stage, will remain in orbit before burning up in the atmosphere. An orbital lifetime is primarily dependant on atmospheric drag, which is subject to change as it is dependent on solar activity. The surface area-to-mass ratio and the density of the atmosphere at an altitude also must be considered as they can increase or decrease the orbital lifespan of debris. 'The atmospheric density at a given altitude depends on the solar cycle; at times of high solar activity, the atmosphere becomes compressed, and there is less drag at higher altitudes.'[119] It is this fluctuating atmospheric drag and

[118] Ibid.P.19

[119] Chen,. 2011. "The Space Debris Problem". 547

solar activity that prevents space agencies relying on a rule that would see larger fragments stay in orbit longer than smaller parts. These calculations are particularly important when estimating the relative speeds and sizes of fragments that have been created via collisions. The smaller, and harder to track, fragments are more likely to have a higher relative speed following the impact than larger fragments of debris. This, in turn, can lead to small fragments moving into 'orbits with higher apogees, and thus they will have an even longer lifetime than larger debris.'[120] Ultimately, without intervention to remove debris from orbit, the cascade effect of Kessler Syndrome will take over and make it impossible for launches into space to take place due to the extreme risk of collision.

When dealing with the categorisation issues of space debris, into either security or environmental groupings, Bowen believes that it should be dealt with an environmental issue. By doing so, it allows room for the engagement of the commercial sector by acknowledging that it is profitable and therefore in the interests of commercial and private actors to be involved. However, it is important to note that Bowen insists that if a person is working for a state's defence ministry, they must ignore the issue of debris and its potential impact. From this, it can be deduced that Bowen believes that although orbital debris remains a security issue in practice, it should not be discussed as such. The reasoning for this view for Bowen is that when defining orbital debris as a security issue, it means that a person or persons threatens others or their property and this description doesn't fit perfectly with the threat posed

[120] Ibid, 550

by orbital debris. Nonetheless, debris does still pose a potential impact on people and property and therefore defining it as a security issue cannot be discounted altogether.[121]

When asked if space debris could be a hybrid security and environmental issue, Bowen issues a warning of the dangers this could create, especially from the United States. The problem with the hybrid idea is that as soon as the United States Department of Defence is involved there are bureaucratic effects that would see the Americans, and other governments around the world, clamp down on anything that requires the sharing of data and information.[122]

It is the belief of Bowen that space debris is being taken more seriously by governments and space agencies than ever before, despite their lack of expertise. Over the last few years, there has been a rise in mass media surrounding the space environment and has highlighted the damaging impact space flight has had around our planet. However, action taken on this issue remains small, but awareness by a more extensive section of the general population has undoubtedly increased. One of the primary issues is that international policy decision takes a long time to trash out and agree on. It is therefore vital that the increased global awareness that is developing around space debris is not lost. It must be used to influence the political and scientific communities that so often struggle to communicate on shared issues. A greater awareness of space debris will allow for more informed policymakers in office

[121] Bowen, Bleddyn. Interview by Author. Tape Recording via Skype. United Kingdom. May 25th 2018

[122] Bowen, Bleddyn. Interview by Author. Tape Recording via Skype. United Kingdom. May 25th 2018

around the world and in international organisations, which will increase the likelihood of action being taken to solve problems such as the cascading impact of space debris. One huge benefit of the growth in knowledge by non-experts in this field is that potential for investors and decision makers to financially support advancements in this field as they have a higher initial understanding of the issues being presented to them.[123]

6 Future Trajectories

It is possible in the future that 'INREMSAT-subscribing governments would be asked to sign a legal instrument to procure INREMSAT's services for the removal of several existing "big" space debris (dead satellites, last stage rockets, rocket fairings used to shield satellites during launch, etc.) from Earth orbit.'[124] This would be under an agreement between the two principal international organisations on orbital debris, IADC and UN COPUOS. However, as discussed in the legal issues section, a legally binding treaty is extremely unlikely to occur within the next decade. Nonetheless, a standard set of goals and norms that have been agreed is possible with the implementation of confidence-building measures, alongside the technological advances that reduce the amount of debris created per orbit.

