Right of Way for On-Orbit Space Traffic Management

Nathan A. Johnson[*]

Abstract

There is currently no single, legally-binding authority to issue instructions for two satellites on a collision course to take evasive maneuvers. Satellite operators are under the authorization and continuing supervision of their separate launching states, whose authority to direct their satellite operators is defined by their own national legislation. But each state is guided by self-interest to oversee satellites launched from their jurisdiction because of a unique provision of Space Law, which holds the launching state, and not the private operator, directly liable for damage caused by a satellite. And as a practical matter, each satellite operator is also presumably guided by their own commercial self-interest to preserve the usefulness of their satellite. Likewise, all parties would be motivated to avoid need for a fault determination of in-space damage under the Liability Convention. This paper will outline different suggestions for right-of-way rules for space objects, as a "set of technical and regulatory provisions," based on a limited history of practice, rules in comparative transportation regimes, and previous studies by other groups such as the ISU. And for each suggestion, further outline the implications for space operations, fault-based liability, and effectiveness in "promoting safe [...] operations in outer space [...] free of physical or radio-frequency interference."

I. Introduction

At first, it sounds like a problem from a math textbook. A satellite in low-Earth orbit (LEO) is traveling at 17,000 miles, or 27,400 kilometers, per hour. A second satellite, from a different country, is also traveling in low-Earth orbit, but at a different inclination, and is also traveling at 17,000 miles per hour. That is when the problem takes a turn. The first satellite operator receives a call from the US Military's Joint Space Operation Center (JSpOC). They have completed a conjunction analysis, which solves the original math problem, and have warned you that there is a significant possibility your satellite will travel dangerously close to the second satellite. Now the problem becomes whether you choose to move your satellite in the hope of avoiding a collision.

* University of Nebraska, College of Law, United States, nathan.johnson@huskers.unl.edu.

This is only one of the problems listed under the heading of Space Traffic Management. But all of the problems exist because Outer Space is a different environment, both from an operational and legal perspective, than Air Space. In terms of law, the major difference between National Air Space and Outer Space is the difference between sovereign jurisdiction and *res communis*, or common property. While the Chicago Convention recognizes that "every state has complete and exclusive sovereignty over airspace above its territory",[1] the Outer Space Treaty explicitly recognizes Outer Space as "the province of all mankind."[2]

So, from a legal perspective, there is currently no single binding authority to issue instructions for two satellites on a collision course to take evasive maneuvers. Satellite operators are under the authorization and continuing supervision of their separate launching states,[3] whose authority to direct their satellite operators is defined by their own national legislation. But each state is guided by self-interest to oversee satellites launched from their jurisdiction because of a unique provision of Space Law, which holds the launching state, and not the private operator, directly liable for damage caused by a satellite.[4] And as a practical matter, each satellite operator is also presumably guided by their own commercial self-interest to preserve the usefulness of their satellite.

So in the event that two actively operated space vehicles were to cross paths, there are also no clear rules-of-the-road to tell those operators who should move first. They would be motivated to preserve their vehicles, and avoid any need to trigger the need for fault determination of in-space damage under the Liability Convention.[5] But they would also be motivated to preserve the usefulness of their vehicle, and expend as little fuel as possible, and move as little as necessary out of their operating parameters.

And just like that, the math problem becomes an economic and legal problem. A problem that seems increasingly likely, as more and more observers note that "[a]s the number of orbiting objects increases with the launching of new applications and the accumulating debris of old ones, spacefarers [...] will need to agree on the codes of behavior that will permit them to ensure compliance with one critical law: two objects cannot occupy the same space

1 International Civil Aviation Organization (ICAO), Convention on Civil Aviation ("Chicago Convention"), 7 December 1944, (1994) 15 U.N.T.S. 295, at Art. I; available at: www.refworld.org/docid/3ddca0dd4.html [accessed 2 Nov 2014].

2 Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies, Jan. 27, 1967, 18 U.S.T. 2410, T.I.A.S. No. 6347, 610 U.N.T.S. 205, at Art. I; [hereinafter Outer Space Treaty].

3 Outer Space Treaty, *supra* note 2, at Art. VI.

4 Convention on International Liability for Damage Caused by Space Objects, Mar. 29, 1972, 24 U.S.T. 2389, T.I.A.S. No. 7762, 961 U.N.T.S. 187, at Art. II; [hereinafter Liability Convention].

5 *Id.,* at Art. III.

at the same time."[6] These concerns that the space environment is becoming more crowded lead to calls for a new solution to Space Traffic Management.
This paper will outline the realities of this Space Traffic Management problem in both the economic and legal sense, which overlap in multiple ways. First, any Space Traffic Management solution must be cost-effective, without inhibiting access to space, but actually ensuring the safety of the operational environment. Second, any Space Traffic Management solution must recognize the freedom of all states to exercise jurisdiction over their own satellites, while respecting the interests of other states in orbit. In the end, the current practices of satellite operators and space-faring states may prove a sufficient basis for standards of right-of-way in orbit, without requiring new difficult-to-ratify treaties, or costly new infrastructure and institutions. In the end, there will be more questions than there are answers. But the goal is to find the right questions to ask in order to develop the best standards for a future Space Traffic Management solution.

II. The Economic Argument for Space Traffic Management

As previously stated, both the launching state and the satellite operator have a financial self-interest in avoiding collisions in Outer Space. The operator's self-interest is based on their business in having a satellite in the first place. Individual satellites can range in cost from $ 290 million,[7] down to the current trend of cube or picosats as low as $ 7500.[8] Add to that the cost of launch, which can also range from $ 50 million up to $ 400 million;[9] and the cost of operation, which can vary depending on the business model. Of course, a satellite operator will weigh the cost of their system against the hopeful revenue the business will generate. Satellite operators have the option of purchasing insurance to secure their financial interest in the profit generated through operation of the satellite, against any potential loss.
So, for the satellite operator, their financial interest in avoiding a collision in outer space is based first on how much profit they stand to lose from the possible loss of their satellite, against the cost of moving their satellite. And moving a satellite does have its costs. If the operational parameters of the satellite

6 Michael K. Simpson, "The Need for Space Traffic Management," Space Safety Magazine, Iss. 4 Summer 2012, available at www.spacesafetymagazine.com/wp-content/uploads/2012/06/Space%20Safety%20Magazine%20-%20Issue%204%20-%20Summer%202012.pdf [last viewed 02 Nov 2014].

