INTRODUCING THE LAW GAMES: PREDICTING LEGAL LIABILITY AND FAULT IN SATELLITE OPERATIONS

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Over recent times there has been a rise in the number of objects placed into Earth orbit. With various countries licensing a number of large constellations, the orbital population is set to increase dramatically. A significant number of technical advances have facilitated this and, in the UK and elsewhere, this has been matched by the updating of legislation and an increased policy focus on the need for increased space surveillance and tracking. The rise of large constellations coupled with an increasing number of experimental techniques such as active debris removal or on-orbit servicing procedures means that establishing fault will be crucial if litigation is to be successful. In doing this, any legal proceedings will look at both norms of behaviour, deviation from which will point towards fault and the types and standard of evidence that will be required.

This paper will outline these problems in detail. It will be proposed that what is required to map out the contours of liability are both codification of the norms for satellite operations and clarity on protocols for evidence gathering in cases where fault may be contested in orbital operations. This discussion will identify that a way in which this could be achieved is by the use of "space law games". These are simulations, similar to military war games, in which fictional scenarios could highlight some of the key legal issues that might need to be dealt with. The paper will outline some of the ways in which the law games might work and pose questions as to what data and other considerations will be needed to make such simulations meaningful.

INTRODUCTION

It is now widely accepted that, as human activity in space increases, there is an increasing need to clean up the orbit of the Earth by not only mitigating the creation of new debris, but through active debris removal (ADR) and proactively removing debris from heavily populated orbits (Welly, 2010). It has been known for some time (Williamson, 2006) that without taking action to remove the detritus of human space activity, there will be a significant increase in the likelihood of collisions between space objects and a resulting reduction of access to the orbital space domain (Degrange, 2018). In addition, given developments in satellite servicing technology, there appears to be a growing interest amongst satellite operators in technologies that can prolong the life of expensive satellites by employing the services of active satellites to engage in on-orbit servicing (Graham and Kingston,

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2015). Yet as the technologies and techniques come within the grasp of the spacefaring community, it is necessary to recognise that these rendezvous and proximity operations (RPO) are still in the experimental stage[1]. Any such untried space operation therefore involves the significant risk of a malfunction causing damage, either to the operator's own spacecraft, or to a spacecraft owned and operated by another (Blount 2019). Under international space law, liability for any damage caused in space by one space object on another is assigned to the launching state on a *fault* basis[2]. Usually, in international law, fault can be established through lack of compliance with treaty obligation, breach of a duty of care or failure to comply with established norms of behaviour (Lyall and Larsen, 2018). In satellite operations there are no normative rules to point to in respect of assigning fault for collisions in space (Blount, 2019). For all RPO missions, the lack of accepted operator practice means that in many circumstances it could be extremely difficult to establish fault. The experimental nature of RPO missions will make it extremely high risk and consequently difficult to establish clear identifiable operational duties which have been breached. The corollary of this is that space activities have entered into a legal vacuum, where operators may be engaging in activities that lay them open to potentially ruinous litigation.

This discussion will look at the legal problems facing operators in respect of establishing 'fault' in on-orbit RPO missions. The paper will start by examining the governance of space activity and its practical operation on three distinct levels. First, the overarching international treaties which impose specific duties on states to both limit unfettered exploitation of the space environment and also to encourage peaceful uses of outer space. It should be noted that while this discussion will mention a variety of actors in the space environment (operators, companies etc.) it is ultimately nation states that bear the liability for damage.

Flowing from this, states discharge their responsibilities under these international treaties by enacting domestic laws which regulate space activity within the context of national boundaries. The paper will identify that the assignment of states to bear liability for damage caused by space activity is not accompanied by any indication of the factors which might point to fault in orbital operations. The paper will then look at an increasingly important aspect of the space governance framework in the form of 'soft law' instruments such as guidelines, which help to establish best practice amongst space operators and can lead to the establishment of normative patterns of behaviour. In the absence of any binding or persuasive guidance, the paper will address the question as to how courts might construct the contours of fault using the common law tort of negligence.