[123] Bowen, Bleddyn. Interview by Author. Tape Recording via Skype. United Kingdom. May 25th 2018

[124] Pelton, 2013. Space Debris And Other Threats From Outer Space. P.30

6.1 Debris Removal

Debris removal is a complicated and high-risk development, even when considering modern technology. To remove debris, there are countless theories about the most effective way that have been developed by many different space agencies and private companies around the world. Naturally, there is no one single way to solve the problem as this piece is being written, yet this should not take away from the importance and urgency of the issue at hand.

One of the most logical disposal modes is to fit spacecraft and satellites with extra fuel and small jets that could fire following the end of the crafts functional life. A 'satellite in LEO will de-orbit and burn up on its descent or splash down into the ocean. [However], for geosynchronous satellites the disposal method is to push the spacecraft to a graveyard orbit that is higher than the geo orbit. When [the defunct object is] positioned there, these [space objects] can stay in super-synchronous orbit for millions of years.'[125] Thus, allowing for more time for a more permanent solution, as apparently, this is not a complete one for higher altitude orbits.

As outlined above, the use of extra fuel is indeed a possibility. Nevertheless, it would require a larger initial payload of fuel to transport the satellite into orbit and make the satellite larger, again increasing weight and therefore fuel needed to carry the satellite into orbit. This solution is also extremely difficult for MEOs as this orbit poses the most

[125] Ibid P.20

significant challenge when considering the disposal of satellites through an EOL manoeuvre. This is because ‘only a small amount of increment fuel is required to de-orbit an LEO satellite or to push a GEO satellite into a higher graveyard orbit. The disposal of MEO satellites is a problem in that a 40 % greater amount of fuel—beyond that used for orbital positioning—is needed to de-orbit a spacecraft launched into this orbit.'[126] This is just not practical for objects in MEOs as the extra weight and amount of fuel is not cost effective and consequently not a possibility for any private company or government agency.

As touched upon when discussing legal issues around the debris problem, ‘removal of debris through known techniques today is expensive, difficult, and complicated by legal liability provisions of the "Liability Treaty".'[127] Nonetheless, this piece has highlighted some of the most likely techniques that will be used in the future through different combinations when considering the size, weight and orbit of the debris that needs to be removed.

When discussing future treaty developments, in relation to orbital debris, Bowen expressed the opinion that a legally binding treaty or form of governance could be possible. However, as explained elsewhere in this research paper the legal and political issues that are involved in such a task are great. For Bowen, the primary concern to avoid would be keeping the technology that is capable of debris removal, such as ADR, out of a space weapons debate. One way of limiting debris that could be

[126] Ibid P.20

[127] Ibid P.24

internationally agreed could be inspections before launches. This wouldn't be required for every launch for a limited number a year and be run by a cross-country group of experts on behalf of the UN. This could involve confidence-building measures between states that would have the potential to increase technological sharing, such as the advanced debris tracking that is currently only operated by the United States. It is unlikely that the United States would share such a technology, but over time it would remain a possibility. One issue with this are finances, should an inspection need to take place the costs would be incurred by the space industry who already must deal with massive costs to just design, build and deploy their assets. However, in the future, as the space debris fields expand and cause disruption of space traffic, Bowen believes that enough political will, through confidence-building measures, will allow for an international agreement curtailing debris production and possibly removing it.[128]

6.2 Removal Techniques

Electro Dynamic Debris Elimination

This approach is 'likely require a new convention to allow a commercial entity to remove space objects of other launching nations from orbit. The system would need to be designed and operated on an international basis in such a manner that it would not be considered a space weapon.'[129] This brings with it legal issues as well as political

[128] Bowen, Bleddyn. Interview by Author. Tape Recording via Skype. United Kingdom. May 25th 2018