7 "The Cost of Building and Launching a Satellite" GlobalCom, available at www.globalcomsatphone.com/hughesnet/satellite/costs.html [last viewed 2 Nov 2014].

8 Sandy Antunes, "Your Own Satellite: 7 Things to Know Before You Go," Make, Apr. 11, 2014, available at http://makezine.com/2014/04/11/your-own-satellite-7-things-to-know-before-you-go/ [last viewed 2 Nov 2014].

9 *Supra* note 7.

require it to remain in a certain trajectory, then moving it out of that trajectory could mean loss of service. Also, physical maneuvering requires fuel, which could be used later to extend the life of the satellite. So an avoidance maneuver could shorten the useful lifespan of the satellite.

The launching and/or operating state's financial self-interest is twofold. First, a launching state is likely interested in the economic success of an industry launching out of its jurisdiction. The operating state is likewise interested in maintaining whatever domestic services those satellites may be providing, and keeping their population invested in the reliability of that industry. Consumer confidence should mean stable markets and increased prosperity for any state.

The second reason for a launching state's financial self-interest is based on what defines a launching state. Article VII of the Outer Space Treaty declares that any state "that launches or procures the launching of an object into outer space ([...] or) from whose territory or facility an object is launch, is international liable for damage to another [state.]"[10] This liability is further defined in the Liability Convention, which differentiates between absolute liability for damage "on the surface of the Earth or to aircraft in flight[,]"[11] and fault-based liability for damage "caused elsewhere than on the surface of the Earth[.]"[12] These provisions together mean that the launching state of a satellite facing a possible collision must consider whether damage will occur for which they will be held financially at-fault.

The problem with this risk analysis is that there are no identifiable standards for determining fault for in-orbit damage. And there is no binding mechanism for two launching states to settle a potential dispute for an in-orbit collision. The Permanent Court of Arbitration in The Hague has published "Optional Rules for Arbitration of Disputes Relating to Outer Space Activities."[13] However, these rules, like the many other available international dispute settlement mechanisms, are optional. And options decrease certainty, which is necessary for any state to make a determination for financial risk.

So, the launching state's financial self-interest in acting to avoid a satellite collision comes down to whether they believe there will be any need to determine fault; and if fault is found against them, whether they will be bound to pay. This is also assuming that any loss resulting from an in-orbit collision will be claimed through Space Law, and redress will not be sought through other channels, such as economic loss through another body like the World Trade Organization. Or that the collision will not result in a less adjudicatory and more political conflict.

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10 Outer Space Treaty, *supra* note 2, at Art. VII.
11 Liability Convention, *supra* note 4, at Art. II.
12 Liability Convention, *supra* note 4, at Art. III.
13 Permanent Court of Arbitration Optional Rules for Arbitration of Disputes Relating to Outer Space Activities, Dec. 6, 2011, available at www.pca-cpa.org/showfile.asp?fil_id=1774.

Even if a launching state does submit to pay an internationally binding award, they are not necessarily bound to take the loss alone. The launching state may, as a matter of their own internal domestic law, require that the satellite operator pay back the government for the amount of the international award. In this way, the satellite operator would be indirectly liable for the damage caused. And in establishing this indirect liability, the launching state would give the satellite operator a new economic incentive to avoid an in-orbit collision, if it too determines that they will be found at fault, and their launching state may come back to them to help pay the award.

These are considerations satellite operators and launching states must always consider. However, when considering this against the cost of any potential new Space Traffic Management regime, the focus must be put back on the potential loss. If a satellite operator loses their satellite in a collision, regardless of whether they are at fault for the damage to the other satellite, their cost may be mitigated by any insurance they purchased, or may be mitigated by the depreciated value of their satellite. Likewise for any damages sought by an adverse satellite operator in a claim for liability payment. The bottom line is, if the cost of losing a satellite and/or paying for the loss of someone else's satellite, is still less than the cost of a new Space Traffic Management regime, then the satellite operator and the launching state will not support it.

A number of these economic factors depend on the outcome of legal determinations. And many of the proposals for how to avoid future damages equally depend on new legal standards for how satellite operators and launching states should direct their actions in the face of possible collision.

III. The Legal Arguments for Space Traffic Management

As stated in the introduction, Outer Space exists in a legal status of *res communis*,[14] where every state's law applies, but only as to space objects under their jurisdiction.[15] Each state must co-exist in the space environment. First, it is important to understand the importance of sovereign jurisdiction on the one hand, and international obligation on the other. Second, a small number of examples exist of international organizations promoting standards in space operations. Finally, there are current suggestions for future Space Traffic Management standards, but their adoption still depends on the mechanisms of international law.

III.1. Sovereign Jurisdiction and International Obligations

Space Law is a product of modern international law, which recognizes the concept of Westphalian sovereignty: each nation-state should enjoy the freedom to control its own territory, without its integrity being threatened by

14 See generally, Outer Space Treaty, *supra* note 2, at Art. I.
15 Outer Space Treaty, *supra* note 2, at Art. VIII.

outside forces.[16] At the same time, Space Law exists in one of the most unique environments in modern international law. *Res communis* means that space belongs to all nations,[17] as opposed to *res nullius*, meaning the lack of ownership or law, which was usually an excuse for a state to conquer and fill the void. So, space is not to be conquered by any state, but rather enjoyed by every state.

The problem becomes, how do multiple states enjoy the space environment under separate and simultaneous sovereignty? Separate sovereignty, over their individual space objects, but simultaneous to other sovereign space objects in the space environment. International Law exists to deal with the interaction of two sovereign states. However, those interactions occur, more often than not, *on* someone's territory, *in* someone's jurisdiction. Take for instance Air Space Law, which is largely governed by the Chicago Convention. By international agreement, separate sovereign states agree to certain rules and behaviors for when an aircraft from one state crosses the national air space of another. However, in Outer Space, there is no delineated national air space for one state to be granted jurisdiction.