These legal elements will lay the conceptual edifice for the final part of the paper in which it will be shown that the legal and soft-law instruments lack sufficient detail to guide state regulators, satellite owners and operators. The paper will, therefore, conclude by arguing for a role-playing style simulation of an incident to try and provide some indication of how a collision event would unfold. This will lay the foundations for what will be known colloquially as the Space Law Games (SLG). It will be argued that there is insufficient clarity as to what the contours of fault will be in litigation and whether an operator has breached a duty of care owed to other space users. Throughout the paper, a series of key questions will arise in trying to establish the legal elements of RPO missions and one theme will become apparent: the need for some sort of legal precedent as to both the type of issues that will attract liability and the type of information that will be available to the courts in order to determine fault. The paper will draw on a unique pair of simulation methodologies: the military approach of employing a

[1] See, for example, the RemoveDEBRIS mission which is testing a number of ADR techniques. https://www.airbus.com/space/space-infrastructures/removedebris.html

[2] See Art III of the Convention on International Liability for Damage caused by Space Objects, (adopted 29 March 1972, entered into force 1 September 1972); 961 UNTS 187; 24 UST 2389; 10 ILM 965 (1971).

‘wargame’ methodology to advocate the need to simulate a collision in space resulting from RPOs and the legal moot to role-play the subsequent litigation. Such simulations should use open source data and information gained from collaborators in the space industry and draw on established rules of conduct for their execution. By ‘war-gaming’ a collision and providing the types of data that will be available to litigators will highlight individual satellite operator responsibility before, during and after a collision event. The paper will argue that simulating a collision (or collisions) in orbit, the data used will enable space law and policy experts to work with satellite operators to fill the void and provide the basis of fault for RPOs.

SPACE GOVERNANCE AND INTERNATIONAL LAW

The analysis of the legal position of space operations in Earth orbit must begin with consideration of the extant international space law position. This informs domestic legislation and has profound ramifications for orbital population, on-orbit servicing, active debris removal (ADR) and indeed any rendezvous and proximity operation (RPO) mission. At the heart of the international law framework is the Outer Space Treaty 1967 (OST) and this is the primary source of space law that needs addressing[3]. All of the rules and regulations for governing space activity flow from this treaty. The OST provides the basic principles governing the behaviour of humans in space but does not have much by the way of granular detail and has no bespoke enforcement mechanisms should states violate the terms of the treaty (Lyall and Larsen, 2018). Nonetheless, it is binding as an international treaty and is a recognised source of international law, providing the codified framework by which national activities in space are regulated (De Man, 2017).

The OST is recognised as the key development in the creation of a set of normative principles underpinning space governance and is the cornerstone of the law governing outer space activity. One of the fundamental reasons behind its longevity is that it is widely accepted by the international community as providing the basis for the ‘rules of the road’ for space having been ratified by over 100 nations[4]. Yet, it is very much a creature of its time. The OST was negotiated against the backdrop of the Cold War and the OST, places security at its heart, aiming to ensure that outer space did not become another theatre of conflict in the Cold War (Blount, 2012, p.516). There are key concepts of the OST that were expanded in additional treaties (Agreement on the Rescue and Return of Astronauts 1968, The Liability Convention 1972, the Registration Convention 1975 and the Moon Agreement 1984). It is instructive that, despite a number of significant advancements in technology and a shift in the geopolitical climate since their inception, there appears to be little appetite to either withdraw from or substantially alter these treaties.

The OST, therefore, establishes the way in which space shall be governed on an international canvas. It grants freedoms for certain activities and then regulates them by imposing specific limitations such as activities needing to be for the benefit of and in the interests of all countries and holds that the use of space is the province of all mankind (Blount, 2019). The OST looks to prohibit the monopolization of space activities by any one nation and

[3] Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies 1967, 610 UNTS 205, 1968 UKTS 10, Cmnd 3519, 18 UST 2410, TIAS 6347, (1967) 6 ILM 386, (1967) 61 AJIL 644. It was adopted by the General Assembly of the United Nations on 19 December 1966 and opened for signature on 27 January 1967 in London. It entered into force on 10 October 1967.
[4] For details on the current status of the OST including details of the ratifying states see http://www.unoosa.org/oosa/en/ourwork/spacelaw/treaties/status/index.html

ensure that space remains a collaborative venture. The OST recognizes that there are three basic activities; exploration, use and scientific investigation. Article I permits the free usage of outer space, including the Moon and other celestial bodies for all nations, with such exploration to be free from interference by other states. Art II of the OST establishes that the Moon and other celestial bodies are *res communis omnium*, that is, they are things of the entire world community and are not capable of being subject to national appropriation or claims of sovereignty. In respect of the core activities considered within this discussion, there is little doubt that ADR, on-orbit servicing and the use of constellations to provide global internet coverage would be considered 'usage' of space for the purposes of Art I and is not immediately prohibited by the OST[5].

