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Innovations for Insurers in Space Traffic Management and Weather Forecasting

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Abstract

Space activities are expanding. The number and types of actors who are involved with outer space is growing. This expansion has significant technological, environmental, and financial implications for the industry. After the research and development of a satellite itself and the provision of launch services, insurance is the third greatest expense to put a satellite into orbit. Though 95% of insured satellites in the last few years have been in geostationary orbit, the greater use of other Earth orbits is leading to an increase in demand for insurance in these orbits.

There are a number of innovative actions that space insurers can take to both grow their business and ensure the sustainable development of the space industry. Insurers can purchase space traffic management services (for example, from ComSpOC) as a centralized point of contact for their insureds. With technical expertise, they can advise insureds regarding recommended debris avoidance maneuvers to mitigate risk. They can provide consultation on design and incentives for greater tracking and maneuvering capabilities to be installed on insured satellites. Insurers can also provide launch weather and space weather services to mitigate the risk of a claim.

In this paper, I will discuss these options for space insurers. In doing so, I will analyze aspects of liability for space objects from a legal perspective and other key legal questions, both under the international space law regime and in the United States in particular. The ultimate goal of the paper is to provide recommendations that can be implemented moving forward.

I. Introduction

Laws and regulations are developed in a particular context. In the case of space, this context is heavily rooted in international law and the understanding that space activities are inherently high-risk activities. Though there is a great deal of risk involved in participating in such activities, there is also potentially a great deal of reward available, both financially and in terms of prestige, to those individuals and entities who seek participation in the space arena in the near term. "Quantifying risk is a survival mechanism innate to the human race. From the days cavemen built shelters to protect themselves from the elements, the goal has been to mitigate risk."[1] As of 2015, the space insurance market covers approximately 205 satellites orbiting the Earth with a value of approximately $26 billion.[2]

As is the case with any risk-bearing activities, insurance is obtained (and in some cases, is required) for space activities. If a collision were to occur between two tracked space objects would involve the legal, insurance, and foreign relations communities, which all share an interest in better information and technologies for space traffic management; the risks of insufficient space situational awareness capabilities are clear for both satellite operators and providers of space insurance.[3]

Space insurance policies are often referred to as "all risk" policies, though critically, they are not "all loss" policies.[4] These policies do not exclude damage, for example, from solar activity.[5] The highest premium cost and most risky phase of a space insurance policy is the launch phase. This portion of the policy will be in effect from three to six months and includes placement of a satellite in its correct orbit and preparation of the satellite for its operational activities. The in-orbit phase commences at the end of the satellite operational capacity assessment. Generally, policies are negotiated on a year-to-year basis for the operational life of the satellite. There can be partial or total losses under in-orbit insurance, depending on whether or not the satellite can still perform a significant portion of its intended function. Partial losses can occur where some but not all transponders are functioning.[6] Both of these forms of insurance are relevant and important from the perspective of space traffic management.

Though it is unfortunate, space insurers tend to view space debris as a threat to space traffic management as a risk that is manageable and not imminent. Even though they can appreciate the danger to satellites in both LEO and GEO, the risk to each individual satellite is minimal enough to evade serious consideration.[7] The difficulties caused by space weather and technical malfunctions are more heavily noted as potentially significant risks by space insurers.[8] In the context of a legal regime that is currently insufficient[9] to manage the risks to these satellites, this paper analyzes some of these concerns and attempts to address them.

Though space weather can have a substantial impact on the operational capabilities of satellites, it is often an afterthought to insurers.

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[1] Scott Ross, "Risk Management and Insurance Industry Perspective on Cosmic Hazards" in eds J.N. Pelton & F. Allahdadi, *Handbook of Cosmic Hazards and Planetary Defense* (Cham, Switzerland: Springer, 2015) at 1086.
[2] *Ibid* at 1096.
[3] William Ailor, "Space Traffic Control: A View of the Future" (2002) 18 Space Pol'y 99 at 104.
[4] Stephen Tucker, "Some Strategic Defense Initiatives Toward Preventing U.S. Space Insurance Related Disputes and Litigation" (1993) 21 J Space L 123 at 126.
[5] Ross, *supra* note 1 at 1089.
[6] Gabriella Catalano Sgrosso, *International Space Law* (Florence: 2011, LoGisma at 492-493.
[7] Philip A. Slann, "Space Debris and the Need for Space Traffic Control" (2014) 30 Space Pol'y 40 at 41.
[8] *Ibid.*
[9] *Ibid*.