The Space Law treaties settled for a system of general international obligations, some of which have been mentioned, including most importantly the Liability Convention.[18] Other obligations include a general prohibition on interfering with another state's operations,[19] a duty to provide aid if possible,[20] and a requirement to register the launch of a new space object.[21] Of these obligations, the registration requirement is applicable to the problem of Space Traffic Management because it includes a list of orbital parameters which must be part of the registration.[22] This represents the beginning of a system to track, or at least predict, where other space objects are supposed to be. In essence, the beginning of space situational awareness.

The Space Law treaties are formal, officially worded, and binding on signatory states. And most argue that the provisions in the Outer Space Treaty, based on the overwhelming support of almost every spacefaring state, rise to the level of customary international law; which is to say that the provisions of the Outer Space Treaty are binding even on countries who have not signed it. However, they represent only one kind of international obligation.

16 United Nations, Charter of the United Nations, 24 October 1945, 1 UNTS XVI, at Art. 2, available at www.un.org/en/documents/charter/ [accessed 2 Nov 2014].
17 See generally, Outer Space Treaty, *supra* note 2, at Art. I.
18 See generally, Liability Convention, *supra* note 4.
19 Outer Space Treaty, *supra* note 2, at Art. IX.
20 See generally Outer Space Treaty, *supra* note 2, at Art. IX ("principle of cooperation and mutual assistance").
21 Convention on Registration of Objects Launched into Outer Space, Nov. 12, 1974, 28 U.S.T. 695, T.I.A.S. No. 8480, 1023 U.N.T.S. 15 [hereinafter Registration Convention].
22 *Id.,* at Art. IV(1)(d).

States can enter into non-treaty agreements, or "soft law"; sometimes a bilateral agreement between just two states, and sometimes a multilateral agreement between a small group of states. One such agreement which has been in development is the International Code of Conduct for Outer Space Activities.[23] What started as the European Code of Conduct has grown to include input from states outside the EU, and represents a growing consensus by the various stakeholders in new standards for enhancing the "safety, security, and sustainability of all outer space activities."[24] The Code of Conduct is itself partially based on a set of UN Guidelines for Space Debris Mitigation, which was drafted by the Committee on the Peaceful Uses of Outer Space.[25] And while these voluntary guidelines, drafted by various states with the involvement with different levels of officials does not represent the same exercise in diplomacy as an official treaty negotiation, they can have an effect. Many observers have noted that these "soft law" obligations can be "incorporated into the means by which normative standards of appropriate international action is regulated."[26] In essence, the new rules have to start somewhere.

III.2. Examples of International Organizations Promoting Space Traffic Management Standards

The UN Committee on the Peaceful Uses of Outer Spaces (COPUOS) is one of the longest operating international bodies in the field of international Space Law. Their power to effect law is limited, as they can only research and develop drafts to submit to the larger UN body. At which point, the UN member states have the power to adopt new law and treaties to varying extent. But the Committee's standing and influence is still felt by spacefaring states.

Another body, which actually predates the UN, is the International Telecommunications Union (ITU). What started as the International Telegraph Union in order to harmonize standards and increase communication between states, took on new relevance in the age of radio signals and later satellite signals. Today, the ITU is a sub-body of the United Nations, and is another system of voluntary entry, by which states agree to allocate positions in Geostationary Orbit (GEO). By its nature, GEO is a valuable orbit, allowing for fixed satellite positioning to

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23 "DRAFT International Code of Conduct for Outer Space Activities," European Union (March 31, 2014), available at www.eeas.europa.eu/non-proliferation-and-disarmament/pdf/space_code_conduct_draft_vers_31-march-2014_en.pdf.

24 *Supra* note 23, at Preamble.

25 "Space Debris Mitigation Guidelines of the Committee on the Peaceful Uses of Outer Space," United Nations Office for Outer Space Affairs, Vienna, January 2010, available at http://orbitaldebris.jsc.nasa.gov/library/Space%20Debris%20Mitigation%20Guidelines_COPUOS.pdf.

26 Gérardine Meishan Goh, "Softly, Softly Catchee Monkey: Informalism and the Quiet Development of International Space Law," 87 Neb. L. Rev. 725, 2009.

provide continuous connection and service with points on the ground. And rather than becoming a crowded mess, the ITU assigns slots to companies that apply to use them, within certain guidelines. These include frequency and spectrum use, as well as general physical parameters.[27] The goal is to provide the sort of certainty one would have in property rights, of freedom from harmful interference and interloping.

And by most accounts, all states seem to comply with the ITU system. It is a successful joint effort by all states who voluntarily enter into the organization. However, the ITU does include certain provisions for dispute settlement, should one arise. The efficacy of dispute settlement in a non-binding, "soft law" organization is not as encouraging. Take for instance the case of France versus Iran, in which the Eurobird 2 satellite, operated by Paris-based Eutelsat, is suffering from signal interference by Iran's Zohreh 2, hosted by Arabsat's Bard spacecraft.[28] After French officials submitting a complaint to the ITU, the response has been less than effective. The ITU has urged Iran to stop using the frequency causing the interference, but Iran has contested that they have maintained their right to do so.[29] Without any binding enforcement authority, the ITU is powerless to force anyone to stop doing anything in GEO.

However, to the credit of the ITU regime, GEO has provided 50 years of valuable service to the world's population, and has benefited the many states who have launched and operated satellites there. Of course, another detraction of the ITU is the claim that it has benefited some states over others, namely colonial, 1st world states over emerging, 2nd world states. This led to an effort by some equatorial states to change Space Law with the Bogota Declaration. It would have taken back the *res communis* status of GEO, and ceded it exclusively to the states along the equator, above whose territory GEO exclusively exists. This attempt at changing the "hard law" was unsuccessful, and the ITU still stands as the practical regulator over GEO.

There are many more orbits for satellites to use, and even as the ITU regime is extended to apply to non-GEO orbits,[30] no single, unified, centralized international authority oversees their use. But some satellite operators have started to band together to provide useful information to each other. The Space Data Association (SDA) operates as a sort of bridge between the Registration Convention and JSpOC. Where the registration convention is sup-

27 "Space Traffic Management: Final Report", International Space University, Summer 2007, at §1.6.2; available at https://isulibrary.isunet.edu/opac/doc_num.php?explnum_id=99.

