ENVIRONMENTAL PROTECTION, SUSTAINABILITY AND THE PREVENTION OF SATELLITE COLLISIONS IN OUTER SPACE

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ABSTRACT

With space commercialization and privatization continuing apace, more space objects are expected to be launched and put into operation in the future, adding to the already large number of defunct satellites and space debris present in outer space. Hence, serious study should be devoted to possible mechanisms for dealing with potential collisions in outer space for the purpose of realizing environmental protection and space sustainability. In view of the inadequacy of the existing legal regime, this article explores possible such mechanisms (including a preventive mechanism, avoidance mechanism and compensation mechanism) from the perspective of interdependence theory and puts forward a practical approach to constructing future mechanisms to realize the goal of environmental protection and space sustainability.

Keywords: Environmental Protection; Space Sustainability; Satellite collisions; Interdependence theory.

INTRODUCTION

Environmental Protection in outer space has caught worldwide attention nowadays. The European Space

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Agency (ESA) has produced an annual Space Environment Report since 2016 to elaborate on the impact of space activities on space environment and how international debris-mitigation measures are enhancing the long-term sustainability in outer space.[1] Prevention of satellite collisions proves to be an important step in the mitigation of space debris with the ultimate goal of protecting space environment.

On December 3, 2021, the Permanent Mission of China to the United Nations (Vienna) informed the Secretary-General of the United Nations (UN) of the potential collisions of Starlink satellites launched by Space Exploration Technologies Corporation (SpaceX) with China's Tiangong Space Station on two occasions in July and October 2021,[2] forcing the Space Station to engage in avoidance maneuvers. This incident raises serious concerns over space safety and security in view of the increasing number of space objects being launched into outer space. With space commercialization and privatization continuing apace,[3] even more space objects are expected to be launched and put into operation in the future, joining the large number of defunct satellites and space debris already present in outer space.[4]

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1. ESA's Space Environment Report 2022 (April 22, 2022), https://www.esa.int/Space_Safety/Space_Debris/ESA_s_Space_Environment_Report_2022.

2. United Nations General Assembly, Committee on the Peaceful Uses of Outer Space, Information Furnished in Conformity with the Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies, Note verbale dated December 3, 2021 from the Permanent Mission of China to the United Nations (Vienna) addressed to the Secretary-General, December 6, 2021, A/AC.105/1262.

3. Timothy Justin Trapp, 'Taking up Space by Any Other Means: Coming to Terms with the Non-appropriation Article of the Outer Space Treaty' (2013) University of Illinois Law Review 4, 1685.

4. RG Harrison, *Unpacking the Three C's: Congested, Competitive and Contested Space*, 11 Int'l. J. of Space and Pol'y. 121, 131 (2013).

The increasing number of satellites and amount of space debris raise serious concerns over the risk of collisions.[5] Research has been conducted on the space laws related to satellite collisions,[6] but more serious study needs to be devoted to possible mechanisms for dealing with potential collisions in outer space and improve space sustainability. This article takes up the task by exploring the way forward for the development of practical mechanisms for the purpose of realizing space sustainability and environmental protection in outer space. Space sustainability is defined as "the ability to maintain the conduct of space activities indefinitely into the future in a manner that realizes the objectives of equitable access to the benefits of the exploration and use of outer space for peaceful purposes, in order to meet the needs of the present generations while preserving the outer space environment for future generations."[7] Space debris mitigation is no doubt one of the most important issues entailed in the concept of space sustainability. Space sustainability can never be realized without proper mechanisms for mitigating space debris arising from satellite collisions. The question thus arises as to how to come up with appropriate mechanisms to deal with the prevention of satellite collisions, realizing in the end of environmental protection in outer space.