> From the space-insurance perspective space weather is currently perceived a low concern with only few claims due to space-weather related damage. An explanation could be that anomalies may not have been claimed, as satellites have redundant systems, or that space weather was not recognised as the root cause of damage. During the severe space weather in 2003 reportedly 45 satellites were affected with 1 science satellite being a total loss. However, no claims were filed with the insurer. Generally, space insurance believes that preparedness levels are low. Satellites may have been designed to resist events of the magnitude of the 1989 and 2003 events but not for the 1921 or the 1859 Carrington event.[10]

Thus, this paper will address the role that insurers can play in both the prediction of and preparedness for space weather incidents.

II. Key Elements of International Space Law

The Outer Space Treaty,[11] the oldest and most comprehensive of the treaties governing space law, is the cornerstone of space law.[12] This treaty has been ratified by 103 States and signed by an additional twenty-six; all of the major space-faring States have become parties to this Treaty.[13] The Return and Rescue Agreement, Liability Convention, and Registration Convention all elaborate specific aspects of the Outer Space Treaty. These conventions, with ninety-four, ninety-two, and sixty-two ratifications respectively, provide more detailed rules relating to return and rescue, liability, and registration requirements.[14] These treaties, together with the less-subscribed Moon Agreement form the body of U.N. multinational treaty law for space. These treaties set the stage on which both space insurance and space traffic management activities must operate.

Article VI of the Outer Space Treaty is one of the key unique features of the international space law regime. It provides that States bear responsibility for the activities of their nationals in space (which can include both natural and corporate persons), including for their compliance with the Outer Space Treaty. States are to authorize and provide continuing supervision for any such space activities. In the case of activities carried on by an international organization, responsibility falls

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[10] Elisabeth Krausmann, "The Space-Weather Awareness Dialogue: Findings and Outlook" online: Clima Espacial, < http://www.climaespacial.net/documentos/ar_11.pdf> at 8.

[11] *Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies*, 27 January 1967, 610 UNTS 205

[12] Francis Lyall, & Paul B. Larsen, *Space Law: A Treatise* (Burlington: Ashgate Publishing Company, 2009) at 53.

[13] *Agreement Status,* Online: UNOOSA, 8 April 2015 *<http://www.unoosa.org/pdf/limited/c2/AC105_C2_2015_CRP08E.pdf>* at 10.

[14] *Agreement on the Rescue of Astronauts and the Return of Objects Launched in Outer Space*, 22 April 1968, 672 UNTS 119; *Convention on International Liability for Damage Caused by Space Objects*, 29 March 1972, 961 UNTS 187; *Convention on Registration of Objects Launched into Outer Space*, 14 January 1975, 1023 UNTS 15.

both to the international organization and the State participants in the organization who are parties to the Treaty. This provision is the basis for national space legislation, unusually placing responsibility for private activities on States. An individual State's policies may impact the availability and affordability of insurance. The ramifications of this article extend into liability and jurisdictional issues in space law, which have direct impact on both space traffic management and space insurance.

In addition to responsibility, each State bears liability for damage its space objects or their component parts may cause to another State (including natural and corporate persons), whether such damage is caused on the Earth, in the air, or in space in accordance with Article VII of the Outer Space Treaty and Articles II and III of the Liability Convention. Risk management is a key feature of any business plan, arguably more so in space. The placement of liability with the State of registry / launching States means that States are more likely to include stringent insurance and/or other financial requirements on space actors in their national legislation.[15] For the purposes of international space law, "the term liability is often used specifically to denote the obligation to remedy any damage caused, especially in the form of monetary payment."[16] In sum, the basic legal responsibility for a space object lies with the launching authority.[17]

An absolute liability standard will be applied to damage caused by a space object on the surface of the Earth or to an aircraft in flight.[18] If an object should cause damage to another space object, liability would be allocated on a fault basis.[19] Though there has been no case law decided on the basis of the international space law treaties,[20] it is worth noting that the Liability Convention has been used only once since its inception: it was referenced by Canada in the diplomatic exchanges resolving the Cosmos 954 crash in the Northwest Territories.

In space law, "[i]t should be noted that although liability under the abovementioned treaties is *unlimited*, in some cases national law does provide for caps or limits, often in combination with obligatory insurance. This implies that the state will assume any risks beyond those limits, as it, under the treaties, is subject to unlimited liability."[21] Given this regime, "[s]ervice providers must therefore take out risk coverage and pay insurance premiums, also covering the State's share of international liability the costs incurred are then transferred to service users."[22]

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[15] Aoki S. "Regulation of Space Activities in Japan," in *Jakhu R., National Regulation of Space Activities*. New York: Springer, 2010; 199 at 209.

[16] Cheng, Bin, "Article VI of the 1967 Space Treaty Revisited" (1972) 26 J Space L 7 at 9-10.