The innovative and disruptive technologies that will be employed by on-orbit servicing and ADR are not explicitly dealt with by extant international space law. Instead, the treaty lays down principles that can be applied to the relevant activity. One of the key principles emphasized throughout, is the peaceful nature of space activity promoted by the Treaty. Both ADR and on-orbit servicing are ostensibly being developed to enable the sustainable development of civilian space, there are undoubted military aspects which make such technology 'dual use'. It is interesting to note that there is no express prohibition on duel use technology, although it may be that overtly aggressive militarization of space may fall foul of established international law and therefore be in violation of Art III (Blount 2019, pp.180-182).

STATE RESPONSIBILITY AND LIABILITY IN THE ORBITAL ENVIRONMENT

With the first five articles of the Treaty establishing the broad contours of the activity that would be permitted by the Treaty, the OST then goes on to provide a troika of articles which outline the contours of state responsibility. Art VI endows states with responsibility for authorizing, licensing and on-going supervision of their national space activities. Art VII of the OST affirms that liability for damage caused by space objects sits with the launching state. The triangle of state responsibility is completed by Art VIII of the OST. This provides that a state whose registry is carried on a space object launched into outer space shall retain jurisdiction and control of that object and any personnel. Outside of these three, it is also important to consider Art XI, which emphasizes the cooperative nature of space activity and provides that states shall conduct their activities in outer space with due regard to the corresponding interests.

As the OST is an international treaty it requires both signature (by the state party) and ratification (in the UK context this means requiring parliamentary approval via primary legislation). Once ratified, the treaty obligations need to be discharged as a State has jurisdiction over any activity from its territory as well as over any activity that is carried on by its nationals. In the United Kingdom, the duties under the OST (and especially Art VI, VII and VIII) are to be found in the Outer Space Act 1986 and the Space Industry Act 2018. These are pieces of primary legislation and establish a regime of regulation to which all entities under the jurisdiction must comply if connected with space activity in the UK. The power to licence space activities is currently dealt with by the UK Space Agency.

[5] The limitations outlined in Art I and II are further delineated by Art III (the incorporation of international law into the corpus of Space Law), Art IV (the prohibition of stationing nuclear weapons and weapons of mass destruction in orbit or on a celestial body) and Art V (the recognition that astronauts are envoys of mankind and should be returned, along with their space craft, to the state of registry).

An oft-criticised aspect of the OST and related treaties is that it does not reflect the new realities of multi-sectored space activity (Lyall and Larsen, 2018), as there is no direct mention of private, commercial companies. It is true that there is no direct mention of commercialization in the OST, yet the treaty does recognise the role of companies and commercial bodies. The usage and exploration sought by private companies, are, therefore subject to requisite authorization from a recognised state party and it is up to the state to ensure that the activity is compliant with the OST as the state should be called to account if it is not. History shows, however, that despite this requirement, states have not been held accountable and the mechanisms by which this could be accomplished are not clear. Article VI of the OST affirms that private individuals and organizations are not excluded from conducting activities in outer space, providing they are appropriately authorized/licensed, and their activities are subject to supervision.

The role of the licensor is, therefore of crucial significance as not only does the grant of a licence authorize space activity, it also signals de facto acceptance of liability for space activity under Art VII of the OST. Indeed, in the context of current orbital activity, and especially in respect of RPO missions, the most significant legal issue is that of liability. It is the Liability Convention (LC) 1972 which builds on the provisions of Art VII of the OST and provides that damage caused by space objects to anything on Earth or to an aircraft in flight will attract absolute liability (Art II LC 1972). It is Art III LC 1972 which speaks to damage cause by the space object of one state to another in orbit. Art III LC 1972 states in full that:

> "*In the event of damage being caused elsewhere than on the surface of the earth to a space object of one launching State or to persons or property on board such a space object by a space object of another launching State, the latter shall be liable only if the damage is due to its fault or the fault of persons for whom it is responsible.*"[6]

This Article envisions liability arising in a series of circumstances where (1) damage is caused elsewhere than on the surface of the earth, (2) to a space object of one launching state, (3) by a space object of another launching state and (4) liability arises *only* if the damage is due to its fault or the fault of persons for whom it is responsible. The elements of this provision, especially in relation to fault, will be explored in more detail below.