28 Peter B. de Selding, "Iran's Claims About Satellite Service Try International Regulatory Regime," SpaceNews, April 8, 2011, available at http://spacenews.com/irans-claims-about-satellite-service-try-international-regulatory-regime/.

29 *Id*.

30 Constitution of the International Telecommunications Union (2010 Ed.), *available at* www.itu.int/en/history/Pages/ConstitutionAndConvention.aspx.

posed to provide a basic flight plan for a registered space object, the SDA is meant to "coordinate operator-provided data and use it to supply the best possible estimates."[31] And where JSpOC is actively monitoring hundreds of thousands of space objects (including debris), the SDA is meant to track satellites based on the theory that "no one knows better than the operators where their satellites are at any moment."[32]

The SDA is a private, non-for-profit organization of 14 satellite operators, which is not a comprehensive list of all parties with interests currently in orbit, nor represents a comprehensive dat. However, it is the sort of voluntary organization which can provide increasingly useful information to private operators and public state agencies in avoiding potential collisions, and form the basis of a new Space Traffic Management network.

III.3. New Standards for Space Traffic Management

While state parties have explored the use of soft law, and private satellite operators have explored working together, other interested parties have made great strides in studying the problem of Space Traffic Management, and have been delivering concrete suggestions for new rules and regimes to implement.

The International Academy of Astronautics (IAA) published a Cosmic Study on Space Traffic Management back in 2005.[33] The created clear definition to focus on as their starting point:

Space traffic management means the set of technical and regulatory provisions for promoting safe access into outer space, operations in outer space and return from outer space to Earth free from physical or radio-frequency interference.[34]

And with this in mind, they produced a number of findings, and drafted a model international inter-governmental agreement in three parts:

1. Securing the Information Needs
2. Notification System
3. Traffic Management

The draft also includes steps to hand over the operative oversight of such a regime to "an already existing forum or organization ([...] or) handled by a non-governmental entity tasked by the State parties[.]"[35]

Most valuable to this paper are the elements listed under Traffic Management, particularly: Zoning (selection of orbits), Right of way rules for in-orbit

31 Simpson, *supra* note 6.
32 *Id.*
33 "Cosmic Study on Space Traffic Management," International Academy of Astronautics, 2006, available at http://iaaweb.org/iaa/Studies/spacetraffic.pdf.
34 *Id.,* at Executive Summary Part II.
35 *Id.,* at Executive Summary Part V.

phase(s), and Prioritization with regard to maneuver.[36] First, the IAA notes that an effective Space Traffic Management regime would restrict activities to certain orbits, to decrease interference and increase predictability. They also note that some national licensing of space activities does effectively limit some activities in different orbits. However, a comprehensive effort by more space-faring states would increase the stability of use in those orbits.[37]

Second, the study promotes the adoption of right of way rules and prioritization for maneuvers by comparing the space environment to both maritime and air traffic.[38] Specifically in air traffic, the IAA notes that state authorities have applied, "as much as possible, the uniform 'standards and recommended practices' developed by ICAO."[39] ICAO is the International Civil Aviation Organization, a specialized agency of the UN, somewhat similar to COPUOS. But the focus should be on ICAO's example of relying on "standards and recommended practices." The history of those standards are based on years of operation of civilian aircraft, including all of the incidents, non-incidents, and regulations tested and improved over time. To apply this to the space environment, satellite operators and state agencies will need to compile, compare, and continue their process of drafting new standards, based on their cumulative experience in operating in the space environment.

After the IAA Cosmic Study, another group from the International Space University, published their own Space Traffic Management Final Report, in 2007.[40] They considered the findings and recommendations of the IAA, conducted an independent analysis of the Space Traffic Management problem, and issued their own recommendations for technical traffic rules and environmental rules. They specifically addressed the issue of collision avoidance, and determined the best rules would "provide the spacecraft owner-operators with the information and tools to help make educated choice and to improve satellite safety."[41] The conclusion was that the satellite operator is currently in the best position to make the cost/benefit analysis to determine if and how to maneuver to avoid a collision. And that good data was necessary to enable them.

As stated in Part I, any operator decision to maneuver away from a collision is weighed against the cost of the fuel involved versus the cost of a satellite loss. The ISU report outlines three scenarios, each with a different suggest outcome. (1) In the case of two maneuverable satellites, they should each

36 *Id.,* at Chapter 4.2.
37 See generally "Cosmic Study" *supra* note 33, at Executive Summary IV ("question of harmonizing … the building blocks for assuring technical safety").
38 *Id.,* at Executive Summary IV.
39 *Id.,* at 12.
40 "Space Traffic Management: Final Report," *supra* note 27.
41 Presentation, "Space Traffic Management," International Space University, 2008, available at www.unoosa.org/pdf/pres/stsc2008/tech-05.pdf.

maneuver to avoid collision, and thereby share in the costs. (2) In the case of two maneuverable satellites, but only one actor maneuvers to avoid collision, then the cost should be borne by the actor who does not have the right-of-way. (3) In the case of only one maneuverable satellite, then the non-maneuverable satellite should indemnify the other actor for any resulting loss of service.[42]

The ISU report also outlines currently available forums for dispute settlement, to which a future Space Traffic Management regime could turn to.[43] However, as previously discussed, voluntary soft-law organizations have proven ineffective so far in settling space law disputes. That is why the ISU outlines a path to turn over any Space Traffic Management regime to an international third-party organization, with the major benefit being a binding, or at least more authoritative set of Arbitration Procedures.[44]

In the end, both the IAA and the ISU support restricted activities in zoned orbits, promoting data sharing between states and private operators to raise everyone's space situational awareness, and both foresee spacefaring states at some point in the future reaching a more comprehensive and binding agreement on the management and adjudication of traffic in space. But the standards for determining right of way still rests upon compiling the best practices of both states and private operators.