[17] Carl Q. Christol, *Space Law: Past, Present, and Future* (Deventer: Kluwer Law and Taxation Publishers, 1991) at 260.

[18] *Liability Convention*, *supra* note 14.

[19] *Ibid*, art III.

[20] Tanja Masson-Zwaan, "Liability and Insurance for Suborbital Flights" (Versailles, 2012) Proceedings of the 5th IAASS Conference 'A Safer Space for a Safer World' at 3.

[21] Piotr Manikowski, "The Columbia Space Shuttle Tragedy: Third-Party Liability Implication for the Insurance of Space Losses" (2005) 8:1 Risk Management and Insurance Review 141 at 3.

[22] Sgrosso, *supra* note 6 at 485.

Insurance can be taken out for an operator's own financial well-being or in order to comply with national legislation or regulations, and can include related organizations or States as coinsured (this is particularly useful in a case where cross-waivers of liability are present, which will be discussed later in this paper). "The insurance industry can help in managing private investment risks against property, financial and liability losses. The insurers, however, need to make use of particularly careful, anticipatory risk valuations, competent inspectors and highly specialized know-how in pricing and claims handling."[23] In order to underwrite an insurance policy, an insurer will develop a 'risk map' to assess the severity of possible occurrences and their probability. This actuarial activity will allow them to set the price at which they are willing to accept the risk.[24] Generally space activities can be found on the far right the risk map, leading to volatile, reactive, and expensive insurance rates.[25]

Article VIII of the Outer Space Treaty grants jurisdiction, control and ownership over space objects located beyond a State's territory.[26] These facets of space law have substantial impact on both space traffic management and liability insurance. The State of registry retains jurisdiction and control over a space object, as well as the personnel of that space object. The placement of an object in space, or its subsequent return to Earth, does not affect the ownership of such objects. If such objects or their component parts are found beyond the limits of the registering State, they are to be returned, though identifying data may be required from the State of registry. This article guarantees continuity of ownership, which is extraordinarily important for space enterprises. It should be noted that by the rules of the Registration Convention, the registering State must also be a launching State – a State that either: launches or procures the launch of a space object, or from whose territory or facility such an object is launched.[27]

So, what is jurisdiction? In the words of Sir Derek Bowett, "[j]urisdiction is a manifestation of state sovereignty. It has been defined as 'the capacity of a state under international law to prescribe or to enforce a rule of law." [28] With respect to space law, "jurisdiction and control include the power of such State to legislate with respect to its space objects and the personnel on board thereof."[29] Jurisdiction

[23] Lovier Schoffski and Andre Georg Wegener, "Risk Management and Insurance Solutions for Space and Satellite Projects" (1999) 24:2 203 at 203, *citing* P.J. Blassel, "Space Projects and the Coverage of Associated Risks" (1985) 10 The Geneva Papers on Risk and Insurance 36 at 51-83.
[24] Masson-Zwaan, *supra* note 19 at 4.
[25] *Ibid* at 5.
[26] Dierdericks-Verschoor, IH Ph. "Space Law as it Effects Domestic Law" (1979) 7 J Space L 39 at 42.
[27] *Liability Convention*, *supra* note 14, art I(c).
[28] D.W. Bowett, "Jurisdiction: Changing Patterns of Authority Over Activities and Resources" in R. St.J. Macdonald & Douglas M. Johnston, eds, *The Structure and Process of International Law: Essays in Legal Philosophy Doctrine and Theory* (Dordrecht: Martinus Nijhoff Publishers, 1986) 555 at 555.
[29] P.P.C. Haanappel, *The Law and Policy of Air Space and Outer Space: A Comparative Approach* (The Hague: Kluwer Law International, 2003) at 24.

itself can be broken down into two types of power: the power to make laws and take decisions, known as jurisfaction, and the power to implement and enforce laws, regulations and decisions, known as jurisaction. [30]

The registration referred to in Article VIII can be considered a status of nationality.[31] This granting of nationality may be compared to the granting of nationality by a State over its flag vessel on the high seas. This form of jurisdiction is "quasi-territorial" jurisdiction because it is comparable to the jurisdiction of sovereign States over their territory[32] (but cannot be traditional territorial jurisdiction due to Article II of the Outer Space Treaty, which forbids territorial appropriation). This quasi-territorial jurisdiction "applies not only to the object as such, but also to all things and persons on board."[33] With regard to space traffic management, it is important to note that "the State of registry has a right to require other States to refrain from interfering with the direction and supervision of the object[.]"[34]

The Outer Space Treaty "protects the attribution of jurisdiction on the basis of the national registry as well as the identification of space objects as a way of securing the principle of liability and the right to retrieve such objects."[35] The assumption of responsibility and liability for space objects is predicated on an assumption of jurisdiction over such objects.[36]

The jurisdiction, control, and ownership of space objects as established in Article VIII of the outer space treaty is permanent;[37] jurisdiction and control remain with the State of registry.[38] Prior exercise of jurisdiction and control is an implied pre-requisite in the wording of the text in order for the State to "retain" such

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[30] Bin Cheng, *Studies in International Space Law* (Oxford: Clarendon Press, 1997) at 622-623.

