Getting Right-of-Way Right in Low Earth Orbit – An (Astro)Nautical Conundrum

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Abstract

The massive increase in number of satellites launched is transforming Low Earth Orbit (LEO) into a much busier domain. Congestion, conjunctions and risk of collisions will be issues that the international space community will have to solve to ensure sustainable use and access to LEO in the future. Already, tensions over conjunctions and collisions risk, between both commercial actors and between nation states, underscores the urgency of agreeing basic Rules-of-the-Road norms, most notably for Right-of-Way to avoid catastrophic collisions and escalations.

The current body of international law does not provide any clarity for operators when determining who has priority and who should maneuver in conjunction scenarios. In contrast, Law of the Sea offers clear and globally accepted norms for priority and Right-of-Way. This paper analyses the transferability of the basic parameters and principles used for assigning right-of-way in nautical navigation from a regulatory perspective.

Keywords: Space Traffic Management, Right-of-Way, Rules-of-the-Road, Priority

1. Introduction

Consider driving on a highway with no rules-of-the-road in place, cars maneuvering seemingly at random, dangerous debris strewn across the lanes and an unprecedented rush-hour approaching. This dramatic image, although not a perfect analogy, has resemblance to the situation facing operators of satellites in Low Earth Orbit (LEO) now and in the near future. The number of active satellites in LEO has been rising rapidly in recent years.[1] One of the

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1 *Jonathan's Space Report | Space Statistics*, https://planet4589.org/space/stats/stats1.html (last visited Aug. 25, 2022).

major drivers behind the growth in the population of satellites is the advent of mega-constellations consisting of hundreds or thousands of satellites. Commercial and national actors all over the globe are planning new constellations, which, if realized, will fundamentally transform LEO into a much more crowded traffic domain.[2] The swelling population and activity results a rapid increase in the number of traffic interaction between active space objects in LEO.

The key traffic interaction in orbit is the satellite conjunction, defined by NASA as: *"A close approach between two objects that is predicted to occur because the secondary object passes within a chosen geometric or statistical safety volume about the primary (protected) asset."*[3] In other words, a conjunction occurs when two objects are deemed to be at risk of colliding. If the conjunction includes maneuverable, active satellites and the risk is assessed to be over a certain threshold,[4] the operators will usually take action to remediate the risk by performing avoidance maneuvers.

As a consequence of the rapidly swelling traffic in LEO and increasing number of conjunctions and because the active satellites are concentrated at specific altitudes,[5] there is a clear trend towards active-to-active conjunctions presenting a larger collisions risk.[6] In sum, addressing conjunctions between active satellites is becoming increasingly more important for collision avoidance and also represents the traffic interaction where rules-of-the-road can have the largest effect. Today, no international rules, standards or guidelines regulate how operators handle conjunctions and avoid collisions.[7]

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2 Fillings have been made to the International Telecommunication Union (ITU) for 426.713 satellites across 13 large constellations of varying sizes. For an updated list of planned constellation see: *Jonathan's Space Report | Space Statistics*, https://planet4589.org/space/stats/conlist.html (last visited Aug. 22, 2022).

3 *NASA Spacecraft Conjunction Assessment and Collision Avoidance Best Practices Handbook* 44 (NASA 2021).

4 A standard common in the industry is to maneuver if the probability of collision in a conjunction is more than 0.0001. See for example the *Best Practices for the Sustainability of Space Operations,* published by *Space Safety Coalition*, https://spacesafety.org/.

5 Dennis Weber et al., *Statistical Analysis of Conjunctions in Low Earth Orbit*, Advances in Space Research 6 (Jul. 2022), https://www.sciencedirect.com/science/article/pii/S0273117722005476.

6 This development has already been observed and reported by ESA: "…*particularly in the lower LEO_{IADC} regime, the increase of conjunction events that require coordination between active operators due to the change in space traffic, whereas higher orbits remain dominated by space debris related events"*. ESA Space Debris Office, *ESA'S Annualspace Environment Report* 69 (European Space Agency Apr. 2022). See also: Weber et al., *supra* note 7, at 5.