Having discussed the foundational principles of space law, it can be seen that these twin elements are at the heart of the legal quandary that operators and litigators will face. Art VII of the OST and Art III LC 1972 are the most commercially significant parts of the international space law as they establish the basic rules for litigation in space-related collisions (Trepczynski, 2007). These treaty provisions, however, are silent on the crucial issue as to what shall constitute 'fault' and how fault will ultimately be determined. Similarly, there is no real discussion as to what forum such disputes should be heard and the role of informal dispute resolution mechanisms so crucial to modern litigation (Blake, Sime and Browne, 2018). In respect of on-orbit servicing, ADR and (to a lesser extent) the use of large constellations of satellites, the extant legal position in respect of liability is limited to a simple re-statement of the basic position under Art III Liability Convention. Damage caused by the space object of one state to the space object of another state will be judged on a fault basis. It is this aspect of the law relating to orbital operations that requires discussion in closer detail.

[6] Convention on International Liability for Damage caused by Space Objects 1972, 961 UNTS 187, (1974) UKTS, Article III.

ON-ORBIT LIABILITY, FAULT AND NEGLIGENCE

As established above, under Art III LC 1972, liability for the space object collision whilst in orbit is established on the basis of fault, whether due to the innate failure of the object itself or failure on the part of the parties responsible for the object (Trepczynski, 2007). The application of fault-based liability within the international realm is rare, traditionally not found beyond treaty violations or international norms such as genocide (Lyall and Larsen, 2018). Contrary to traditional fault-based liability, space liability concerns 'intent or negligence to cause damage in respect of someone else active in space' (von der Dunk, 1992). Fault liability itself relies on standards of care to judge whether behaviour is reasonable. However, since the UK Outer Space Act 1986 obliges any non-state spacefaring actor to indemnify the Government against any claims of liability, which were not conducted on the state's authority and no definition exists to outline how fault may be found with the Liability Convention itself (Stamps, 1989). It is, therefore, necessary to apply more traditional, terrestrial approaches to determining fault. Doing so will establish the way in which a space liability case would proceed and how reparation via compensation will be calculated, although only to the extent of the share of damage caused in a space object accident (von der Dunk, 1992).

In establishing fault, whether in orbit or on the Earth, the essence of the claim is the same: that one of the parties was in some way responsible for behaviour which was wrong, but which was not criminal. Such behaviour is dealt with under the common law tort of negligence[7]. The modern tort of negligence has its roots in the seminal case of *Donohue v Stevenson*[8] and the judgment of Lord Atkin. In that judgment Atkin employed a three-stage test which form the basis of all modern claims for negligence. First, is the so-called '*neighbour principle*'. In relation to space activity, it somewhat crudely could be categorized thus: every state engaged in using the space environment owing a duty of care to other space users (von der Dunk, 1992). The second element of tort is that there was a breach of that duty by falling below the appropriate standard of care – it is this element that the inquiry will focus on. The final element is that damage to the satellite was caused by the breach of duty of the operator at fault and that there is a clear causal link between the damage caused and the actions (or failure to act) of the operator at fault (Goudkamp and Rogers, 2014). As stated above, whilst there are numerous legal issues germane to the liability of a spacecraft in orbit, the fundamental one within the purview of this inquiry are the contours of the duty of care and what behaviour should the appropriate standard be judged against.