Following this introduction, the article examines the existing legal regime for dealing with environmental protection in outer space, space sustainability and the prevention of satellite collisions in Part 2. In view of the inadequacy of that regime, Part 2 explores ways to improve it to prevent satellite collisions in future. Part 3 then analyzes the feasibility of the proposed mechanisms from the perspective of interdependence theory. Building on the

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5. Ntorina Antoni & Federico Bergamasco, *To Orbit and Beyond: Present Risks and Liability Issues from the Launching of Small Satellites*, 1 1 Int'l. Inst. of Space L. (2014).

6. Dan St. John, *The Trouble with Westphalia in Space: The State-Centric Liability Regime*, 40 Denv. J. Int'l L. & Pol'y 686 (2012).

7. Secure World Found., Space Sustainability: A Pratical Guide 33 (updated 2018).

theoretical analysis in Part 3, Part 4 puts forward a practical approach to constructing future mechanisms. The article concludes by noting that the issue of space sustainability and preventing potential satellite collisions in outer space needs to be resolved in a comprehensive manner. Beyond the discussion herein on possible mechanisms, it should be borne in mind that ongoing international discussions are indispensable to realizing improvements in space traffic management (STM),[8] trust- and confidence-building mechanisms[9] and space debris mitigation.[10]

1. EXISTING LEGAL REGIME AND SATELLITE COLLISION PREVENTION

It is important to first examine the existing space law regime that may apply to space sustainability and the prevention of satellite collisions. Space sustainability is to be understood broadly, with the major issue being environmental protection in outer space and space debris mitigation. It essentially supports achieving the Sustainable Development Goals.[11] What is intended to sustain include both long-term sustainability in outer space and sustainable development on Earth because these two concepts are correlated to each other. To a certain extent, sustaining the planet Earth is a base while sustaining space activities is the tool for further developments on the Earth.

Traditionally space sustainability focuses on issues such as environmental protection and space debris mitigation; however, it is also of utmost importance that all states, including both developing and developed countries, have

8. TANJA MASSON-ZWAAN & MANHULENA HOFMANN, INTRODUCTION TO SPACE LAW 115-16 (4th ed. 2019).

9. G.A. Res. 60/66 (Dec. 8, 2005). *See* JANA ROBINSON, THE ROLE OF TRANSPARENCY AND CONFIDENCE-BUILDING MEASURES IN ADVANCING SPACE SECURITY (ESPI 2010).

10. Lubos Perek, *Ex Facto Sequitur Lex: Facts Which Merit Reflection in Space Law in Particular with Regard to Registration and Space Debris Mitigation*, in SPACE LAW: CURRENT PROBLEMS AND PERSPECTIVES FOR FUTURE REGULATION (Marietta Benko & Kai-Uwe Schrogl eds., 2005).

11. UNDP, *What Are the Sustainable Development Goals?*, https://www.undp.org/sustainable-development-goals (last visited April 8, 2024).

equal access to space and the ability to benefit from space. The UNCOPUOS released a set of Guidelines for the Long-Term Sustainability of Outer Space Activities in 2018 to cope with a wide range of concerns over space sustainability, including space debris mitigation, international cooperation, capacity-building and awareness. The set of guidelines are not legally binding, thus it would be necessary to examine binding rules to deal with space sustainability.

The 1967 Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies ("Outer Space Treaty" hereafter)[12] is no doubt the ideal starting point for the current discussion, as this is the first binding legal document dealing with peaceful uses of outer space. Although the Chinese government has specifically mentioned in its Note verbale to the UN Secretary-General the need to protect the safety of astronauts under Article V of the Outer Space Treaty,[13] this article examines the issue of satellite collisions in a more comprehensive manner. The duty of notification defined in Article V of the Outer Space Treaty arises only in cases of danger to the life or health of astronauts, which means that it applies only to situations involving crewed spacecraft. Accordingly, this article looks to other relevant provisions in the same document for discussion of three mechanisms: the preventive mechanism, avoidance mechanism and compensation mechanism.

12. Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies, Dec. 19, 1966, 610 UNTS 205.