[31] E.R.C. van Bogaert, *Aspects of Space Law* (London: Kluwer Law and Taxation Publishers, 1986) at 115.

[32] *Lotus (France v. Turkey),* (1927) PCIJ (ser. A) No. 10 at 25.

[33] Cheng, *Studies*, *supra* note 30 at 467.

[34] Manfred Lachs, *The Law of Outer Space* (Leiden: Sijthoff, 1972) at 69.

[35] Aldo Armando Cocca, "Convention on Registration of Objects Launched into Space" in Nandasiri Jasentuliyana & Roy S.K. Lee, eds, *Manual on Space Law Volume I* (Dobbs Ferry: Oceana Publications, 1979) 173 at 177-178.

[36] Stephen Gorove, "Criminal Jurisdiction in Outer Space" (1972) 6 Int'l L 313 at 316 [Gorove, *Criminal Jurisdiction*].

[37] N. Jasentuliyana, "Regulation of Space Salvage Operations: Possibilities for the Future" (1994) 22 J Space L 5 at 13.

[38] *Report of the Scientific and Technical Subcommittee on its Forty-Ninth Session*, COPUOS, UN Doc. A/AC.105/1001 (28 Feb. 2012); Ram Jakhu et al., "Space Policy, Law and Security" in Joseph Pelton & Angie Bukley, eds, *The Farthest Shore: A 21st Century Guide to Space* (Burlington: Apogee Books, 2009) 202; *see also* van Bogaert, *supra* note 31 at 135; Tucker, *supra* note 4 at 601; Stephan Hobe, "The Legal Framework for a Lunar Base Lex Lata and Lex Ferenda" in *Outlook on Space Law over the Next 30 Years* (Boston: Kluwer Law International, 1997) 135 at 135; Lachs, *Outer Space, supra* note 34 at 69; Lyall & Larsen, *supra* note 12 at 83; Dierdericks-Verschoor, *supra* note 26 at 42; Gbenga Oduntan, *Sovereignty and Jurisdiction in the Airspace and Outer Space* (New York: Routledge, 2012) at 180.

jurisdiction and control.[39] "There is no suggestion that a State or other entity can divest itself of obligations in relation to space objects by their abandonment. In short, authors Lyall and Larsen believe that a State cannot cease to be 'responsible for' or avoid any correlative duties by abandoning a space object.[40] Several prominent jurists have stated that they believe abandonment of a space object to be both impossible and prohibited by law.[41] Even if a space object itself can be abandoned, effectively abandoning jurisdiction and control, "the responsibility for space objects rest[s] with the launching State and could not be abandoned."[42] As in-orbit liability for satellites that are no longer operation is rarely purchased,[43] a collision with a derelict satellite causing damage to one or more functional space assets could be detrimental for the launching State of the derelict object.

Jurisdiction and an inability to abandon a space object are essential elements for an understanding of the space debris problem that is impacting space traffic management today. It is impermissible for an actor from one State to interfere with a space object of another State, even if that object is a derelict satellite or piece of debris that could cause substantial damage. Thus, it is necessary for the State retaining jurisdiction over their space objects to have plans in place long before launching to mitigate the amount of debris they will create. Insurers can help to set the standards and enforce them.

III. Key Elements of U.S. National Space Law

As this conference takes place in the U.S. and the U.S. has a robust set of laws and regulations dealing with commercial space activities, this short paper will focus its discussion of national space laws on the U.S.

Because the international regime places responsibility with the State of nationality for space activities,[44] individual States will enforce their own requirements with regard to space activities. Of course, these requirements will include standards for obtaining authorization for launch and re-entry activities -- which, in the United States is handled by the Federal Aviation Administration (FAA).[45] The private space sector in the US has been perceived as integral to the use of space in terms of economic viability as well as international prestige and competitiveness, to the extent that NASA has been required to utilize commercial

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[39] Gorove, *Criminal Jurisdiction, supra* note 36 at 318.

[40] Lyall & Larsen, *supra* note 12 at 84.