The *Bolam* test[9] is employed in the legal system of England and Wales as the standard in law by which it is established whether fault exists through deviation from the professional common practice of a specialized field. Although the facts of the *Bolam* case itself surrounded medical negligence, the test has since been applied to a wide variety of professions. Due to the higher level of knowledge which professionals possess, the standard of care incumbent upon them can be reasonably expected to be higher in correlation[10]. Consequently, the *Bolam* test is that where professionals '*acted in accordance with a practice accepted at the time as proper by a responsible body of…opinion…[are] not guilty of negligence merely because there was a body of competent professional*

[7] '*At a very general level… tort law is concerned with allocating responsibility for certain types of losses*' for further details see Peel, E and Goudkamp, J. (2014) *Winfield & Jolowicz on Tort* (19th Edition, Sweet & Maxwell)
[8] [1932] AC 562
[9] Bolam v Friern Hospital Management Committee [1957] 1 WLR 582
[10] Bolam v Friern Hospital Management Committee [1957] 1 WLR 582 per MacNair, J.

opinion which might adopt a different technique'[11]. In respect of space activity, the assumption could, therefore, be made that provided operators of space objects act in an accepted professional manner, even if professional opinion does differ, they would not be in breach of their duty of care and consequently would not be liable for any damage caused by the collision of space objects.

Whilst this is good law, there are two fundamental weaknesses when trying to apply the Bolam test to space operations. First, is that the test fails to distinguish between what has been done and what ought to have been done, making comparison to the relevant standards of care difficult. The true difficulty in establishing fault via the Bolam test is that it relies on a peer review system. In contrast to medical negligence, it may be more difficult in space operations to find an independent, reasonable third party to establish whether the actions taken did not breach the standard of care since space industry peers are competitors may well be mutual victims of damage (von der Dunk, 1992). That is not to say that third parties do not exist but, in any event, such litigation may end up revolving around a credibility battle between competing experts – a situation that does not lend itself well to establishing generalizable rules for fault in space operations.

The second issue in relation to establishing fault is even more fundamental and takes us into another realm of the governance of space, away from space law and into the realm of soft-law, informal mechanisms. The problem can be crystalized in the following terms: In establishing what constitutes good practice within any profession (beyond the subjective opinion of fellow professionals), guidelines and codes of conduct have provided a reliable third-party basis in the past for medical negligence cases. Making decision on this kind of basis, against an authoritative third-party guide as to whether liability occurred, removes the problematic element of peer review (Samanta and Samanta, 2003). Yet, the granular rules for space objects engaging in rendezvous and manipulation in orbit are not explicitly addressed by current space law (either nationally or internationally). Such RPO missions do not even, as yet, have informal codes of conduct or recommended elements of best practice. The Consortium for Execution of Rendezvous and Servicing Operations (known colloquially as CONFERS) is an industry-led initiative which promises to promulgate non-binding guidelines based around a broad consensus of operators. Their work is, however, still on-going and the industry is, as yet, untested in space. This leaves a significant amount of legal ambiguity surrounding the appropriate duties incumbent on both RPO operators and customers will mean that establishing fault in litigation will be extremely challenging.

GUIDELINES AND BEST PRACTICE FOR RPO MISSIONS

Having identified the crucial role that guidelines and codes of conduct will play in establishing the duties upon operators in respect of RPOs, this discussion will consider the crucial role that such soft-law agreements have in the overall governance of space. Indeed, in contrast to the static nature of international treaty law for outer space, the last decade has seen the rise of informal, non-binding codes of conduct as a way of attempting to shape and influence normative behaviours of rational space actors. The use of such agreements has a number of advantages over more formalistic, binding treaty arrangements (Goh, 2007). An illustration of this can be seen when considering efforts to deal with space debris. Whilst no formal, legally binding treaty exists in relation to addressing the threat posed by space debris, in 2002 the Inter Agency Space Debris Coordination Committee (IADC) promulgated guidance on how to mitigate the rise of debris on future missions. These were presented to

[11] ibid

UNCOPUOS and in 2007, the UN Office for Outer Space Affairs (UNOOSA) promulgated the Space Debris Mitigation Guidelines of the Committee on the Peaceful Uses of Outer Space[12].