[129] Pelton, 2013. Space Debris And Other Threats From Outer Space. P.36

one. However, electrodynamic debris elimination is 'appealing in that it uses Earth's magnetic field for propulsion and thus can operate cost efficiently and over an extended period.'[130]

Tether-Based De-Orbit Systems Using Electro Dynamic Techniques

This tether based design also uses robotics that is currently under development and would not be ready for any testing in space for someone. The current idea and design would allow for a 'robotic device [that] would attach a tether to a derelict satellite or debris element. The tether's movement through Earth's magnetic field could potentially power an ion electronic thrust system to aid de-orbit.'[131] To aid this, the disproportionateness of the tether would create instability on the debris to help aid de-orbit as it slows its orbital speed.

Ground-Based Laser

A ground based-laser system is one of the most controversial of all debris mitigation measures, and it also remains one of the most 'sci-fi' solutions. It would work primarily on small debris elements but could also function to speed up the decay of larger objects. However, this would increase costs. The 'small debris elements would be moved rather quickly to a new orbit that would decay due to the pull of gravity. In the case of larger derelict satellites, however, it would take a continuing array of pulses to

[130] Ibid P.35

[131] Pelton, 2013. Space Debris And Other Threats From Outer Space. P.36

push a large mass into a new orbit that would accomplish de-orbiting.'[132] The controversy of this type of debris removal stems from Article 4 of the OST as a 'number of countries have strongly objected to such use of ground-based lasers as an anti-satellite weapon'.[133]

Solar Sails Devices

This technique does not raise any specific space weapons concerns, at the time of writing. However, it is possible if changes are made to differing designs in the future. Nonetheless, it has already been proposed that global organisation be in control with this system and not a single space agency, which raises doubt over the feasibility of such a system when considering the political and legal implications. The 'solar sail arrays would be designed to attach themselves robotically to large debris object, and over time this would facilitate the active de-orbit of the derelict satellite. This would work only on LEO debris and would not assist with MEO and GEO debris.'[134] The use of this system would rely on atmospheric drag, which is limited at higher altitudes.

Tether-Deployed Nets

Similar to the above solar sails technique, in respect to the limited space weapon threat, is tether-deployed nets. The risk of this system is the possibility of creating new

[132] Ibid P.37

[133] Ibid P.37

[134] Ibid. P.38

debris with a failed attachment. 'This system would deploy "nets" around smaller elements of space debris and speed up their de-orbit' through the increased mass of the debris.[135]

Space Mist

Space mist is a possible future technique that has been subject to limited testing and no space-based testing. However, it would be deployed using satellites 'in LEO that could spray gas mists [around the debris], and the frozen gas mist would serve to bring down small orbital debris elements' as it freezes onto the debris and increases mass.[136] The frozen mist would then burn up easily in Earth's atmosphere. The main issue that has arrived in Earth-based testing has been the limited and mixed results when the gas has not been able to be fully projected onto the target. The consequence of this has been that it is likely that gas would dissipate into the vacuum of space.

Robotic Systems

The use of robotic systems is one of the most expensive to develop and maintain when tackling the orbital debris problem. With limited testing on Earth, concerns have already been raised by states and international organisations about the possibility that robotics could constitute a space weapon. Also, 'there [has been] concerns as to how

[135] Ibid P.38

[136] Ibid P.39

such a system might be operated and who would control it.'[137] This technique would use robots to 'clamp on to space debris and then essentially throw the object into an orbit that would rapid degrade.'[138]

Adhesives

Finally, adhesives would use 'sticky adhesive balls composed of substances such as resins or aerogels would be "shot" on to large space debris to alter their orbits and to bring them down over time'.[139] Once again, space weapon fears are surrounding this technique and the need for an international group to operate such a system should it be deployed into space.

7 Discussion

Throughout this piece, it has been emphasised that 'the problem of space debris is clearly complicated by the lack of enforceable regulations, the lack of a revenue source to cope with the problem and lack of an entity that is globally accepted to impose sanctions, fees, or enforce other remedial actions.'[140] There is also much disagreement between academic factions on the best framework to adopt when

[137] Pelton, 2013. Space Debris And Other Threats From Outer Space. P.40

[138] Ibid P.39

[139] Ibid P.40

[140] Pelton, 2015. New Solutions For The Space Debris Problem..P.33

dealing with future space affairs, such as space debris while keeping outer space a demilitarised zone.