[41] *Ibid* at 67, 84; Ram S. Jakhu, "Iridium-Cosmos Collision and its Implications for Space Operations" in Kai-Uwe Schrogl et al., eds, *Yearbook on Space Policy 2008/2009* (Springer Wien, 2010) 254 at 259; H. Baker, *Space Debris: Legal and Policy Implications* (Leiden: Martinus Nijhoff Publishers, 1989); Jasentuliyana, *supra* note 37 at 16.

[42] *Report of the Legal Subcommittee on its Fifty-First Session*, COPUOS, UN Doc A/AC.105/1003 (2012) at 10.

[43] Ross, *supra* note 1 at 1098.

[44] *Outer Space Treaty, supra* note 11 at art VI.

[45] *Commercial Space Launch Activities Act*, 51 USC §§ 50901 et seq. (2010); *Aeronautics and Space,* 14 CFR at chapter III, parts 415, 420, 431 & 435 (2004).

services where possible.[46] Given the US's intent to foster the growth of the commercial space industry, there has been a wide array of legislation and regulation promulgated in this area. The relevant federal legislation on National and Commercial Space Programs has been consolidated into Title 51 of the US Code.[47] In addition to this legislation, the executive branch issues regulations in the form of National Space Policy and Space Transportation Directives.[48]

Aerospace companies in the U.S. continue to cite commercial enterprises of foreign governments and use of industrial policy to continue to justify the favorable U.S. government-industry risk-sharing regime that exists in U.S. launch law.[49] "This regime is comprised of mandatory cross-waivers of liability, insurance and financial responsibility requirements, and conditional catastrophic indemnification."[50]

In general, undertaking a launch in the U.S. includes significant elements of analysis, including risk assessment, policy review,[51] and environmental review.[52] While environmental impact assessment can determine whether or not a launch is approved, assessment of the maximum probable loss (MPL) in case of a failure will determine the levels of liability for a launch, including how much insurance (or funding, in the case of self-insurance) must be obtained in order for the launch to go forward.[53] Under this regime, the launch or reentry licensee must obtain insurance to cover claims of third parties based upon the MPL, or otherwise demonstrate financial responsibility, not to exceed the lesser of $500 million (which is periodically adjusted for inflation) or the maximum available on the world market at reasonable cost.[54] "Launch liability for US providers has always resided in the comprehensive product liability policy. The market capacity for liability is based on sub-limiting exposure by each market is based on sub-limiting exposure by each market rather than the amount of worldwide capacity, as is the case for space markets."[55] Thus, availability on the world market is still limited to the insurance capacity available to support the U.S. The U.S. government, subject to appropriations, may pay third-party claims in excess of the required insurance up to $1.5 billion (periodically adjusted for inflation) above the amount of the MPL-based

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[46] *National Aeronautics and Space Program*, 51 USC § 20102 (2010); Paul Stephen Dempsey "The Evolution of US Space Policy" (2008) 33 Ann Air & Sp L 325, 340.
[47] *National and Commercial Space Programs*, 51 USC (2010).
[48] Michael Mineiro, "Commercial Human Spaceflight in the United States: Federal Licensing and Tort Liability" (LLM Thesis, McGill University Institute of Air and Space Law, 2008) [unpublished], 11.
[49] Joanne Irene Gabrynowicz. "One Half Century and Counting: The Evolution of U.S. National Space Law and Three Long-Term Emerging Issues" (2010) 4:2 Harv L & Pol'y Rev 405 at 410-412.
[50] Michael Mineiro, "Assessing the Risks: Tort Liability and Risk Management in the Event of a Commercial Human Space Flight Vehicle Accident" (2009) 74 J Air L & Com 371 at 392.
[51] *Aeronautics and Space,* 14 CFR § 431.23 (2004).
[52] *National Environmental Policy Act,* 42 USC § 4321.
[53] *Commercial Space Launch Activities Act*, 51 USC §§ 50914-50915.
[54] *Insurance Requirements for Licensed or Permitted Activities* 14 CFR § 440.9.
[55] Ross, *supra* note 1 at 1098.

insurance.[56] Above this indemnification, the licensee or legally liable party will retain financial responsibility.[57] Additionally, cross-waivers of liability must be maintained between the licensee and all commercial entities that are involved in the activity, including contractors and subcontractors, as well as between those parties and the U.S. government for amounts in excess of the mandated insurance coverage.[58] According to FAA calculations, there is less than a one in ten million chance of a loss exceeding the required insurance and triggering U.S. government liability.[59]