7 Hjalte Osborn Frandsen, *Looking for the Rules-of-the-Road of Outer Space: A Search for Basic Traffic Rules in Treaties, Guidelines and Standards*, JOURNAL OF SPACE SAFETY ENGINEERING (Feb. 2022).

This paper seeks to fold out the seemingly simple concept of right-of-way and expose how the imposition of such rules would be useful, but require a conscious balancing of a complex web of interests. The paper then presents a review of right-of-way concepts from other traffic domains and the parameters used in constructing the rules. Finally, the paper concludes with proposing directions for further study, and conversation by industry about the concept of right-of-way.

1.1. What is right-of-way?

One of the most basic functions of rules-of-the-road is to provide actors with a clear understanding of right-of-way.[8] The right-of-way rules determines who has the right to stay a course and who has the obligation to move out of the way to avoid a collision. This simple concept is central to efficient and safe conduct in most established traffic domains. Various parameters are used as the basis for assigning right-of-way, such as propulsion (e.g. sail vs motor for ships), relative position (e.g. cars yielding for traffic from the right). Some right-of-way principles and parameters are found in some form across different traffic domains, e.g. yielding to vessels in distress, while others are unique to their domains. Principles and parameters used in other traffic domains can serve as a starting point and inspiration for proposing right-of-way provisions for conjunctions between satellites.

1.2. Why do we need right-of-way for orbital traffic?

Today, no binding right-of-way rules exist to guide operators when two spacecrafts are heading for a conjunction. With no rules or norms to guide actors, most collision-avoidance-maneuvers are negotiated between operators on an ad hoc basis. This process is becoming burdensome with the increasing traffic[9] and the rapidly increasing number of conjunctions. The impromptu handling of conjunctions is prone to failure, such as when operators fail to establish contact in time and both make uncoordinated maneuvers that end up nullifying each other, resulting in collision. In a future with a much higher number of conjunctions, the coordination between operators to avoid collisions needs to move beyond ad hoc negotiations via social media, phone

8 The term Right-of-Way has two separate meanings; the right to passage over another person's property or the precedence in passing accorded to one vehicle over another by custom, decision, or statute. *Definition Of Right-of-Way,* Https://Www.Merriam-Webster.Com/Dictionary/Right-Of-Way (Last Visited May 26, 2022). It is in the latter meaning of the term that it is used here.

9 See Ryan Shepperd in Astrodynamics 2020: Proceedings of the AAS/AIAA Astrodynamics Specialist Conference Held August 9-12, 2020, Virtual Event (Wilson AIAA/AAS Astrodynamics Specialist Conference Roby S et al. eds., 2021); Theodore J. Muelhaupt et al., *Space Traffic Management in the New Space Era*, 6 Journal of Space Safety Engineering 80, 81ff (Jun. 2019).

and email.[10] The conclusion that the time is ripe for rules-of-the-road is echoed across industry, policymakers and academia.[11]

2. Comparing legally and technically different domains

This paper draws inspiration and adopts terminology from the well-established terrestrial traffic regimes, such as those governing traffic on roads and seas.[12] When transplanting concepts and terminology from one domain to another, it is necessary to be mindful of the obvious and nonobvious differences to avoid faulty conclusions. When legal regimes are challenged by new technological developments, legal scholars tend to reach for analogies and argue that the new technology can or should be regulated as a known one.[13] This paper seeks to avoid this proclivity and makes no *a priori* assumptions about the applicability or usefulness of rules from other traffic domains and the need to duly consider the distinct condition for traffic in outer space. The physical and technical constraints on vessels operating in outer space are vastly different from those operating on the oceans of Earth. It is beyond the scope of this paper to exhaustively list all relevant technical, legal and physical differences.

2.1. Technicalities of collision avoidance in orbit

Unlike most other traffic domains, we are familiar with from earth; line-of-sight is not relevant to collisions avoidance for satellites. Satellite conjunctions are identified based on catalogs of tracked space objects being propagated into the future. The most comprehensive catalog of space objects is maintained by the 18th Space Control Squadron (18 SPCS) on behalf of the Unites States Space Command.[14] Through the website Space-track.org the

10 Salvatore Alfano et al., *Risk Assessment of Recent High-Interest Conjunctions*, 184 Acta Astronautica 241, 248 (2021).