The strength of these voluntary guidelines is that they reflect the existing practices of national and international actors and provide a consensus of the current thinking regarding debris mitigation. There has been widespread acceptance of them and, whilst not being a legal duty under the OST, the guidelines are accepted as representing a normative, default position in respect of all space missions (Li, 2015). Although not directly applying to RPO missions, the agility of non-binding norms to change in-line with technology can be seen in the example of the recommended 25-year post mission lifetime guideline for satellites within the UN Debris mitigation guideline. This is broadly accepted now as the 'industry standard'. Yet it is now being postulated that, given the increase in the orbital population, 25 years is no longer appropriate and should be reduced considerably. It is anticipated that within 5 years, the orbital environment will have sufficient number of objects to necessitate a change in the post-mission disposal criteria with operators simply including this change in their licensing application (Rajapaksa and Wijerathna, 2017). This flexibility could prove invaluable as both the technology and procedures involved in RPO missions are developed and refined.

Whilst guidelines are a promising mechanism by which to effect meaningful change in normative behaviour without the protracted negotiations of an international treaty, there is a note of caution that must be sounded. Guidelines and codes of conduct are only successful when they reflect genuine areas of consensus and have acceptance on a global level. The International Code of Conduct for Outer Space Activities (ICOCOSA) represented an attempt by the European Union in 2014 to produce a non-binding international instrument around which efforts to encourage responsible use of space could coalesce into normative behaviour. Whilst there are numerous reasons why ICOCOSA has failed to cultivate support, the main objection came from non-EU states who felt that the Code was an attempt at the imposition of a 'top-down' instrument and not the result of widespread consultations (Rajagopalan and Porras, 2014).

Moving beyond established guidelines, the space industry does have certain standards of care which have developed over the years. As space exploration develops, these standards may evolve in order to stay consistent with the technology, but nonetheless, they do represent extant and accepted norms amongst operators (Jakhu et al, 2017). Before each launch, and where propulsion is part of the mission design, satellites will be equipped with enough fuel for the purpose of maneuverability. Satellites with propulsion should be able to propel themselves out of the path of fellow space objects or recorded debris, execute end-of-life procedure and retire out of critical orbiting space. It is expected that satellites will be monitored throughout their lifetime, and all relevant data will be shared, to limit any potential space object collisions. Given the damage which debris causes; the risks will be reduced by construction and initial design: through the application of appropriate shielding materials to launched satellites (Jakhu et al, 2017).

Nonetheless, there are – as yet - no industry guidelines on the use of constellations, on-orbit servicing and ADR (or indeed any RPO mission in space). It could well be that a national regulator will be approving these missions and, in doing so, providing the template for future missions of a similar nature. The legal position, therefore, is something of a Mobius Loop, with regulators looking to grant licences for experimental missions which become the template for future missions and future licences. In essence, the grantor of the licence becomes the arbiter of

[12] Debris Mitigation Guidelines of the Committee on the Peaceful Uses of Outer Space, as annexed to UN doc. A/62/20, Report of the COPUOS (2007)

good practice for RPO missions, which is as the OST intended. Although outside the remit of this inquiry, there is clearly a need for research to be done benchmarking the performance of national regulators to ensure that standards are consistently applied by the space actors of each nation. Even if broadly accepted by space operators, informal, non-binding guidelines still need to work within the legal framework which currently exists in respect of human space activity but more crucially they need to be based on established data and, failing that, adequate simulations.

DATA GATHERING AND GUIDELINE FORMATION

So far, this paper has identified the elements of space law which address liability for space collisions. Art III LC1972 is clear that liability will arise under the following circumstances; (i) where damage is done by the space object of one state, (ii) to the space object of another state, (iii) the state whose object caused the damage will be liable if the damage is either (a) the fault of the state or (b) the fault of someone for whom the state is responsible. As Hertzfeld and Baseley-Walker (2010) identify, however, collisions in space occur on a spectrum. At one end are largely blameless collisions of natural debris impacting upon artificial satellites and at the other end are grossly negligent and willful acts where culpability is beyond doubt. The problem facing those states and responsible satellite operators is, that the existing liability regime does not define who will be blameworthy for collisions in the middle of that spectrum where fault is disputed and both actors can legitimately claim to be acting as reasonable space actors.