There is an inherent gap between science and policy when dealing with all space-based threats, especially space debris. Both views have overlooked a terribly essential and obvious route in which to increase the pace of humanity's actions regarding the debris threat. They have both failed to look at the history of human nature and therefore, 'the missing element in many of these discussions is how to create the economic wherewithal to address the debris problem and how to create financial incentives to correct the problem.'[141] This point of view also links with human behaviour that has been seen on Earth since humans evolved. Humanity is a destructive and polluting species and only since an enormous increase in population has steps been taken to limit this impact. It should not be any surprise that when the space race began it opened a new environment for humans to pollute and damage.

The current majority of debris has been collecting in space for decades and has been placed there by very few countries on Earth. However, it is not suggested that blame is assigned to the larger space fairing nations. The benefits that satellites have given all nations make everyone responsible for dealing with space junk. It is arguable that the most significant and most pressing matter in this topic area is 'what to do with historical debris?' Historic debris, dating back to the dawn of the space age must be dealt with by governments in one form or another. There are many options available

[141] Pelton, 2013. Space Debris And Other Threats From Outer Space. P.26

and that are being developed through modern technological advancements. Yet, without any current possibility of creating a viable business model out of removing old space debris, the private sector cannot and will not act. Up to now, governments and their space agencies have been slow to adopt space debris mitigation measures. They have used the continuing debate in the academic realm on the definitions of what space debris is and how it can be solved to slow progress further. This has been highlighted as private companies, such as Astroscale, are proving that the technology is well on the way to being ready to deal with future debris reduction through viable business models. In comparison with public sector advancements in historical debris removal measures, these two sectors are worlds apart.

Another possible solution for the debris problem is to make sure spacecraft, such as satellites, to have enough reserve fuel at the end of their lifespan to place themselves in a graveyard orbit or increase the rate in which they burn up in the atmosphere on their return to Earth. In principle, this solution has merit for the future. However, it fails to deal with the current problem properly. Thousands of defunct satellites and debris are currently in orbit with no fuel reserves and cannot be controlled from Earth. This solution also does not account for the possibility that a satellite may 'lose their ability to be commanded and thus be stranded in their orbits.'[142] Also, it only proposes a solution for the remaining section of a satellite or spacecraft 'elements of the launch such as the upper stage rocket, fairings that served to protect the satellite from the atmosphere during launch and other extraneous parts [will have been] launched and

[142] Pelton, 2013. Space Debris And Other Threats From Outer Space. P.20

stranded in orbit with no mechanism to de-orbit them except for gravitational pull and atmospheric drag.'[143]

Presently, the political and legal issues are a significant hindrance to the development of a collective space security agenda. Consequently, they inhibited an effective global response to the threats posed by orbital debris. It could be possible that with an international agreement, likely to be held in place by TCBMs, on space weapons could allow many debris mitigation policies and debris removal technologies to be tested in space sooner. However, for this agreement to be considered the United States and its European allies would seek clarification on the limitation of Earth-based space weapons. Consequently, China and Russia would be unwilling to participate and as two of the largest debris creators, this would allow for little change in the fight against the prevention or cessation of Kessler Syndrome. Perhaps the use of several different agreements that focus on separate areas of space security could be a solution. For example, agreements between states could focus on the reduction of MROs, and through several agreements, this could lead down a path towards a broader and more encompassing agreement. This would take time to develop, however, should the use of TCBMs be honoured it would help secure a more active dialogue to pursue space security resolutions.