11 John Hardie et al., *SIA Calls For Space Traffic Rules ASAP*, Breaking Defense (Sep. 24, 2020), https://breakingdefense.sites.breakingmedia.com/2020/09/sia-calls-for-space-traffic-rules-asap/; Ryan W. Shepperd, and Kristina C. DiOrio, *The Time for a Set of Traffic Rules Has Arrived*, Astrodynamics 2020, Advances in the Astronautical Sciences (American Astronautical Society Sep. 2020); Frandsen, *supra* note 9.

12 From the very inception of space law, scholars have sought analogies and inspiration in the Law of the Sea. See for example: Jack H Williams, *The Law of the Sea: A Parallel for Space Law*, 22 Mil. L. Rev. 155 (HeinOnline 1963).

13 A. Michael Froomkin, *The Metaphor Is the Key: Cryptography, the Clipper Chip, and the Constitution*, 143 University of Pennsylvania law review 709, 860-61 (University of Pennsylvania Law School 1995); Rebecca Crootof & B.J Ard, *Structuring Techlaw*, 34 Harvard journal of law & technology 347, 386-87 (Harvard Law School, Harvard Journal of Law & Technology 2021).

14 The database and conjunction identification services provided by the military unit 18 SPCS is in the process of being transferred to a civilian unit under Department of Commerce. For an account of the historical and political background, see: Travis S. Cottom, *Creating a Space Traffic Management System and Potential Geopolitical Opportunities*, 19 Astropolitics 92 (Routledge May 2021).

18 SPCS gives operators a limited access to the catalog of space objects. Through the website, operators can register to automatically receive notifications when a conjunction is predicted to occur between one of their assets and another object in the database. Other public and private services exist that offer similar services that operators can use instead or in addition to the data from the Spacetrack.org catalogue.[15]

From a technical perspective, avoiding collisions requires; 1) precise data about where objects in orbit are, 2) the ability to maneuver[16] at least one of the objects and 3) a decision about which of the object to maneuver. There are technical and physical limits on how precisely an object's position and trajectory in orbit can be determined. Operators may have different perceptions of collision risk of a given conjunction, depending on the availability of data, methodology used, risk thresholds applied etc.[17] This absence of an unambiguous and agreed upon understanding of where the different traffic participants physically are in relation to each other differentiates the orbital traffic from other terrestrial situations. This presents a challenge for creating traffic rules, as actors may disagree on whether a traffic encounter is even happening.[18]

Additional technicalities of maneuvering presents clear difference to other traffic domains. Traffic in LEO moves at speeds of around 27.000 km/hour and circles the earth in less than two hours. Airplanes, cars and ships are usually capable of maneuvering to avoid a collision on very short notice, based on line-of-sight of a human pilot, while most spacecraft's are uncrewed and generally require several hours notice to perform evasive maneuvers.[19] This means that decisions about avoidance maneuvers are taken about conjunctions happening several revolutions into the future, based on data

15 See for example: *EU SST – European Space Surveillance And Tracking*, https://www.eusst.eu/; *AstriaGraph*, http://astria.tacc.utexas.edu/AstriaGraph/ (last visited Mar. 8, 2022); *Privateer Wayfinder*, https://www.privateer.com/ (last visited Dec. 12, 2022).

16 Maneuvering refers to consciously manipulating an objects trajectory, e.g. using propulsion, differential drag, reaction wheels etc.

17 For a more detailed discussion of the technical aspects of orbital traffic management, see: Daniel L. Oltrogge & Salvatore Alfano, *The Technical Challenges of Better Space Situational Awareness and Space Traffic Management*, 6 Journal of Space Safety Engineering 72 (2019).