It is worth noting that while the FAA retains jurisdiction over launch and reentry activities, it does not specifically hold jurisdiction with regard to on-orbit activities, meaning in the understanding of some authors "that the risk-sharing regime would not extend to over an accident that occurred in orbit."[60] On-orbit activities are not specifically excluded in that loss must result from a "permitted or licensed activity," meaning that on-orbit activities theoretically would fall within the scope of the financial responsibility requirements. [61] However, the financial responsibility requirements are placed upon launch or reentry licensees on the basis of an MPL that would result from licensed launch or reentry activities. MPL calculations only take into consideration on-orbit risk analysis with respect to "assessing risks posted by a *launch vehicle* to operational satellites" (emphasis added).[62] It is unclear when an event becomes too attenuated from the launch to be considered eligible for consideration under the risk-sharing regime;[63] a requirement for damage to be proximately caused by the launch or re-entry event may exist.[64]

IV. Options for Insurers

Insurance is the third-highest cost of a space activity (after research and development and launch costs), and thus should not be unduly laid aside as a secondary concern. Despite the fact that the research in the area of space debris highly points toward a need for increased mitigation and/or remediation of debris, "[e]ven now, the spacecraft operators and insurance industry do not appear overly

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[56] *United States Payment of Excess Third-Party Liability Claims,* 14 CFR § 440.19.

[57] *Liability Risk-Sharing Regime for U.S. Commercial Space Transportation: Study and Analysis,* Federal Aviation Administration (April 2002), available at: <https://www.faa.gov/about/office_org/headquarters_offices/ast/media/FAALiabilityRiskSharing4-02.pdf>.

[58] 51 USC §§ 50914-50915.

[59] Matthew Paul Schaeffer, "The Need for Federal Preemption and International Negotiations Regarding Liability Caps and Waivers of Liability in the US Commercial Space Industry" (2014) Berkeley J Int'l L, online: <http://ssrn.com/abstract=2420538> at 13.

[60] Kleiman M, Lamie J, Carminati M. *The Laws of Spaceflight.* Chicago: American Bar Association, 2012 at 86.

[61] *Determination of Maximum Probable Loss,* 14 CFR § 440.7.

[62] *Determination of Maximum Probable Loss,* 14 CFR § 440 Appendix A.III.C.

[63] *Financial Responsibility Requirements for Licensed Launch Activities,* Federal Register Vol 63 : No 165 (26 Aug 1998) at 45612.

[64] *Ibid*.

concerned with addressing space debris."[65] In many cases, space debris mitigation efforts are seen as more costly than they are beneficial, in terms of the individual actuarial analysis on each insurance policy. This is not only unfortunate, but also counterintuitive. In order to maintain the safe and sustainable operation of orbital spacecraft (and eventually more frequent missions that will pass through Earth orbit to travel beyond) and maintain reasonable but still profitable insurance premiums, this issue must be addressed.

Insurers are in a unique position to be able to take additional steps promote debris mitigation, and thereby safe navigation of space. By employing technical experts within insurance companies, it is possible to implement both additional services and more effective review for implementation of premiums that take into account effective debris mitigation measures (or lack thereof). Perhaps most importantly, insurers are in a position to develop more stringent and specific debris mitigation guidelines, or even requirements, than would possible for political or other reasons at a governmental or intergovernmental level.

Additionally, insurers may be able to procure space situational awareness data (SSA) for their insureds as a group, and provide recommendations to their insureds regarding whether or not to undertake maneuvers from a risk perspective when an SSA provider advises such maneuvers. Ultimately, awareness and exploration of such options is the first step to developing innovative solutions to foster the development of a sustainable space industry and successful space traffic management. There is an incentive for insurers to promote use of these services to protect their insured assets.[66]

There are a number of ways in which insurers can promote the safe operation of space objects. These strategies include repurposing solutions that have been proposed for other actors. For example, one author has suggested that "a tax or fee levied on both operators of both launch vehicles and spacecraft to account for their impact on elevating collision risks for (current and future) space fleets" would be one option.[67] Instead of a tax levied by a governmental authority that would likely create a forum shopping race to the bottom for space debris regulation, an insurer or group of insurers could either offer discounts for meeting more stringent debris mitigation requirements, or could require additional premium from those entities not undertaking a sufficiently robust debris mitigation plan. Unlike nationally imposed regimes, insurers can implement their policies across international boundaries, reducing "possibilities of debris "leakage" if operators of spacecraft divert their launch and mission control activities to countries without corrective taxes."[68] (Macauley, 161)

Critical elements of debris management are collisional breakup debris, mission-related debris, and end-of-life debris. The diversity of debris creation

[65] Hanspeter Schaub et al., "Cost and risk assessment for spacecraft operation decisions caused by the space debris environment " (2015) 113 Acta Astronautica 66 at 69.
[66] Ailor, *supra* note 3 at 103.
[67] Molly K. Macauley, "The economics of space debris: Estimating the costs and benefits of debris mitigation" (2015) 115 Acta Astronautica 160 at 161.
[68] *Ibid.*

mechanisms makes accounting for debris a difficult prospect.