[143] Ibid P.20

The influence of the IADC in matters related to space securities progress in dealing with orbital debris cannot be understated. The IADC is unrivalled in its dedication to dealing with and stopping Kessler Syndrome. With its international members, it can speak on behalf of several different nations with one voice on space debris. Therefore, the IADC will be needed in the development of TCBMs and future international space law to govern and ensure the security of spacecraft in the space environment. One area in which improvements are desperately needed are within organisations such as the IADC and ESAs Orbital Debris office is to encourage dialogue with policymakers and scientists. These two examples could provide a model for all space agencies in their incorporation of different experts. Although, as discussed earlier, the involvement of policy and science is not natural and it is possible that they would benefit from some theoretical input. This would limit the development of the policy of technological advancements that could not be put into practice. This would not seek to limit or constrain ideas for dealing with space security issues such as orbital debris, merely apply an amount of realism in the deployment capabilities that are available to aid in the prompt restoration of debris free orbital environment.

As noted earlier in this research piece, ‘framing a problem as a security issue usually means that a threat could escalate into an issue of survival'.[144] It was argued by Bowen that it might be difficult to escalate the potential threat of space debris to this level, especially when compared to nuclear war. The reasoning for this was that space debris is not capable of sudden loss, it is conversely stressed that a nuclear war could lead to

[144] Barry Buzan, Ole Waever, and Jaap de Wilde, Security: A New Framework for Analysis (London: Lynne Rienner, 1998), 5.

sudden loss of space assets that have been targeted. On the other hand, it could be argued that space debris can cause a sudden loss in a manner fitting that of nuclear war. A large and untracked piece of debris could easily cause a chain reaction in orbit around the earth by disrupting and destroying satellites. With many satellites limited in their adjustment by fuel reserves and the amount of space junk that exists, especially in LEO, it is possible that this cascade could strike so suddenly and with such speed that it leaves no time to move other satellites out of the debris field. It is also the case that nuclear-armed states rely on satellites for their nuclear capabilities and their launch procedures. With a cascading debris field orbiting the Earth, it would leave humans trapped on our planet with limited communication and major, irreparable damage to our modern way of life. The debris issue would not seem to be 'staggered and long-term' in that scenario.[145]

The space debris problem is extremely large and complex; however, it is put forward by Pelton that an economic fund that creates incentives for governments and private companies to reduce the debris in orbit is a possible step towards a solution. This economic fund comprises of five stages and contains incentives as well as penalties for participants.

Firstly, it is suggested that rewarding 'entities for a clean launch of the satellite and removal of upper stage rockets and protective fairing covers from orbit' would slow the build-up of large debris objects.[146] It is possible that through the use of small

[145] Bowen, 2014. "Cascading Crises: Orbital Debris And The Widening Of Space Security". 52

[146] Pelton, 2013. Space Debris And Other Threats From Outer Space. P.28

thrusters built into the rocket stages that contain a small supply of fuel that they could be moved into an orbit that would see them burn up in the atmosphere much quicker than if they remained in the orbit in which they find themselves with no reserve fuel.

Following this, Pelton seeks to 'reward operators for removing debris properly at the end of life'.[147] It can be deduced from this that a possible reward for removing debris out of orbit could be given out. However, this statement is extremely vague as it does not define what 'removing debris properly' would entail. It is likely that rewards would not be given for moving space junk into a graveyard orbit as this would still constitute space junk but this remains unclear.

A time restraint is developed for this economic fund, as the use of a '"sunset provision" [would] establish a specific goal to get the job done'. [148] This would eliminate claims for rewards by companies and space agencies even years after launch when debris naturally returned to Earth. This provision is detailed as having a twenty-year limit and therefore gives a clear deadline for successful missions.

The economic fund may develop from several different national funds and Pelton believes this 'would allow the competitive development of the best and most cost-efficient technology'.[149] Of all the sections of the economic fund, this might be the

[147] Ibid P.28

[148] Ibid P.28

[149] Ibid.P.28

most plausible. More cost-effective debris mitigation technology would reduce debris through its increased use.