18 For example, China officially alleged that the Tiangong space station had to maneuver to avoid a SpaceX satellite, while SpaceX claimed that their satellites trajectory was nowhere near the space station. See: *The Space Review: The Starlink-China Space Station near-Collision: Questions, Solutions, and an Opportunity*, https://www.thespacereview.com/article/4338/1 (last visited Jul. 27, 2022).

19 Many operators needs upwards of 24-hours to plan maneuvers. Some newer LEO satellites, such as the ones in the Starlink mega-constellation, have autonomous maneuvering capabilities significantly cutting down the lead time needed for evasive maneuvers, but this is not yet industry standard.

with numerous uncertainties. Any proposed rules-of-the-road for orbit, must be checked against these technical constraints.

3. The purpose of right-of-way rules

At the core, right-of-way is a rule granting certain traffic participants the right to precede and others the obligation to wait or maneuver to avoid getting in the way. However, the regulation of the most central traffic interaction, the meeting of two actors, has far reaching implications for the traffic system in general. Right-of-way rules can serve different regulatory purposes and any formulated rule represents a balancing of different interests and regulatory aims. In the following the diverse potential regulatory aims for right-of-way provisions is discussed.

3.1. Coordination and predictability

Imagine if every time you met another car at an intersection, you had to get out and coordinate with the other driver, about who should go first. This ad hoc coordination is tolerable if you only very rarely meet other drivers, but becomes burdensome and inefficient in a busy traffic domain. When a satellite operator is notified that one of their satellites is heading for conjunction with another active satellite, they are forced to go through the process of contacting and coordinating with the other operator to ensure the safety of their asset. Before executing an evasion maneuver, the operators must coordinate to ensure that they do not waste fuel or inadvertently cause a collision by maneuvering at the same time. As the number of conjunctions increases, so does the cost associated with the manual coordination between operators. As an additional complication, coordination is not always achieved in scenarios where collisions risk is identified. Ad hoc coordination requires that communication and agreement on how to mitigate the collision risk is established in time. With no standardized method, coordination is prone to failure, due to a multitude of causes, from distrust[20] to technical issues.[21]

Right-of-way norms would reduce the need for ad hoc coordination and negotiation by allowing each operator to know when they should maneuver and when they should maintain course in certain clearly defined scenarios. In addition, the rules would let operators know what behavior to expect from another operator even if they have not succeeded in establishing communication. The predictability of rule-bound conduct also simplifies the

20 See for example: Andrew Jones, *China's Space Station Maneuvered to Avoid Starlink Satellites*, SpaceNews, https://spacenews.com/chinas-space-station-maneuvered-to-avoid-starlink-satellites/ (last visited Aug. 31, 2022).

21 See for example: Loren Grush, *A Bug in SpaceX's Communication System Kept the Company in the Dark about Potential Satellite Collision*, The Verge, https://www.theverge.com/2019/9/3/20847243/spacex-starlink-satellite-european-space-agency-aeolus-conjunction-space-debris (last visited Aug. 31, 2022).

implementation of autonomous collision avoidance systems. Many satellite constellations, making up the lion's share of new satellites, are designed to perform autonomous collision avoidance in order to reduce the manual labor needed for planning maneuvers.[22] Fully automated collision avoidance can potentially handle debris and the constellations self-conjunctions, but coordination would still be needed between autonomous systems from different operators and for conjunctions with non-automated satellites.

3.2. Cost allocation

Executing a maneuver in space expends costly fuel and reduces the lifetime of the satellite. In addition, a maneuver will in some cases disrupt the mission of the satellite, by e.g. preventing an earth observation satellite from collecting data from a specific position.[23] Any decision about right-of-way in orbit is therefore also a decision about who should bear the cost of maneuvering. The rate of conjunctions between active satellites is still low enough that the cost of maneuvering is negligible in the fuel budget of most missions, however the sharply increasing number of satellites in LEO may well change this. The rising costs in addition to the potential disruption of the services delivered by the satellites increases the potential for conflicts about who should shoulder the cost of maneuvering. This issue is exacerbated when satellites in a conjunction belong to national adversaries or commercial competitors. Right-of-way rules could mitigate conflicts by assigning the responsibility and therefore cost of maneuvering clearly to one party and removing the need for individual negotiations.