> Unlike smokestack pollutants, for example, the externality cannot be directly priced to automatically and optimally exploit all the debris reduction strategies. In particular, debris managers cannot observe small debris releases from craft, nor can society credibly commit to penalties for large debris generation when defunct craft may remain in (actively used) orbits for decades or more.[69]

Dealing with these diverse mechanisms requires implementation of multiple solutions, which from a technical perspective can include: orbital maneuvering capability, graveyarding capability, and/or shielding. As discussed by Molly Macauley, orbital maneuvering increases the possibility for a spacecraft to evade observable debris, graveyarding capability removes the satellite from the path of usable satellites through atmospheric burn-up or retirement to an unused orbit, and shielding that reduces damage risk and creation of additional debris in case of a collision. As discussed in the ITU recommendations on space debris mitigation, graveyarding capability requires monitoring and maintaining sufficient fuel to ensure that there will be capability to move the satellite to the appropriate graveyard orbit or de-orbit path.[70] Additional steps to be taken can include de-energizing batteries, propellant, and other systems and augmenting the satellite to improve the ease of tracking for conjunction assessment.[71] All of these would be documented in a project's technical specifications and an insurer with sufficient technical specialization could price a premium accordingly not only with the general risks faced by the design, but also for debris mitigation which, importantly, includes collision avoidance technologies.

Some new technologies designed to decrease the cost and difficulty of placing a satellite in orbit actually increase risk from a space traffic management perspective. For example, satellite operators are now implemting efficient, low thrust transfer in order to insert their satellites into the correct orbit. Because these transfers use low thrust, the slow travel through altititue ranges creates a greater potential for collision or radio frequency interference.[72]

As explained in mathematical detail in Molly Macauley's article, there are means to determine an economic impact of likely debris creation and debris mitigation strategies in order to appropriately price such an endeavor. The U.S. Joint Space Operations Center (JSpOC) provides warning of possible satellite collisions, generally 72 hours in advance, but it is ultimately up to the satellite operator to

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[69] *Ibid*.

[70] *International Telecommunication Union Radiocommunication Sector,* "Environmental protection of the geostationary-satellite orbit" (2010) Recommendation ITU-R S.1003-2 at 6.

[71] James D. Rendleman & Sarah M. Mountin, "*Responsible SSA Cooperation To Mitigate On-orbit Space Debris Risks*" (2015) Recent Advances in Space Technologies (10.1109/RAST.2015.7208459) at 3.

[72] Ailor, *supra* note 3 at 100.

determine whether or not to perform an avoidance maneuver.[73]

The decision taken involves a cost-benefit analysis, balancing on the one hand a risk of collision and on the other the mission disruption, use of propellant or other resources, and any risks associated with the maneuver. Insurers may be in a position to advise insured satellite operators regarding collision avoidance maneuvers if satellites are equipped in accordance with insurer requirements or recommendations. A centralized unit within a space insurer could be created to provide such a service utilizing both actuarial data and experience from insuring a large number of satellites, for a fee or built into the cost of the policy.

Insurers can also purchase services through the Commercial Space Operations Center (ComSpOC) or other such emerging services for collision avoidance and manage notifications for insureds. ComSpOC offers a "facility that fuses satellite-tracking measurements from a continually growing global network of commercial sensors" generating highly accurate space situational awareness data.[74] There are historical precedents for insurers undertaking such specialized, technical mechanisms in order to ensure the safety and sustainability of the insured industries, for example the Hartford Steam Boiler Inspection and Insurance Company.[75] Better tracking data could also help insurers and regulators to verify that operators are conforming to standards and technical plans in their satellite operations.[76]

Finally, insurers can contribute positively to both better space weather traffic forecasting and preparedness for space traffic weather occurrences in several ways: 1) put in place methods to contribute to a greater understanding of extreme space weather and the impacts of normal and extreme space weather on infrastcuture, 2) assist insureds in being prepared to mitigate the effects of a space weather event, and 3) provide data on space weather threats to insureds. Every functioning satellite is subjected to the space environment, which includes solar winds, micrometeoroids, and other forces that can have a negative impact on the operation of a satellite's electronics, solar panels, and other systems.[77] Effects on space infrastructure can include "electrostatic charging, degradation of electronics and solar-cell damage, memory bit-flips, atmospheric drag that affects the satellite's orbit, loss of stability (star tracking), etc."[78] Ideally, satellites could be fitted with onboard sensors that could provide data on the space environment to a central data clearinghouse for the purpose of predicting space weather and providing information on current status. Some satellites in GEO are already equipped with sensors intended to measure the satellite's surface charge.[79] Telemetry data could also contribute positively to this set of information. In terms of preparedness,

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[73] Rendleman & Mountain, *supra* note 71 at 3-4.