13. *Supra note 2.*

The five extant space treaties[14] were adopted in the 1960s and 1970s,[15] and we should also bear in mind the gaps in the existing legal regime with respect to non-governmental entities.[16] The preventive mechanism and avoidance mechanism do not apply directly to non-governmental entities, but only indirectly through the state that has regulatory and supervisory obligations.[17] It is therefore vital to have a national legal regime in place to ensure the implementation of those obligations; otherwise, non-governmental entities lack sufficient incentives to actively take up the tasks of notification and avoidance. The same applies for the compensation mechanism, with states being the sole subjects of compensation for damages at the international level.

Despite the aforementioned gap in the existing legal regime, enacting new rules would be complicated and time-consuming. It would be more realistic to construct a

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14. Agreement on the Rescue of Astronauts, the Return of Astronauts and the Return of Objects Launched into Outer Space, 672 U.N.T.S. 119, T.I.A.S. 6599, 19 U.S.T. 7570, U.K.T.S. 1969 No. 56, Cmnd. 3786, A.T.S. 1986 No. 8, 7 I.L.M. 151 (entered into force Dec. 1968); Convention on Registration of Objects Launched into Outer Space, opened for signature Jan. 14 1975, 1023 U.N.T.S. 15, T.I.A.S. 8480, 28 U.S.T. 695, U.K.T.S. 1978 No. 70, Cmnd. 6256, A.T.S. 1986 No. 5, 14 I.L.M. 43 (entered into force Sept. 15 1976); Agreement Governing the Activities of States on the Moon and Other Celestial Bodies, adopted in 1979, 1363 U.N.T.S. 3, A.T.S. 1986 No. 14, 18 I.L.M. 1434 (entered into force July 1984).

15. Francis Lyall & Paul B. Larsen, Space Law: A Treatise, Adel. L. Rev. (Routledge 2018) 3-4, https://law.adelaide.edu.au/system/files/media/documents/2019-03/ALR_39%282%29_08_Lisk.pdf; Nina Tannenwald, Law Versus Power on the High Frontier: The Case for a Rule-Based Regime for Outer Space, Yale J. of Int'l L. 29, 370 (2004), https://openyls.law.yale.edu/bitstream/handle/20.500.13051/6495/18_29YaleJ Intl L. 363_2004_.pdf?sequence=2&isAllowed=y. Ivan A. Vlasic, The Space Treaty: A Preliminary Evaluation, CAL. L. REV. vol. 55 no. 2 507 (May 1967), https://www.jstor.org/stable/3479358.

16. P. J. Blount, Renovating Space: The Future of International Space Law, DENVER J. OF INT'L. L. & POL'Y, vol. 40, no. 1, Art. 28 (Jan. 2011).

17. Frans G. von der Dunk, *The Origins of Authorisation: Article VI of the Outer Space Treaty and International Space Law*, Space, Cyber, and Telecommunications Law Program Faculty Publications (2011).

mechanism for preventing satellite collisions through further development of the existing regime.

1.1. Preventive Mechanism

Articles VI and IX of the Outer Space Treaty provide a sufficient legal basis for a preventive mechanism for satellite collisions with regard to the rights and duties of notification and consultation. Article IX provides that a state party shall undertake appropriate international consultations before proceeding with any space activities or experiments that are believed to cause potentially harmful interference with the space activities of other state parties.[18] The term "consultation" per se consists of both notification and negotiation. Article IX thus indicates that a state party has a duty of prior notification and consultation with respect to any space activities that may involve the risk of a satellite collision[19]. Correspondingly, state parties facing the risk of potential collisions have the right to request notification and consultation.[20] With respect to timing, it has been argued that the former state party should "enter into consultation prior to the authorization or commencement of an activity" and that the states potentially affected "can supposedly ask for consultation not only before, but also during the performance of such activity or experiment."[21]

In putting the rights and duties of notification and consultation into practice, specific rules should be in place to provide guidance on, for example, situations in which there is sufficient reason to believe in the possibility of

18. Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies, art. IX, *opened for signature* Jan. 27 1967, 18 U.S.T. 2410, 610 U.N.T.S. 205, 61 I.L.M. 386 (entered into force Oct. 10 1967).