3.3. Equity and access

The very first article of international space law's foundational treaty, the Outer Space Treaty, provides that space and celestial bodies "*…shall be free for exploration and use by all States without discrimination of any kind, on a basis of equality…*"[24] Rules-of-the-road can serve the purpose of supporting these freedoms, by facilitating access and equitable sharing of the orbital highways. At the same time, instituting rules risk systematically favoring or handicapping certain groups of operators, mission-purposes or technologies. It is essential to realize that the right-of-way question is not merely a technical safety issue for which an apolitical, optimal solution exists. In addition to being technically sound and efficient, right-of-way rules should ideally express a balancing of a complex web of interests of the global, heterogeneous space community.

22 Muelhaupt et al., *supra* note 11, at 83.

23 See infographic about the cost of associated with collision avoidance maneuvers: *The Cost of Avoiding Collision*, https://www.esa.int/ESA_Multimedia/Images/2021/02/The_cost_of_avoiding_collision (last visited Jul. 25, 2022).

24 *Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies* Art. 1.

For example, the NASA Spacecraft Conjunction Assessment and Collision Avoidance Best Practices Handbook prescribes the following general right-of-way principle: "*… the ascending/descending spacecraft that is equipped to maneuver needs to yield the right-of-way to existing on-orbit assets by performing risk mitigation maneuvers or ascent/descent trajectory alterations.*"[25] The principle that ascending/descending space crafts should yield is reminiscent of terrestrial traffic rules, such those prescribing that vehicles entering a road should yield to the traffic already on the road. However, the granting of right-of-way to satellites already in operation over newly launched satellites could potentially make it difficult for late-comers to enter specific crowded orbits. The potential threat to Equitable Access posed by mega-constellations has been raised in the literature[26] and could be exacerbated by right-of-way rules.[27] On the other hand, right-of-way rules could be intentionally designed to give priority to certain groups of operators based on nationality or mission purpose to ensure their access.

3.4. From isolated incidents to ongoing system optimization

As conjunctions with other satellites change from being rare and special incidents happening a few times during the lifetime of a satellite to becoming a regular and ever-present issue, the management of conjunctions will have to change character from ad hoc to ongoing, planned process. Having right-of-way rules would contribute to the transition from ad hoc to structured process of conjunction management by providing a common understanding about how collisions risks should be resolved by operators. Without common rules operators can only standardize their internal processes for collision avoidance, or at best bilaterally agree on standard procedures with a few other operators. Internationally agreed right-of-way rules would effectively serve as protocols to allow operators to apply standard procedures to common traffic scenarios.

The right-of-way rules furthermore could elevate the focus of optimization from the individual interaction to the full orbital traffic system. In the ad hoc regime, a less risk-averse operator with small inexpensive satellites can in principle avoid any maneuvering, as other, more risk-averse operators will generally move their satellite out of the way to avoid collision. The result would be that larger, more expensive and capable satellites would maneuver

25 *NASA Spacecraft Conjunction Assessment and Collision Avoidance Best Practices Handbook*, *supra* note 3, at 13.

26 Matteo Cappella, *The Principle of Equitable Access in the Age of Mega-Constellations* 11, 17ff (Springer International Publishing 2019).

27 Prior work has looked at right-of-way models in other traffic domains. See: Ruth E. Stilwell, *Who is Right When It Comes to Right of Way in Space?* 4 (2020); Martin Michel & Reinhold Bertrand, *Assessment Of Inter-Operator Rule-Based Collision Avoidance Operations*, Proceedings of 8th European Conference on Space Debris (ESA Space Debris Office).

more than less expensive and less capable satellites.[28] This would clearly be suboptimal from a systems perspective. Right-of-way rules can in contrast be designed to favor safety and efficiency on a system level.
In conclusion, right-of-way rules for orbit can potentially serve to mitigate a number of important issues for the global space community, beyond the obvious aim of mitigating collision risk. At the same time, the indirect implications for important areas such as cost allocation and equitable access reveals that the deceptively simple concept of right-of-way, cannot be developed for orbit without due consideration for the balance of interests across different areas.