The UNOOSA has been identified as taking the lead on this fund and therefore, there is ‘no need to "dismantle" an international agency at the end of the process.'[150] This is one of few advantages of this initial plan, yet due to the bureaucracy at the UN, this would take an extended period to organise and set up successfully.

Pelton briefly explains the details of this economic fund, and what level of rewards, incentives and penalties would be available, however, it is no explained if this fund would be mandatory. The United Nations Office for Outer Space Affairs is highlighted to take the lead in this fund, and as mentioned above, this would not need to be dismantled following the completion of its missions. This would be improbable as an increase in budgets for governments it's not desirable, and the United Nations would take an extended period to agree upon and set up such a system, that is if it was agreed by its member nations.

The economic fund itself, as mentioned above, may develop out of several different funds to create a global fund. It is suggested that the economic reward would be put aside before the launch and be approximately three to five per cent of the total operational cost. The immediate issue with this would be the increase in costs for launches which would, in turn, has the consequence of reducing the number of

[150] Ibid P.28

launches due to financial issues. This would undoubtedly reduce new debris in orbit but would stagnate technological development. Pelton has described this economic fund in a similar way as purchasing insurance. However, insurance is already purchased for launches as the massive amount of expensive to send a spacecraft into orbit has been protected for decades. Therefore, this model would still increase operational costs.

Nonetheless, it is perhaps a small glimmer into the possibilities of making the removal of space debris economically viable and rewarding. In can be compared to the increase in recycling in the Western world as public opinion changed and more was expected by governments to protect the environment. This allowed companies to begin recycling plants and be paid by governments and councils to take away recyclable waste. It was through the development of a business model as opposed to a dramatic shift in human behaviour that a more environmentally friendly position emerged. This initial plan for an economic fund may have some merit in theory, but it is in practice where it may fail. The main issue with such a fund is that it would take many years of negotiation to implement via the United Nations and during this time the debris crisis would be out of control, a quicker solution is required.

It has been put forward that should ten of the largest and most dangerous debris elements be removed annually ‘even if employing technology that removes only large defunct spacecraft at a time, that progress on the proliferation of space debris could at least be initiated'.[151] This is an extremely pivotal moment for space as the choices it makes regarding space debris will undoubtedly influence what the orbital environment becomes in future generations.

From a theoretical perspective, humanity has developed space security theory and space law from models based on Earth, such as Clausewitzian thinking around war and politics. However, it could be argued that space is such a different realm and environment that require its own set of theoretical governance systems and ideas. For Bowen, space law and space security theory must be based on current Earth-based ideas and norms. It is argued here that humans will always refer to something they already know when making future developments, analogical reasoning will always be prevalent in human development. The example given by Bowen is legal practices, when there is no legal code a lawyer will always go through precedent for their cases, in the practical legal sense that's what they do but in some more psychological and strategic sense humans always developed thinking out of what they already know. Of course, smaller aspects will always adapt and change, but that is in the details rather than the broader principles. Bowen develops this point by referring to some of his work in this area, lots of strategic concepts throughout his analysis are established out of the sea. The more significant principles and concepts of commanding the medium, exploiting its lines of communication, are like space as the strategic experience is the same, both environments cannot sustain human life, and that is the backbone of what defines them. Bowen claims that the sea and the air are as alien as space because

[151] Pelton, 2015. New Solutions For The Space Debris Problem..P.36-37

humans cannot live in either, these environments can only be used for transit. Should humanity be based in one of these realms, it requires a tremendous amount of supply and logistics to maintain a presence compared to living on land. Bowen acknowledges that smaller arguments could be made on land, for example, deserts do not generally allow life to flourish for humans, but in the broader context of his argument, the point still stands.[152]

Space is like the international seas, they are travelling through and are exploited by humanity, but they are not owned. However, items and objects that are sent to space and international seas have sovereignty on their platforms, and they are owned and operated by a company or state. Returning to the initial topic of discussion, Bowen discusses how creating a new space theory, not based on previously developed models on Earth would be difficult. Bowen believes that analogies are a useful crutch to lean on when something is new but the trouble but there are always going to be the critical difference between topic areas and that does not mean that conventional wisdom should be thrown out. The ultimate danger of ignoring previously proven frameworks is wasting time reinventing the wheel.[153]