III.4. Comparative Standards in Other Modes of Transportation

In studying the potential development of a Space Traffic Management regime, it is helpful to look at the rules that have developed in other modes of transportation, particularly aviation and maritime. Both examples showcase the culmination of decades of use and best practices, but also have limitations in their application to the unique characteristics of orbital traffic.

III.4.1. Aviation

The International Civil Aviation Organization has represented a unified codification of principles and techniques for air navigation for over 65 years.[45] Countries participate in these standards to participate in an integrated global aviation network. And in those standards, the definition of right-of-way states: "The aircraft that has the right-of-way shall maintain its heading and speed."[46]

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42 "Space Traffic Management: Final Report," *supra* note 27, at 5.2.5.
43 *Id.,* at 5.1.
44 *Id.,* at 5.1.10.
45 "About ICAO," International Civil Aviation Organization, *available at* www.icao.int/about-icao/Pages/default.aspx (last visited April 20, 2015).
46 Convention on International Civil Aviation, Annex 2 (10th Ed. July 2005) [hereinafter ICAO Annex 2] at 3.2.2, *available at* www.icao.int/Meetings/anconf12/Document%20Archive/an02_cons%5B1%5D.pdf.

As applied to Space Traffic Management, this definition would provide greater certainty to spacecraft operators in what party would bear the burden of maneuvering to avoid collision. To that end, the ICAO standards state that the non-priority aircraft "shall avoid passing over under or in front of the other, unless it passes well clear and takes into account the effect of aircraft wake turbulence."[47]

The standards include default courses of action for both parties in a potential collision, depending on the situation. For head-on collisions, the standards direct both air craft to "alter its heading to the right."[48] This is likely not applicable to most potential situations in Space Traffic Management, since orbital mechanics dictate that satellites all travel in the same direction.

The ICAO standards do address two other scenarios that are more likely to be seen in orbital traffic, based on visual avoidance confirmation. First, for two aircraft that are "converging," the standards direct "the aircraft that has the other on its right shall give way (with exception)."[49] And for an aircraft "overtaking" another, the right-of-way is given to the "aircraft being overtaken," and directs the other aircraft to "alter its heading to the right."[50] These collision trajectories are more likely to be found in orbital traffic patterns, but as will be discussed, their solutions may not also be as applicable or easy to execute in the space environment.

However, these standards and best practices give clear guidance to individual operators on the best course of action to take in case of a projected collision, and an agreed course of action between all operators, so that no coordination is necessary between aircraft to predict what the other party will do. This type of certainty and predictable action helps support a safe and stable air traffic system.

Technology has also advanced to give aircraft more sophisticated ad-hoc solutions to individual situations. The Airborne Collision Avoidance System (ACAS) is a piece of equipment on board an aircraft, independent of air traffic control ground systems, which uses transponder signals of nearby aircraft to track their altitude and range.[51] When the system detects another aircraft in the vicinity, the two systems will coordinate to find a solution for both

47 ICAO Annex 2, *supra* note 46, at 3.2.2.1.

48 *Id.*, at 3.2.2.2.

49 *Id.*, at 3.2.2.3 Those exceptions include a hierarchy based on type of aircraft, including "power-driven heavier-than-air aircraft" giving way to "airships, gliders and balloons;" within which airships give way to gliders and balloons, and gliders giving way to balloons.

50 *Id.*, at 3.2.2.4.

51 See *generally* Airborne Collision Avoidance System (ACAS) Manual, ICAO Doc. 9863 AN/461 (1st ed. 2006), *available at* www.icao.int/Meetings/anconf12/Document%20Archive/9863_cons_en.pdf.

aircraft to avoid collision. This solution is delivered to the aircraft operators as a Resolution Advisory (RA), and the operators are required to comply.[52]

The ACAS standard is a promising concept for Space Traffic Management, giving spacecraft operators the individual power to assess and coordinate solutions to possible conjunction. However, before being able to implement an ACAS system for orbital traffic, spacecraft operators will need to advance technology for individual space situational awareness, which can compensate for the exponentially greater speed, and related greater distances for safe operation. These same limitations apply to spacecraft operators being able to use the previous visual avoidance standards on their own, but would still be useful with enough advance warning from tracking systems like JSPOC and SDA.

III.4.2. Maritime

Analogous standards for maritime traffic were codified in 1972 in the Convention on the International Regulations for Preventing Collisions at Sea.[53] Maritime traffic typically travels at speeds slower than aviation, making it less applicable to high-speed orbital traffic. However, certain single-plane principles of surface vessels may find applicability to zoned orbital traffic.

First, the Convention is made applicable to "all vessels upon the high seas,"[54] which mirrors the non-sovereignty of the space environment. The Convention also gives leeway to special rules "made by an appropriate authority," and vessels "of special construction," requiring that they "conform as closely as possible."[55] This type of flexibility would be very important for Space Traffic Management for purposes of permanent spacecraft, like the ISS, and applying the international agreement of the ISS as an "appropriate authority."

One of the first requirements is for every vessel to "maintain a proper lookout by sight and hearing as well as by all available means[,]"[56] as well as "use all available means appropriate [...] to determine if risk of collision exists."[57] This would apply to Space Traffic Management requirements for operators to have access to space situational awareness, either aboard their own spacecraft, or through tracking organizations.

The most applicable scenario to orbital traffic would be what the Convention calls a "crossing situation."[58] The rule states that "the vessel which has the other on her own starboard side shall keep out of the way."[59] This designation

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52 *Id.*, at Table 6-1.
53 Convention on the International Regulations for Preventing Collisions at Sea, 1972 [hereinafter COLREGS].
54 COLREGS, *supra* note 53, at Rule 1.
55 *Id.*
56 *Id.*, at Rule 5.
57 *Id.*
58 *Id.*, at Rule 15.
59 COLREGS, *supra* note 53, at Rule 15.

of which vessel has right-of-way comes with subsequent responsibilities, for the non-priority vessel to "take early and substantial action to keep well clear,"[60] and the right-of-way vessel to "keep her course and speed."[61] The right-of-way vessel does have options to take their own corrective action, where "it becomes apparent to her that the [other] vessel is not taking appropriate action[,]" or when "collision cannot be avoided by the action of the [other] vessel alone[.]"[62]

There are other recognitions of responsibility in the Convention, including the standard for vessels "to keep out of the way of: (i) a vessel not under command; [and] (ii) a vessel restricted in her ability to manoeuvre[.]"[63] These qualifications require a certain amount of actual, reasonable, or observable knowledge of the other vessel, and would require the same for spacecraft in orbit.