4. Right-of-way in other traffic domains

Although the concept of right-of-way is simple, there are clear advantages to having them and space actors are generally in favor of regulation, the formulation of the actual rules is far from straight-forward. Right-of-way rules would have great impact on satellite operators freedom of operation and on development of the orbital environment. At the core of right-of-way provisions are the parameters used to decide who gets priority. From other traffic domains we see many different parameters used as basis for judging who has the right-of-way, ranging from propulsion (sail vs motor) to directional (e.g. right-lane priority in road traffic). The orbital domain is significantly different from any other traffic domain and it is unlikely that any rules from terrestrial traffic domain can be transferred unaltered. Therefore, it is sensible to review the principles and parameters used in other traffic domains while being mindful that the right solution for orbital traffic might be something else and new.[29]

4.1. Learning from the long history of collisions avoidance at sea

The domain where international rules-of-the-road has the longest history is in the law of the sea, where rules to mitigate collisions between ships have evolved over centuries.[30] Today, the traffic conduct of traffic on the seas is regulated by *The International Regulations for the Prevention of Collision at Sea*[31] (COLREGs) adopted under the auspices of the International Maritime Organization. The regulations enjoy broad, international support among seafaring nations. The COLREGs contain detailed rules-of-the-road covering

28 This situation has been conceptualized as right-of-way determined by playing "chicken". Nathan A Johnson, *A Game of Chicken in Space: Developing Standards for Right-of-Way In Orbit* (2014).
29 Ruth E. Stilwell, *supra* note 29, at 3ff.
30 J. Harrison, Making the Law of the Sea: A Study in the Development of International Law (Cambridge University Press 2011).
31 *Convention on the International Regulations for Preventing Collisions at Sea*, UNTS 1050 (International Maritime Organization Oct. 1972).

a host of traffic scenarios from overtaking to head-on collisions and for many different vessel types.

The COLREG rules governing the situations most directly analogous to satellite conjunctions is laid down in the steering and collision avoidance section of rule 4-19. Although several provisions have the purpose and form of right-of-way provisions, it is important to note that the COLREGs do not use the term right-of-way. The difference is not just semantic. Instead of giving one vessel right-of-way over another vessel, the rules designate vessels as either give-way or stand-on vessels. The focus is on obligations, rather than on rights. Give-way vessels have the obligation to maneuver and stay out of the way.[32] Stand-on vessels have the obligation to maintain course and speed and only maneuver if needed to avoid collision.[33] The requirement for stand-on vessels to refrain from maneuvering is there to maximize predictability for the other vessel. When planning collision avoidance maneuvers in orbit, it is likewise essential to know if or when the other satellite will maneuver. When discussing the future right-of-way rules for orbit, this structure of rules based around reciprocal obligations rather than rights, may be worth carrying over.

Another ancient and tested concept present in the law of the sea is that of priority between vessels. In essence, the priority rules create an ordered hierarchy determining which vessels should stay out of the way of other vessels; e.g. a power-driven vessel shall keep out of the way of vessels with no or little ability to maneuver, vessels engaged in fishing, sailing vessels and so forth.[34] As with satellite conjunctions, seagoing vessels will usually prefer not to maneuver and so, the list of priority reflects a balancing of interests. The complex balancing of interests is reflected in the fact that the list contains several different types of parameters for judging priority, including propulsion (power-driven vs sailing vessels[35]), status (vessel not under command[36]) and mission (vessels engaged in fishing[37]).

Deciding on parameters and their hierarchy for orbital traffic is likely to be one of the major points of contentions for formulating the future right-of-way rules for space.[38] Clearly, the categories of parameters found in the

32 *Id*. Rule 16.
33 *Id*. Rule 17.
34 *Id*. Rule 18.
35 *Id*. Rule 18 (a,iv).
36 Rule 18 (a,i) *id*.
37 *Id*. Rule 18 (a, iii).
38 The discussion of relevant parameters for right-of-way in orbit has not yet been developed much in the literature. A few technical conference papers have started making contributions. See: Ryan W. Shepperd, and Kristina C. DiOrio, *supra* note 13; Mariel Borowitz et al., *An Investigation into Potential Collision Maneuver Guidelines for Future Space Traffic Management* (AMOStech 2021); Michel & Bertrand, *supra* note 29.