19. Nandasiri Jasentuliyana, *International Space Law and the United Nations* 218 (Kluwer L. Int'l 1999).

20. Michael C. Mineiro, *FY-1C and USA-193 ASAT Intercepts: An Assessment of Legal Obligations under Article IX of the Outer Space Treaty*, 34 U. Miss. J. of Space L., 324 (2008).

21. Stephan Hobe et al., *Cologne Commentary on Space Law: Volume 1, Outer Space Treaty,* 180 (Carl Heymanns Verlag, 2009).

harmful interference, the scope of harmful interference, and the appropriateness and adequacy of consultation.[22]

A state party is required, in accordance with Article VI, to ensure the conformity of national space activities conducted by non-governmental entities with the relevant provisions of the Outer Space Treaty and to continuously supervise such activities.[23] Accordingly, a state party has the same duty of notification and consultation for space activities by non-governmental entities that may carry the risk of a collision.

Consequently, the preventive mechanism can be established in accordance with Articles VI and IX, with further concretization of the duties of notification and consultation. A state party shall conduct a comprehensive review of all space activities to be carried out by both governmental and non-governmental entities to prevent potential collisions in orbit. In the case of potential collision risks, the state shall notify the other relevant states and conduct appropriate consultations before granting a license for or proceeding with the activities, with the duties of notification and consultation not conditional on requests from other states.[24] The state engaging in activities that pose a potential collision risk has a responsibility to—and moreover is in the best position to—determine whether such a risk exists and to undertake the duties of notification and consultation. Other states have the right to request consultations before or during such activities, and the exercise of that right implies that the state conducting the activities has failed to fulfill its duties of notification and consultation.

To ensure the proper functioning of the preventive mechanism, it is necessary to explore international rules and domestic regulatory regimes to assist states in carrying out

22. Delbert D. Smith, *Space Stations: International Law and Policy* 115 (Routledge 1979).

23. Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies art VI, Jan. 27, 1967, 610 U.N.T.S. 205, 18 U.S.T. 2410.

24. Sonia Boutillon, *The Precautionary Principle: Development of an International Standard*, 23 Mich. J. of Int'l L. 429, 432 (2002).

their duties and overseeing non-governmental entities. In view of the ongoing work on STM, it is necessary to set up an information sharing platform on space orbit, strengthening the work on the collection, processing and analysis of orbit information. Transparency in orbit information would greatly improve the ability of early warning systems on the collision risks of space objects. Furthermore, in addition to information sharing, STM also involves coordination among states. Consultation can thus also be conducted on the aforementioned information sharing platform.

A national supervisory framework is another area worthy of examination. The Guidelines for the Long-term Sustainability of Outer Space Activities provide a useful basis for such a framework, particularly Guideline A.1 ("adopt, revise and amend, as necessary, national regulatory frameworks for outer space activities"), B.1 ("provide updated contact information and share information on space objects and orbital events) and B.4 ("perform conjunction assessment during all orbital phases of controlled flight").[25] In line with these guidelines, all states should include within their domestic regimes a provision requiring all entities conducting space activities to actively monitor and report potential collision risks.