[74] "Overview" online: *ComSpOC*, (https://comspoc.com).

[75] Glenn Weaver, *The Hartford Steam Boiler Inspection and Insurance Company 1866-1966* (Hartford: Connecticut Printers, 1966).

[76] Ailor, *supra* note 3 at 101.

[77] *Ibid.*

[78] Krausmann, *supra* note 10 at 4.

[79] Ailor, *supra* note 3 at 101; Krausmann, *supra* note 10 at 4.

satellites can be required to maintain maneuvering capability, built-in redundancies in case of space weather damage, and other technical attributes that harden a satellite in case of adverse conditions in the space environment.

Much like with possible conjunction data, insurers could provide guidance to insureds on which steps may be appropriate to take in reaction to an early warning regarding a space weather event. In case of a space weather event warning, lines of communication, responsibilities, and reactions need to be put in place ahead of time.[80] Insurers could help build this plan with their insureds and build them into policy language.

V. Final Remarks

The interconnectedness between space insurance, space traffic management, and the legal and regulatory aspects of space activities can be very complicated. This paper has attempted to demonstrate some of the ways in which that is true, and some possible ways this interconnectedness can contribute to solving real problems of space insurance and space traffic management today.

Insureds are already under a strict contractual obligation to provide technical and non-technical data in the form of underwriting information and a failure to provide this information can result in the denial of a claim.[81] Not only are technical details required by the insurer in order to initially underwrite the policy, but space insurance policies typically contain a material changes condition requiring that the insured notify the insurer of such material changes. Failure to notify can result in lack of coverage in cases where changes led to a loss.[82] Thus, the kinds of technical data that would be necessary for many of the above-discussed options for insurers are already being provided by the insureds.

This transfer of information, however, can be tricky due to the implementation of export controls. Satellites and related technologies have generally fallen under the set of regulations known as the International Traffic in Arms Regulations (ITARs), which are administered by the U.S. Department of State,[83] though the National Defense Authorization Act of 2013 has authorized the U.S. president to move satellite technologies from the ITAR list to the Commerce Control List (CCL).[84] Exporting, in the context of ITARs, is defined broadly and includes not only physically sending or taking an article beyond the borders of the U.S., but also transferring control or ownership (including on-orbit transfer), and notably disclosing technical data to foreign persons (in the U.S. or elsewhere,

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[80] Krausmann, *supra,* note 10 at 8.

[81] Philippe Montpert, "Space Insurance" in Contracting for Space, Lesley Jane Smith & Ingo Baumann, eds (Burlington: Ashgate, 2012) at 285.

[82] Tucker, *supra* note 4 at 128.

[83] U.S. Department of Commerce & Federal Aviation Administration, Introduction to US Export Controls for the Commercial Space Industry (2008), available at < http://www.space.commerce.gov/library/reports/2008-10-intro2exportcontrols.pdf>.

[84] *National Defense Authorization Act for Fiscal Year 2013*, US Pub.L. 112-239.

including oral or visual disclosure).[85] There are not many insurers worldwide that maintain specialized space risk departments. Those that do are based in the U.S., U.K., France, Italy, Switzerland, and Germany.[86] Export controls' applicability to technical data furnished to insurers, causing serious difficulty obtaining quotes for insurance premiums and obtaining reinsurance.[87] Where such a significant proportion of total cost of a project is dedicated to insurance premium, barriers to both price and policy shopping are highly undesirable. Furthermore, with the shifting U.S. export control regulations, consistent monitoring is necessary for efficient and effective compliance.[88] Additional data sharing and information pooling with non-American insurers as recommended in this paper could prove to make the export controls situation even more complicated. Thus, it is important to be aware that space insurance does not exist in a vacuum (even though space activities do), and that it is important to analyze the comprehensive ramifications of any proposed solutions.

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[85] 22 CFR § 120.17.
[86] Montpert, *supra* note 81 at 286.
[87] Matthias Creydt and Kay-Uwe Horl, "Export Control Issues in Space Contracts" in Contracting for Space, Lesley Jane Smith & Ingo Baumann, eds (Burlington: Ashgate, 2012) at 293.
[88] *Ibid*.