COLREGs, such as propulsion type, relative position, mission or status of craft can serve to inspire the conversation about relevant parameters for space priority. Still, spacefaring is vastly different from seafaring. As explained above, the COLREGs rely heavily on line-of-sight and the ability of sailors to observe facts, such as distinguishing sailing boats and powered ships. As discussed earlier, space operation does not rely on line-of-sight. For right-of-way rules to work, the operators must be able to sense or in other ways have access to reliable data about the relevant parameters used in judging priority. A large part of the COLREGs are dedicated to ensuring clear and timely communication between vessels through standardized, mandatory signaling with lights, flags and sound.[39] For right-of-way to work in orbit, analogous requirements for technology to ensure communication and easy identification of relevant facts about a vessel for other operators, might well be necessary. The appropriate solution for satellites is unlikely to include flags and lights, but could include onboard transponder systems, increased requirements for registration and data sharing.[40]

Concluding on his review of two hundred years of rules-of-the-road regulating collision avoidance on the seas, the author Kemp states: "… *that past experience contains a clear lesson that rules specifying or implying specific manœuvres are unsatisfactory and dangerous unless there is communication between the parties to an encounter, or objective criteria can be set up to determine when the rules become operative*".[41] Both sides of what Kemp concludes from his historical review of nautical collision regulation, is worth recalling when discussing orbital right-of-way. For the rules to function as intended, traffic participants must share a reasonably similar view of the situation they are facing. In other words, operators must both agree that a conjunction is probable and have a way of establishing communication. The right-of-way rules do not remove the need for direct communication between operators, but they could ease the task of coordination and lessen risk of conflict.

39 See rule 20-37 about signaling with lights and sound, as well as the detailed technical requirements for the placement and capability of the signaling equipment in Annex I, *1972 COLREGs*.

40 See proposal for a GPS-based identification system for space traffic: Andrew Abraham, *Gps Transponders for Space Traffic Management*, NO. APRIL. COLORADO SPRINGS, CO (2018); For an overview of technological solution which might be implemented for trackability and identification see also: S. W, *IISL, IAA and IAF Conclude Major Report on STM*, International Institute of Space Law (Sep. 20, 2022), https://iisl.space/iisl-iaa-and-iaf-conclude-major-report-on-stm/.

41 John F Kemp, *Two Hundred Years of the Collision Regulations*, 29 THE JOURNAL OF NAVIGATION 341, 347 (Cambridge University Press 1976).

5. Conclusion

Right-of-way rules for orbit requires global support and collaboration. Though discussed at other occasions by the author,[42] the likelihood or potential paths to the establishment of an international space traffic regime has not been considered here. The paper has skipped the thorny issue of how to establish global accord, and instead focused on the potential concepts and principles that could inspire future right-of-way rules for orbital space. Concepts used to construct right-of-way rules in other traffic domains, can be used as starting points for discussing how to design right-of-way norms for space. Centuries of human experience with nautical navigation, underlines that traffic rules depend on actors being able to establish communication easily and to have common understanding of the traffic situation they are facing.

We are still very early in the discussion of orbital right-of-way, but the need for them is still more pressing. There is a need for academic research, to expand our understanding of, if and how, right-of-way rules might help solve the challenges of keeping our orbits safe and accessible with much higher satellite populations. Parameters are, across traffic domains, the essential building blocks needed to construct right-of-way rules. Exploring which parameters are available, relevant and feasible to use for constructing future rules is an essential step towards governing orbital space traffic and a sensible area for further study. In addition, the major operators, including private industry and public space agencies, need to develop positions on and have an open conversation about right-of-way rules and parameters. Traffic rules cannot realistically be formulated without input and engagement from the operators with the experience of the developing traffic situations.

42 Frandsen, *supra* note 9.