When considering the most effective way to deal with space threats, such as space debris, Bowen highlights many different avenues that are potentially viable. The option of using the UN is generally used because it represents almost all states on Earth. However, as not all members of the UN are space fairing nations agreements

[152] Bowen, Bleddyn. Interview by Author. Tape Recording via Skype. United Kingdom. May 25th 2018

[153] Bowen, Bleddyn. Interview by Author. Tape Recording via Skype. United Kingdom. May 25th 2018

have sometimes been forged through other international bodies, such as IADC. Conversely, a more controversial idea put forward by Bowen is to create an agreement between the largest space-faring nations and organisations, such as the United States, Russia, China and the EU with the possibility of adding India and Japan. This would create a 'cartel' of space fairing nations that would force others to follow as they would not have the economic or political weight to challenge such decisions. Between the above-mentioned nations are the bulk of the space economy and the most powerful space-faring nations, especially in relation to technology and access to space. The benefit of employing such a system is that it is likely that more would be completed when dealing with outer space issues. However, one of many downsides would be the dictatorship enforced on others by the larger space fairing nations. It is also possible that the largest and most technologically advanced nations may not wish to tolerate smaller 'free riders' as they have injected the most capital. Nonetheless, Bowen believes that orbital debris could benefit from such a system due to its indiscriminate nature, and the pooling of resources would likely lead to cheaper solutions in a shorter timeframe.[154]

[154] Bowen, Bleddyn. Interview by Author. Tape Recording via Skype. United Kingdom. May 25th 2018

8 Conclusion

The arguments put forward in this thesis have often addressed space security on a broader level rather than a series of issues. Space is infinitely vast, and Earth's orbits also cover enormous areas, compared to any distances that are governed on Earth. Along with the vastness of space, the security concerns that develop over time are almost limitless. Future developments cannot even be predicted, yet there are currently enough problems to tackle to last for centuries. Earth and space are two remarkably different realms and deserve different approaches. Humanity will always seek to use what it already knows to help develop new ideas. This concept has proven successful throughout history, but with the constant technological developments, it is possible that human development of governance will be unable to adequately keep up with the ferociousness of future space endeavours.

When developing theoretical guidelines for future study of space security, it is important to remember that ‘security has no constant meaning, the concept means something different for every school of thought within security studies. Security's meaning is dependent on questions of the epistemology, ontology and methodology underlying the respective school of thought.'[155] This means that any comprehensive new theory to govern space must be able to adapt and evolve such as the environment it is designed to simplify does. It is often the cause of issues in international security

[155] Floyd, Rita. 2007. "Towards a Consequentialist Evaluation Of Security: Bringing Together The Copenhagen And The Welsh Schools Of Security Studies". Review Of International Studies 33 (02): 333

that if one singular definition existed then political and legal decisions would be easier. However, no singular meaning has ever or will ever exist for 'security' and therefore it is imperative that an all-encompassing view is used to deal with the orbital debris problem.

The widening of the space security agenda certainly delivers risks. The concerns over ADR technology and other dual-use spacecraft would be at the forefront of any debate that ensued if a globally adopted space security approach was developed out of a broader sense definition. It has been put forward by Bowen that 'keeping space security traditional improves the change of a routinization and normalisation of ADR activities.'[156] This is not to say, however, that a broader view would not eventually see the same conclusions. It is not truly the view of this paper that a narrow approach to space security that excludes several aspects of the space environment is the most effective way forward for the space security agenda. Nonetheless, the complications associated with an unlimited broadening of the term 'security' would lead to extensive complications that would hinder and slow any resolutions due to the infinite number of possible security threats.