1.2. Avoidance Mechanism

Articles VI and IX of the Outer Space Treaty can also serve as the legal basis for the avoidance mechanism. Although it does not specifically mention a duty to avoid collisions, Article IX emphasizes the principle of cooperation and mutual assistance and the principle of due regard to the corresponding interests of all other states in conducting space activities.[26] The latter principle implies that the space

25. Comm. on the Peaceful Uses of Outer Space, U.N. Doc. 105/2018/CRP.20 (2018).

26. Melissa K. Force, When the Nature and Duration of Space Becomes Appropriation: "Use" as a Legal Predicate for a State's Objection to Active Debris Removal, 1 1 INT'L. INST. OF SPACE L. (2014).

activities of one state should not endanger the safety of the space objects of other states. Accordingly, in the case of potential collision risks, the state that intends to conduct the space activities in question must pay due regard to the interests of other states and has an obligation to take active measures to avoid the occurrence of a collision in compliance with the principle of cooperation and mutual assistance.[27] Correspondingly, other states have the right to request that the state concerned take avoidance measures. When a non-governmental entity is involved, the state with regulatory and supervisory obligations, as defined in Article VI, should ensure that that entity complies with relevant provisions in the Outer Space Treaty and takes active avoidance measures.[28]

However, it must be noted that Articles VI and IX lack clear wording on the duty of active avoidance. We can only deduce such a duty from textual analysis of the two articles. Moreover, no detailed rules are provided on how to determine the entity that owes the duty or on how the duty should be carried out. A state could easily argue against any potential duties, thereby weakening the validity and effectiveness of the avoidance mechanism.

Accordingly, there is an urgent need to further improve the avoidance mechanism, whose essence lies in a comprehensive explanation of the duty of active avoidance. Such improvement could be made a part of negotiations over responsible conduct in space activities or STM. In determining the duty of active avoidance, three elements should be taken into account: the state at fault in inducing risks, that state's ability to avoid risks and the value of the space objects in question. Generally speaking, the state with a major fault, greater capacity to avoid a collision and/or

27. Gordon Chung, *Emergence of Environmental Protection Clauses in Outer Space Treaty: A Lesson from the Rio Principles* 2, in A Fresh View on the Outer Space Treaty (Annette Froehlic ed., 2018).

28. Peter P.C. Haanappel, The Law and Policy of Air Space and Outer Space: A Comparative Approach 57 (Kluwer Law International, 2003).

with a lower-value space object should assume the duty of avoidance.

1.3. Compensation Mechanism

Article VII of the Outer Space Treaty, in conjunction with the 1972 Convention on International Liability for Damage Caused by Space Objects ("Liability Convention" hereafter),[29] can be used to justify the establishment of a compensation mechanism.[30] Article VII defines the liability of a launching state for damage to another state or its natural or juridical persons.[31] The Liability Convention develops this article by providing detailed and comprehensive rules on the imputation principles,[32] allocation of liabilities,[33] time limit[34] and channels[35] for claims.

However, the Liability Convention fails to clarify certain issues.[36] For example, ambiguity exists over the apportionment of liabilities when a state's emergency avoidance measures cause damage to other states because of a risk-inducing state's failure to take avoidance measures. In addition to loss of life, personal injury or other health impairment, and property loss or damage, it is also time to consider including losses arising from collision avoidance

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29. Convention on International Liability for Damage Caused by Space Objects, Sept. 1, 1972, 961 UNTS 187.

30. Andrew Brearley, *Reflections upon the Notion of Liability: The Instances of Kosmos 954 and Space Debris*, 34 J. SPACE L. 291, 307 (2008).

31. Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies art VI, Jan. 27, 1967, 610 U.N.T.S. 205, 18 U.S.T. 2410.

32. Convention on International Liability for Damage Caused by Space Objects arts. II & III, Mar. 29, 1972, 961 U.N.T.S. 187, 24 U.S.T. 2389.

33. Convention on International Liability for Damage Caused by Space Objects arts. IV & V, Mar. 29, 1972, 961 U.N.T.S. 187, 24 U.S.T. 2389.

34. Convention on International Liability for Damage Caused by Space Objects art X. Mar. 29, 1972, 961 U.N.T.S. 187, 24 U.S.T. 2389.

35. Convention on International Liability for Damage Caused by Space Objects arts. IX, XI, & XIV, Mar. 29, 1972, 961 U.N.T.S. 187, 24 U.S.T. 2389.