Assuming (and this is a significant but necessary leap of faith) that damage to one state's space object can be shown to be caused by another state's space object, the fundamental issue will be one of assigning fault. Given the discussions and issues outlined above, it would seem that the following questions arise; (1) In the absence of any codes of conduct, best practice or industry standards for RPO, what rules should exist to minimize the risks of collision and what are the core roles and responsibilities of all space operators in avoiding such outcomes? (2) When a collision caused by an RPO cannot be avoided, what evidence is required to properly assign fault and (3) What information will be needed by the litigation team in order to successfully either prove or disprove fault.

Whilst it might be possible to construct these rules and answer the questions in abstract, it is argued that a much better way to develop the rules is to see events develop by means of a simulation, role-play or even a war game. The use of war-gaming methodology to simulate complex and contested events leading to uncertain outcomes is well established. Indeed, Paikowsky and Tzezana (2018), have suggested that such an approach can be used to simulate the response of nations to a successful space mining operation in the future. As they rightly identify;

> "*Roleplaying games are also of particular use when trying to forecast the impact and consequences of large changes. Experts have an advantage in understanding the results of small changes in their field of expertise, but they lose this benefit when confronted with major and disruptive changes that span many fields.*" (Paikowsky and Tzezana, 2018, p.13)

There are, however, a considerable number of different variables that need to be tested. There are the actions of the space operators both before, during and after an RPO-led collision. There is the collection of data by those on the ground, both connected to the operators and those responsible for the acquisition of data regarding the orbital population. There is, essentially a requirement both for estimation of the amount of data that would be received, what gaps exist in that data and then a requirement to interpret that data for the purposes of litigation. It is apparent, therefore that in order to effectively role play a collision and the litigation arising from that, there would need to be two simulations; one regarding the event and furnishing the data, another litigating the matter based upon the data gathered and analyzed from the first simulation. These role plays will be independent but interconnected. For the purposes of identification, they will be conducted under the banner of the Space Law Games (SLG).

SLG: CREATING THE TWIN EVENTS

The first element of the SLG will draw upon the experience of the US military in predicting and role-playing critical conflicts in space. Having run since 2001, the US Air Force Command Schriever War Games[13] have been a rich tradition and methodology that can be imported directly into the study. Usually, the scenario for the games involves the use of global scenarios which re-create conflict in the space domain. The scenario cuts across military and civilian challenges and seeks to use existing capabilities to predict the actions of other actors within the space environment (AFSPC, 2017). As Paikowsky and Tzezana (2018) have identified, war-gaming has been used for centuries in trying to forecast the way in which complex events might unfold. Given that the template for such a simulation exists in the form of the Schriever War Games, it would seem a natural model for the simulation of an RPO event which could provide information on the type of data that might be available and the type of data that would be missing from a failed RPO mission.

Johnson-Freese (2017) identifies, the key lesson learned from successive Schriever war games is the danger of rapid escalation. It will therefore be of peripheral, yet significant benefit that a civilian focused war game may be able to project the information given from a non-hostile (i.e. non-wilful) but flawed RPO event and feed into military calculations about whether a collision in orbit is hostile or not. Yet the data that could be gleaned from the simulation poses a crucial question about the location of the simulation. The nature of the RPO mission is likely be contingent upon the altitude of the spacecraft that are docking with each other. As Blount (2019) identifies, RPO missions in LEO are likely to be centred around the removal of debris from congested orbits, while GEO missions are likely to focus on extending the life of expensive space assets. These two missions, whilst falling under the umbrella of RPOs are very different in both execution and outcome. In all likelihood, to gain sufficient richness of data, it will be necessary to conduct two separate, independent simulations of RPO missions, an ADR mission in LEO and on-orbit servicing simulation in GEO.

Identifying the war-gaming methodology for the first simulation, and the need for two distinct ‘games’ in different orbits is crucial as these will provide the data for the legal phase of SLG. Just as war-gaming is a well-established method of gathering data about decision-making in theatres of armed conflict, so law has its own tradition of role-playing. The legal moot is used extensively within law training; therefore, this seems a natural way to simulate the litigation needed for the second half of the SLG. The Moot is a role play which involves the posing of certain legal questions that need addressing. The role-play itself, however, is open-ended and such a simulation may produce conclusions which will surprise both the student and the adjudicator (Phillips, 2012). Given the total absence of litigation in this respect, the moot seems an ideal way in which to test the contours of fault within a courtroom setting using the data produced by the space war game[14]. The rules for both the creation

[13] See https://www.afspc.af.mil/News/Article-Display/Article/1349906/schriever-wargame-concludes/ for further details.