As highlighted throughout the theoretical sections in this research piece, the potential for consensus and collaboration between international security schools is one of the most promising solutions for the space debris problem. By using a combination of the Copenhagen and Welsh schools, while adding some influences from the human

[156] Bowen, Bleddyn E. 2014. "Cascading Crises: Orbital Debris and the Widening Of Space Security". Astropolitics 12 (1): 64

security agenda, it could be possible to create a theoretical school that can adapt to the space environments demanding security issues. This framework could allow for both state and national security threats that develop in outer space as well as environmental threats in space being dealt with efficiently by either state actors or private companies.

Space security requires more attention from international organisations and states to fully develop. However, from a theoretical perspective, this thesis agrees with the views of Floyd as the most proactive solution: ‘a combination of the two schools into a larger approach paves the way for a more critical engagement with security on the part of the security analyst, allowing for normative, but denying infinite conceptualizations of security'.[157] This research paper concludes that the more united the international security schools, the greater the chance that a common, unified theory can emerge encompassing all perspectives, allowing a consensus to prevail. This ‘hybrid’ framework would allow governmental policy makers the guidelines they require, whilst allowing private companies the freedom to expand their influence within the space environment.

It is indeed possible that in the future international space debris mitigation policies would be based on the consensus of the IADC guidelines. This could aid in the implementation of any space debris mitigation measures. ‘Internationally agreed standards could enforce appropriate debris mitigation measures on spacecraft

[157] Floyd, Rita. 2007. "Towards a Consequentialist Evaluation of Security: Bringing Together The Copenhagen And The Welsh Schools Of Security Studies". Review Of International Studies 33 (02): 336

operators and launch service providers through the mechanisms of conditional launch license issuance and insurance coverage, depending on the acceptance of a space debris mitigation plan.'[158] However, this is not currently the case. This thesis believes that the future of space law does not lie in the hands of the United Nations, but with space agencies and governments adapting to the challenging environment by increasing the use of TCBMs. This will remain the case until a point where current space law treaties and agreements are unsustainable due to advances in technology and the diverse and challenging nature of the space environment make them redundant. TCBMs are not perfect, but they should be used by states as a stepping stone to a new era of space law to limit the impact of the human presence in space whilst serving to resolve the space debris problem. The indiscriminate nature of orbital debris should serve as a reference point for the discussions and implementation of TCBMs and future legal dialogue. It has the potential to impact every space fairing nation and requires an immediate response to limit the effect it may have on the future orbital environment.

Looking towards the future of the space debris problem, there are encouraging signs that space security issues are being more widely acknowledged by the mass media and governments. This increase in attention will lead to a great public awareness and with it a push to address these issues. However, as can be seen with climate change and plastic pollution, it takes decades to force change and even throughout this process there will be some who deny its existence. This is not a luxury that can be

[158] Klinkrad, Heiner. 2006. Space Debris - Models And Risk Analysis. Chichester, UK: Springer, Praxis Publishing Ltd.P.313

afforded when dealing with orbital debris as it poses a real and immediate threat to future space affairs. The cascading impact of Kessler Syndrome, as highlighted throughout this research paper, will only continue to increase even with total cessation of all launches into space. Yet, companies such as Astroscale, who are seeking to limit debris in the future, are a positive force in the fight against orbital debris creation.

Ultimately human nature needs to evolve to be able to proceed sustainably on earth and space while eradicating the scourge of our polluting behaviour. Without doing this, the development of the space security agenda and global consensus concerning issues of outer space will be meaningless, and humanity's future utilisation of space will be lost for generations.

9 Abbreviations

ASAT – Anti-Satellite

CBM – Confidence Building Measures

EOL – End of Life

ESA – European Space Agency

GEO – Geostationary Orbit

IADC – Inter-Agency Space Debris Coordination Committee

LEO – Low Earth Orbit

MEO – Medium Earth Orbit

MRO – Mission Related Object

NASA – National Aeronautics and Space Administration

UNCOPUS – United Nations Committee on the Peaceful Uses of Outer Space

UNOOSA – United Nations Office for Outer Space Affairs

TCBM – Transparency and Confidence Building Measures

10 List of Figures

11 Bibliography

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