36. Trevor Kehrer, *Closing the Liability Loophole: The Liability Convention and the Future of Conflict in Space*, 20 CHI J. INT'L 178, 179 (2019)

actions, such as the shortened service life and/or performance disorder of space objects, in the concept of "damage" defined in the Liability Convention.[37]

Furthermore, the Liability Convention does not cover the apportionment of liabilities between a state and non-governmental entity, which is left to national legal regimes.[38] Accordingly, it is vital that national legislation include provisions on the liability of non-governmental entities involved in space activities, obtaining compensation from non-governmental entities, the imputation principle, and the apportionment and sharing of liabilities.[39]

2. KEY STATES IN THE CONSTRUCTION OF AN INTERNATIONAL MECHANISM WITH REFERENCE TO INTERDEPENDENCE THEORY

With the mechanisms essential for the prevention of satellite collisions established, we now examine the theoretical basis for constructing a future mechanism. In this regard, it is necessary to make reference to interdependence theory in elaborating the role that key states can play in the construction process. It has been argued that asymmetrical interdependence is the source of power, as it affords an actor the ability to influence the patterns of outcomes.[40] Interdependence can be further differentiated into two dimensions: sensitivity and vulnerability. The deliberations of interdependence theory are most helpful in the present discussion for locating the key states in the construction process that have the most power/influence over the patterns and approaches of the future mechanism.

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37. Convention on International Liability for Damage Caused by Space Objects arts. I(a), Mar. 29, 1972, 961 U.N.T.S. 187, 24 U.S.T. 2389.

38. VALERIE KAYSER, LAUNCHING SPACE OBJECTS: ISSUES OF LIABILITY AND FUTURE PROSEPCTS 43, (Kluwer L. Int'l 2001).

39. JULIAN HERMIDA, LEGAL BASIS FOR A NATIONAL SPACE LEGISLATION 175-77 (Kluwer L. Int'l 2004).

40. ROBERT O. KEOHANE & JOSEPH S. NYE, JR, POWER AND INTERDEPENDENCE (4th ed., 2012).

2.1. Sensitivity Interdependence: State Sensitivity to the Issue of Satellite Collisions

Sensitivity in interdependence "involves degrees of responsiveness within a policy framework—how quickly do changes in one country bring costly changes in another, and how great are the costly effects?"[41] Accordingly, a state's sensitivity to the issue of satellite collisions reflects the degree of the effects of other states' actions on it, including the speed and scale of such effects.

The speed and scale of such effects are in large part related to two factors: the number and value of a state's space objects. A state with more space objects in orbit is affected to a greater degree by collision risks; similarly, a state with higher-value space objects is more readily affected, as it will suffer a greater loss in the event of a collision.

As far as the speed of the effects is concerned, an increase in the number of space objects heightens a state's sensitivity.[42] Accordingly, a state with more space objects is more readily affected by the issue of satellite collisions, and is correspondingly more likely to have an impact on other states with space objects in orbit.[43] States without space objects lack sensitivity to satellite collisions, and thus have no incentives to participate in the construction of an international mechanism. If other conditions remain unchanged, a state with more space objects has a higher degree of sensitivity; the more space objects a state has in orbit, the greater the likelihood of other states' space activities affecting it and the quicker the effect will be felt. Correspondingly, owing to its high degree of sensitivity, such a state has more incentives to pursue an international mechanism. In light of the large number of space objects under its control, changes in behaviors resulting from the

41. *Id.*

42. Carmen Pardini & Luciano Anselmo, *Evaluating the Impact of Space Activities in Low Earth Orbit*, 184 Acta Astronautica 17 (2021).

43. J.C. Liou, *Collision Activities in the Future Orbital Debris Environment*, 38 Advances in Space Research 2102 (2006).

space policies and rules of this type of state can exert significant effects on other states. Consequently, from the perspective of sensitivity interdependence, with all other conditions remaining unchanged, a state with more space objects in orbit has more power/influence than other states over the issue of satellite collisions.