These maritime standards offer the same predictability and stability for individual operators on the high seas, without a centralized authority to direct and adjudicate traffic, and allow operators across sovereignties and languages to coordinate traffic.

III.5. Role of Standards in Determining Responsibility and Liability

The standards for right-of-way as discussed in this paper focus on determining between two parties in a possible conjunction who should have priority in maintaining their trajectory, and who should bear the responsibility to undertake collision avoidance maneuvers, and who should bear the burden of cost. But in discussing right of way in those terms, it is important to distinguish the legal consequences of how those terms are defined and applied.

The purpose of developing a right-of-way standard is to provide certainty to operators in how they can operate and maneuver in the space environment. That certainty is further supported by applying legal enforcement and consequences. The Outer Space Treaties provide for a direct means of enforcement in terms of liability, in particular fault-based liability for damage which occurs elsewhere than on the surface of the Earth.[64]

These possible standards for who should have right-of-way are a means to help determine that fault. Where fault can be described as the failure to maintain a standard of conduct,[65] then determining which party has the responsibility to move to avoid collision would provide a standard for determining who is at fault for a collision, and liable to pay damages under the Liability Convention.

60 *Id.*, at Rule 16.
61 *Id.*, at Rule 17.
62 *Id.*
63 *Id.*, at Rule 18.
64 Liability Convention, *supra* note 4, at Art. III.
65 Black's Law Dictionary 683 (9th Ed. 2009).

As this paper uses the term responsibility, it is important to differentiate between the responsibilities of space craft operators in how they conduct their activities, from the very specific doctrine of state responsibility. International law recognizes claims for "internationally wrongful acts," with two elements: (1) "a breach of an international obligation" (2) that is "attributable to the [responsible] State."[66] Under the doctrine of state responsibility, damages could include immaterial damage, indirect damages, or even punitive damages.[67]

Under the Outer Space Treaty, state parties do bear international responsibility for the activities of non-governmental actors, and are required to provide authorization and continuing supervision of those non-governmental activities.[68] This level of supervision could be considered as "due care" of the state party to reasonably prevent non-governmental actors from violating the terms of the Outer Space Treaty.[69]

However, the claim most useful to providing the legal certainty and recourse for space craft operators is not state responsibility, but of liability. Liability claims, with a narrower view of damages, would still be adjudicated between state parties if claimed under the Liability Convention. But the narrower scope of damages would provide a less contentious claim, and would better fit the domestic regulatory regimes of most countries,[70] and the terms of most insurance policies.

For the purposes of this paper, the term responsibility does not refer to the doctrine of state responsibility, but only to determining fault-based liability.

IV. Application of Proposed Right-of-Way Rules

While industry development and activity in space continues to grow, there is no guarantee that governments and state parties to existing treaties will take up the task to establish new laws, treaties, or regimes for on-orbit traffic. As laid out in the previous studies, the best option for spacecraft operators facing a possible conjunction with another spacecraft is to make a decision based on the best available information they can acquire.

The usefulness of that information also depends on the operator's amount of control over their spacecraft, and ideally an ability to predict or expect certain corresponding action from the other spacecraft. This is hopefully facilitated by open communication between separate spacecraft operators. However, the

66 Art. 3, Draft Articles on State Responsibility.

67 von der Dunk, Frans G., "Liability versus Responsibility in Space Law: Misconception or Misconstruction?" (1992). Space and Telecommunications Law Program Faculty Publications. Paper 21, at p. 367.

68 Outer Space Treaty, Art. VI.

69 See e.g. Art. 11(2), Art. 23, Draft articles on State responsibility, Part 1.

70 See generally FAA Regulations.

realities of identification, communication, and timeliness usually mean that operators are on their own to decide what action to take.

Both the IAA Cosmic Study, and the ISU Report hesitated to promulgate right-of-way rules for these operators, instead deferring to developing a record of best practices by operators over time, as has been done in both sea and air transportation.

However, any right-of-way rules that would develop over time would likely fall into one of three categories: granting right-of-way to (A) one party, (B) both parties, or in a special variation (C) to the least-able party (primarily for inactive space objects). Each of these categories would have different implications for responsibility, liability/fault, arbitration, and damages.

This paper will now discuss each of the three categories, and how they would affect the economic and legal issues of Space Traffic Management previously mentioned.

IV.1. Granting Right-of-Way to One Party

The first category for right-of-way would grant the right to one party, over another. This could be implemented a number of different ways, including: first in time,[71] largest mass, fastest speed. (For a variation of this, see category (C) for least-able party.)

The one thing all of this metrics have in common is that they require a comparison between the two objects in possible conjunction. So in order for this category to be implemented, it would require that as many parties as possible have access to as much information as possible, including real-time information, on all spacecraft in orbit.

One way to limit the scope of how much information a party must have access to on an emergency basis is the practice of zoning, which has been suggested in the previous studies. The reality of regular operation in orbit is that a spacecraft is not crossing paths with every object, but only with those objects in its zone. A central database for all spacecraft and space object information would still be preferable, in the event that an object controllably or uncontrollably changes zones. However, as far as private parties accessing this information, they would only need to have provisional access limited to their current zone.

If both parties have access to this information through a shared database, they should also quickly have a determination for which spacecraft qualifies for the right-of-way, depending on the eventual criteria. Once it is clear which operator has right-of-way, then it falls to the other operator to move their spacecraft out of conjunction.

71 The first-in-time standard itself could have different variations, including: first to register, to launch, to operation, all of which serve as starting points to length of time.

This determination then creates a responsibility on the part of the second spacecraft operator. Whereas under *res communis*, neither party can be denied access and use of outer space, the right-of-way determines who is harmfully interfering with the other's activities, and therefor bears the burden under the Outer Space Treaty to avoid such interference.