[14] The Space Law Games represents a new, hybrid approach to simulating possible outcomes. There is, however, a long history of space lawyers engaging in mooting. The annual Manfred Lachs Space Law Moot Court competition was introduced in 1992

of the skeleton argument and the subsequent oral presentation are well defined and clearly understood by lawyers (Baskind, 2016).

CONCLUSION: TOWARDS THE SLG

This paper has outlined the legal vacuum that exists in respect of defining fault in space collisions. The discussion has identified that for all RPO missions, the lack of accepted operator practice means that in many circumstances it could be extremely difficult to establish fault. Whilst clear negligence or malpractice may be easy to identify, in the early years of on-orbit servicing, ADR and the operation of a very large constellation, the experimental nature of the ventures will make it extremely high risk and consequently difficult to establish clear identifiable operational duties which have been breached. There will undoubtedly be guidance issued for operators, through forums such as CONFERS and this may form the basis of establishing duties and roles but until such time as RPO missions become ubiquitous, the legal uncertainty surrounding the appropriate duties incumbent on both RPO operators and customers will mean that establishing fault in litigation will be extremely challenging.

The proposed SLG will attempt to ameliorate some of that uncertainty by combining two recognised forms of open-ended simulations designed to be led by the data that emerges. It is hoped this will complement the discussions underway within the space industry and appropriate government agencies in respect of identifying best practice. Each phase of the SLG will yield valuable data and go some way towards answering the key questions posed by this paper. The first 'on-orbit' phase will highlight the data that could and should be available to both operators and observers, possibly highlighting the gaps and illustrating what additional tracking capacity is needed that is not already available. The legal moot phase will take that data and identify the duties owed at each stage of satellite operations. This will highlight the kinds of evidence that will be admitted, the scrutiny and weight that can be placed on that evidence. It will also be used to draw together the contours of liability to give operators *some* indication of how a collision in LEO or GEO will proceed should the case go to court. The SLG represent an ambitious attempt to use a variety of simulations and methodologies to close one of the biggest gaps in extant space law and governance.

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Dear Madam/Sir,

Resubmission of original research article

We are writing to confirm resubmission and to provide details of the compliance with the reviewer comments. We are extremely gratified that our piece has been subject to such an assiduous and supportive peer review. We have complied fully with the recommendations made and will detail the amendments made in the table below.

Reviewer 1 Comments	Response
Page 3 - lines 13-14 - the formulation of Article I OST is that the 'use' of space is the province of mankind not that outer space itself is the province of mankind	Text has been amended to reflect this.
Page 4 line 24 - that the State is responsible is without question but I think part of the issue is that States aren't "called to account"	Text has been amended; "History shows, however, that despite this requirement, states have not been held accountable and the mechanisms by which this could be accomplished are not clear."
Would also think about referencing the Manfred Lachs moot court competition when discussing the value of moots	Footnote reference has been added (see fn 14).
Few minor typos: page 3 line 15, there's a stray 'is' after OST page 3 lines 23/32 inconsistent capitalization of On Orbit Servicing Page 3 line 35, dual as in two not duel as in combat page 3 line 47, endow should probably have an s on the end page 4, line 19, an errant) page 4, line 20, missing 'of' between role and companies page 5, you start capitalizing State when previously you hadn't	All typos have been corrected.
Reviewer 2 Comments	**Response**
Some practical (even if very simplified) examples of a "space law game" would definitively strengthen the paper	We absolutely accept this observation. As there has never been a Space Law Game, at this stage we do not yet know quite what it will look like (and would not wish to provide any incorrect information). We have sought to reflect the novelty and originality of the endevour in footnote 14.
Please, fix the typo line 19, page 4.	All typos have been corrected.
Comments from the ASR Editor for Special Issues	**Response**
The only thing I noted was that the title, authorship, affiliations and Abstract should be repeated on the first page of the manuscript itself. Please correct	Manuscript updated to include Authorship, Affiliations and Abstract.

Yours Faithfully,

Christopher J. Newman
Ralph Dinsley
William Ralston