When it comes to the scale of the effects, an increase in the value of space objects heightens a state's sensitivity. The greater the value of a single space object owned by a state, the greater the effects on that state, which thus has a stronger incentive to take active avoidance measures when faced with the risk of collisions. Correspondingly, a state with a lower-value space object has a lower degree of sensitivity because it will suffer fewer losses in the event of a collision. Furthermore, such states may assume that states with higher-value space objects will take active avoidance measures when there is a collision risk in order to avoid suffering more expensive losses. Accordingly, less sensitive states are less likely to take active avoidance measures. A state with space objects of a generally low value, even if large in number, has a low degree of sensitivity owing to its prediction that other states will take active avoidance measures to avoid losses. Such a state's lack of incentives to take active avoidance measures inevitably amplifies the sensitivity of other states. In these circumstances, states with fewer but higher value space objects have greater sensitivity.

Sensitivity interdependence suggests that states with space objects are likely to be more willing to participate in the construction of an international mechanism owing to their sensitivity. Furthermore, states with a higher number of lower-value space objects amplify the sensitivity and influence of other states. According to the Outer Space Objects Index maintained by the UN Office for Outer Space Affairs, the United States (U.S.) has the largest number of space objects under its control (5557 in total, 4085 in orbit),[44] a much higher number than that of other states.

44. United Nations Office for Outer Space Affairs, Outer Space Objects Index, https://www.unoosa.org/oosa/osoindex/index.jspx (last visited Apr. 5, 2022).

Furthermore, most space objects owned by the U.S. are Starlink satellites, which have very low manufacturing and launch costs. Accordingly, on the issue of satellite collisions, U.S. conduct has a greater and more quickly felt impact on other states than the conduct of other states. Without the participation of space powers such as the U.S., the efficacy of any future collision avoidance mechanism would be extremely limited.

2.2. Vulnerability Interdependence: A State's Vulnerability to the Issue of Satellite Collisions

Vulnerability is defined as "an actor's liability to suffer costs imposed by external events even after policies have been altered."[45] It has been further pointed out that "the vulnerability dimension of interdependence rests on the relative availability and costliness of the alternatives that various actors face."[46] Accordingly, a state's vulnerability to the issue of satellite collisions depends on whether it has alternative means of avoiding collisions and on the cost of doing so. This state then becomes a potential party in setting the rules of the game.[47]

Early perception, early avoidance and active avoidance are three major ways to avoid satellite collisions and can be achieved through bilateral or multilateral cooperation among relevant states. A state's early perception capability relies on its space situational awareness technology, which can help the state to detect collision risks in advance. Early avoidance can facilitate the advance arrangement of satellite orbits to avoid collisions, with all relevant parties coordinating and adjusting the orbits before their own space objects enter or change orbits. Active avoidance involves the maneuverability of the space object itself. In the event of an imminent collision, a space object with sufficient

45. Keohane and Nye, supra note 40, at 11.

46. *Id.*

47. Richard N. Cooper, Prolegomena to the Choice of an International Monetary System, 29 Int'l Org. 63 (1975).

maneuverability can take action to avoid the collision. Obviously, collision avoidance capacity is closely related to a state's aerospace technology; the more advanced a state's aerospace technology, the lower its degree of vulnerability. States without the necessary technology will obviously face difficulties in implementing the necessary measures to avoid satellite collisions, and thus must rely on possible collaboration with the space powers.