Such a unilateral responsibility would also result in a unilateral cost for maneuvering to avoid conjunction. Such a cost could easily be included in most private operating budgets, considering the practice of operators of large satellite constellations to launch and hold spare satellites in orbit. While the practice may be based on the fear of mechanical failure, it is imaginable that the cost of such a back-up could also be allocated to moving operating satellites out of the way and back in to place for fear of conjunction.

The unilateral responsibility would also extend to the spacecraft's possible interactions with uninvolved spacecraft. For instance, if spacecraft A were maneuvered to avoid conjunction with spacecraft B, because B had right-of-way, then spacecraft A would also be responsible for any interactions with spacecraft C, a spacecraft not previously in conjunction, but for spacecraft A's avoidance maneuver. In other words, spacecraft B would bear no responsibility to spacecraft C, even though it was because of B that spacecraft A had to move.[72]

One solution to this hypothetical would be to flow-down the right-of-way to spacecraft A. Again, in the hypothetical, spacecraft B had the first right-of-way. Now that spacecraft A has moved because of its responsibility, spacecraft A could have right-of-way in a possible conjunction with spacecraft C.

This chain of action could all happen very quickly, and require real-time updates and real-time communication between all parties involved. If a central database did indeed have as much possible information on all spacecraft and space objects in orbit, then it is possible to project the possible implications of the first avoidance maneuver, and contact any third-parties which would be implicated in subsequent avoidance maneuvers.

If on-orbit traffic were to become so congested, it would be an economic argument between spreading the cost of avoidance amongst multiple parties, or requiring the first party to bear all costs. Imagine spacecraft A bearing the responsibility and cost of avoidance not only in regards to spacecraft B, but to spacecraft C as well, and any other spacecraft it may bounce between before arriving again at a safe position.

Regardless of how many times a spacecraft without the right-of-way would have to move, each conjunction responsibility would likely also carry with it liability, particularly for inaction. The concept of having right-of-way also implies that opposing party is at fault for crossing paths. In the Liability Convention, damages caused in space are attributed by fault.

72 If not for B, A would not have come into conjunction with C.

It is possible for state practice to say that even if both parties recognize a right-of-way, they do not recognize an attached liability or fault for an actual collision. The current practice of collision avoidance includes a probabilistic conjunction assessment. As large as space is, and as fast as spacecraft and space objects are moving, there is never a guarantee that two objects will actually collide. Data used to predict conjunctions is based on best available observations, because every operator and threat assessor must depend on instrumentation on the ground or on board the spacecraft, or quickly evolving space satellite networks. No one has the scope to directly observe both spacecraft in real time in fine enough detail to give exact predictions.

As applied to liability and fault for collision avoidance, parties could agree that even though only one operator has right-of-way, the other operator has no greater control or accuracy to truly avoid a collision. Everyone is operating as best as they can. If an operator in good faith tries to follow the suggested avoidance maneuver, and inadvertently causes the conjunction everyone was trying to avoid, it would be unjust to still hold them completely at fault.

There is less and less ambiguity, however, for parties who are given a conjunction assessment, who abide by the practice of determining right-of-way, and on finding out they have the responsibility to maneuver, objectively choose not to. For parties who by their own opinion choose not to move out of the way, their rejection of their clear responsibility would amount to fault.

With responsibility and fault determined by who has right-of-way, any arbitration and claims for damage should be fairly clear. Previous theoretical hurdles to adjudicating on-orbit or in-space accidents included ability to collect evidence and analyze the event. However, if this Space Traffic Management regime were implemented, than all relevant information to determining the cause of the accident would not only already be collected, but it would also be validated and accepted by the practice of both parties involved.

Other mitigating and intervening factors could still be considered, such as the actual remaining value of the complainant's spacecraft, and whether by best practices the satellite could have been built or operated in such a way as to survive the damage. But nevertheless, the fault for which party should have maneuvered out of the way would be clear and predetermined.

In the end, operating on-orbit traffic under a right-of-way to one party would require a great deal of knowledge and real time analysis and communication in order to determine and effectively direct one party to commit to an avoidance maneuver. The benefit would be a clear assignment of responsibility, cost, and most likely liability. The problem would be a unilateral burden for operating on-orbit, and a possible chilling effect on maneuvering in the face of subsequent conjunction assessments.

IV.2. Granting Right-of-Way to Both Parties

The second category would grant the right-of-way to both parties. This could also be conceptualized as granting the right to neither. (However, a more compatible reading with the Outer Space Treaty would suggest that all parties have a right to outer space, and so all parties would have a right-of-way, even if the practical result is nullification.)

As opposed to the previous category, where the responsibility to make an avoidance maneuver clearly rested on one party, here the responsibility weighs ambiguously on both parties. The ambiguity lies only on the proportion of cost each operator will take on in conducting a coordinated avoidance maneuver.

Many of the same considerations from the first category remain. A truly comprehensive Space Traffic Management regime, especially one which requires independent operators to make their own decisions, requires real-time data acquisition, tracking, analysis, and sharing, as well as effective and coordinated communication between both parties involved.

Another similarity between the first and second category is the possible need to make a comparative analysis. For instance, spacecraft A and B may have an equal right-of-way in a possible conjunction, but the two spacecraft may be physically different. Spacecraft A may be a large conventional communications satellite, while spacecraft B may be a newer small satellite. Or spacecraft A may be designed for maximum maneuverability, and spacecraft B may only be designed for infrequent correctional maneuvers.

Such differences in physical characteristics and ability would result in different cost-effectiveness determinations. While granting right-of-way to both spacecraft gives each the responsibility to avoid conjunction, it does not necessitate that both operators must incur equal cost. Nor does it require that both spacecraft move an equal distance.

In fact, through communication and collaboration, the two spacecraft operators may find a minimally invasive avoidance maneuver, by evaluating and comparing their respective operational requirements. If the parameters of spacecraft A require it to stay closer to its current trajectory, while spacecraft B operates in a network that allows greater variance, then the total cost of avoidance may be lower if only spacecraft B executes a change of maneuver.

With this much coordination, it is easier to imagine both parties sharing the cost of the maneuver equally, by having one operator financially contribute to the operator who initially bore the greater cost. This solution does also require a greater amount of trust between operators, or a greater reliance on arbitration and adjudication to recoup that cost in a timely manner.

Not all avoidance maneuver cost calculations are self-contained. As mentioned in the previous category, in a crowded traffic situation, one avoidance maneuver may place a spacecraft in a subsequent possible conjunction. In which case, the spacecraft operators must not only weigh the cost of avoiding the first conjunction, but subsequent cost, responsibility, and possible liability in a second conjunction.

One solution for simplifying the decision model is to follow the same mandatory practice developed at sea, in particular the conduct of vessels in head-on situations.[73] The practice developed over time, and shared by all operators, is for two active vessels to turn in opposite directions. In particular, both vessels turn starboard. This works for vessels in head-on situations due to the 2-dimensional nature of travel on the sea's surface.

The difficulty would be in adapting this to the 3-dimensional and more uni-directional nature of on-orbit traffic. While there are different types of orbits, the nature of staying in orbit typically requires satellites in the same zone to all be traveling in the same direction, the direction of Earth's rotation. In this case, conjunctions typically do not happen in head-on trajectories, but side-to-side trajectories. This means that if both spacecraft "turned starboard" by drifting right, they would not necessarily solve the conjunction.

One way to adapt the rule would be to have the spacecraft each move in opposite directions of their conjunction. For instance, if spacecraft A and B were in low Earth orbit, and in their trajectories before conjunction, spacecraft A was further North and spacecraft B was further South, then they could each effect a maneuver to travel more in those directions.

The complexity of orbital mechanics make these maneuvers no small feat. Nor does this even solve the conjunction. In all likelihood, if two spacecraft were projected to collide, having them maneuver to alter their trajectory further in opposite directions will not reverse their conjunction, but may only delay it. In such case, a delay may give the two parties more time to collaborate on a solution.

If the two parties cannot communicate to come to a solution, cannot agree, or if one party refuses to take any action to help avoid conjunction, then the same issues on determining fault and liability remain. As mentioned in the previous category, proving fault in an orbital collision while the investigators are on Earth has been a hypothetical hurdle. And unlike the first category, there is no agreed-upon determination of responsibility. The only agreed upon facts would be that a collision happened, and neither party had a priority right-of-way.

In the end, granting right-of-way to both parties in a possible conjunction does less to encourage parties to abide by a predetermined allocation of responsibility, but does more to encourage parties to collaborate in real-time to find the most cost-effective solution. It similarly requires a great deal of data collection and real-time analysis. And the lack of predetermined responsibility also hinders any subsequent arbitration of claims resulting from a failed avoidance maneuver.

IV.3. Granting Right-of-Way to Least Able Party

The final category appears to be a variation of the first, in which right-of-way is granted to one party. However, there is a very important difference.

73 COLREGS, *supra* note 53, at Rule 14.

In choosing the criteria by which to determine which party is given priority right-of-way, granting it to the least able party comes with the implication that they also should bear the cost of avoidance (as opposed to the first category which grants both right-of-way and freedom from cost). At the same time, the party that is most able to move bears a positive responsibility to undertake collision avoidance measures, or face a burden of unclean hands in the event that they suffer a loss for failure to act.

In other words, granting right-of-way to the least able party is a predetermined split of responsibility to move to avoid collision, and responsibility to pay for that collision avoidance. As opposed to the second category, where burden of movement and cost is determined on a more ad-hoc basis; or the first category, where the same party bears both.

This final category is most applicable to the actual history of on-orbit collisions, which have occurred most often not between two operational and maneuverable spacecraft, but more likely involving at least one inoperable spacecraft, or a piece of uncontrollable space object.

The assignment of responsibility is somewhat split. Here, the responsibility to maneuver out of the way rests on the more able spacecraft, even though the determination shows the conjunction might not have happened but for the inoperability of the second spacecraft. Finding an inoperable spacecraft or space object in an active orbital zone does not mean they are immediately recognized as at fault; however, the trend in space debris mitigation and end of life practice would suggest that state parties are developing that standard of fault.

In the end, granting right-of-way to the least able spacecraft to avoid a conjunction would reinforce a strong presumption against operators who leave inoperable spacecraft or uncontrollable debris in highly trafficked orbital zones. As in all categories of right-of-way rules, and any truly comprehensive Space Traffic Management regime, operators need as much data, analysis, and real-time updates as possible. But developing these best practices and assumptions of how risk and cost will be apportioned will help provide certainty to all parties in their exploration and use of orbit.

V. Conclusion

Back to the original problem. Two satellites, from different launching states, operating nominally at the same orbit but at different inclinations, are projected to collide based on an outside conjunction analysis. Who moves first?

As of right now, there is no clear legal answer. There are plenty of legal reasons, and economic ones, for both the private operator and the state responsible to consider. In the end, it usually comes down to two elements: is it worth it, or who will be liable?

A satellite collision, involving the loss of one or both satellites, or even a wrong maneuver, resulting in the total or premature loss of service, is a difficult scenario to even predict. But many observers turn to the increasing probability of such events occurring, even if they cannot identify when or to whom they will occur. And even the most robust Space Traffic Management system will not be able to keep track of every danger.

Each legal and policy analysis that address the problem of Space Traffic Management comes back to the operator. The standard of care for in-orbit operations depends on the history of in-orbit actions, and the consensus of a history of decision making.

Now, legal scholars and policy makers can suggest new rules, regimes, and organizations, to oversee and direct future Space Traffic Management decisions. Each new regulation can come with more oversight, more enforcement at both a national and international level. And if disputes become more common, then more dispute settlement and arbitration forums can be created, increasing the cost of finishing business.

But before any new suggestions are implemented, stakeholders must come back to the cost-benefit question. If the cost of losing a satellite, or paying for someone else's satellite, is still less than any new Space Traffic Management regime, is it worth it? Are incremental costs, like joining a new space situational awareness network, improving collision detection sensors, and making more efficient avoidance maneuvers, preferable? And would a new international consensus on right of way solve the liability question, and create a more predictable in-orbit space environment?