Here, we can again use the U.S. as an illustrative example. The U.S. has ample low-cost alternative means of avoiding satellite collisions. In terms of early perception, it has the world's most advanced Space Situational Awareness System (SSA), which is able to detect collision risks relatively conveniently and quickly.[48] Accordingly, the U.S. has more time than other states to consider countermeasures in response to an imminent collision. When it comes to early avoidance, given the large share of space objects belonging to the U.S., the country can take effective measures to avoid collisions through internal coordination. For example, SpaceX reached an agreement on collision avoidance with the U.S. National Aeronautics and Space Administration (NASA) in 2021.[49] Under the agreement, SpaceX is committed to taking measures to prevent Starlink satellites from affecting the International Space Station and NASA satellites by providing early notification, maintaining distance and performing active collision avoidance maneuvers.[50] As far as active avoidance is concerned, U.S. aerospace technologies are highly advanced, with most U.S. space objects having a maneuvering function. However, the U.S. can prevent most collision risks simply by relying on

48. Malgorzata Polkowska, *Global Space Security and Counter-space Capabilities: The Legal and Political Challenges*, 9 Przegląd Prawniczy Uniwersytetu im. Adama Mickiewicza 110 (2019).

49. J.D. Harrington, Nat'l Aeronautics and Space Admin., NASA, SpaceX Sign Joint Spaceflight Safety Agreement (Mar. 19, 2021), https://www.nasa.gov/news-release/nasa-spacex-sign-joint-spaceflight-safety-agreement/.

50. Jeff Foust, *NASA and SpaceX Sign Agreement on Spaceflight Safety*, SpaceNews (Mar. 19, 2021), https://spacenews.com/nasa-and-spacex-sign-agreement-on-spaceflight-safety/.

early perception and early avoidance, owing to its strong advantages in these two methods, without the need to take direct avoidance measures, which greatly reduces the cost of preventing potential collisions for the U.S. Consequently, the U.S. is able to avoid most collision risks even in the absence of an international mechanism for collision avoidance, meaning that it is likely to prefer unilateral actions or international cooperation of a limited scale to proactively negotiating with other states for the establishment of such a mechanism in future.

Other states have fewer and more expensive alternatives than the U.S., and thus the adoption of active avoidance measures is their main option. Their space situational awareness technology is less advanced than that of the U.S., making it more time-consuming and costlier to identify potential risks.[51] Moreover, the number of space objects owned by other states is much lower than that owned by the U.S. Accordingly, they have a strong incentive to cooperate with the U.S. to enhance their early perception and early avoidance capabilities in a cost-effective and efficient manner. Without cooperating with the U.S., states will be less effective in avoiding collisions through early perception and early avoidance. At the same time, taking active avoidance measures on their own will have only limited effects and at a high cost, as active avoidance consumes large amounts of energy and shortens the lifespan of space objects.

Vulnerability interdependence suggests that other states are more vulnerable than the U.S., which has more effective and lower-cost alternatives to respond to potential collision risks. Owing to their higher degree of vulnerability, other states may thus have to seek cooperation with the U.S. to lower their collision risks. The power imbalance among states adds to the difficulties of cooperation on an international collision avoidance mechanism.

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51. Sobia Paracha, *Military Dimensions of the Indian Space Program*, 11(3) Int'l. J. of Space Pol. & Pol'y. 156-86 (2013).

3. Main Approaches to Constructing a Future Mechanism

The foregoing analysis on the three mechanisms and key states with reference to interdependence theory lays a solid foundation for discussing the main approaches to constructing a future international collision avoidance mechanism, with a focus on how key states might use existing laws and international rules to push forward the construction and operation of such a mechanism. Combining the substance of the three mechanisms discussed above with the preferences of key states, this part of the article, taking the U.S. as an example of a key state, puts forward realistic suggestions for the main approaches to and path toward the construction of a future mechanism.

3.1. U.S. Preferences for Future Mechanism

Given the huge number of space objects it has in orbit, the U.S. will be indispensable to the construction of the proposed future mechanism, whose actual effect would be extremely limited without U.S. participation and compliance. Hence, U.S. participation in the mechanism's construction is essential to its ultimate success. However, given that the U.S. has less sensitivity and vulnerability to the issue of satellite collisions, it is less reliant on international collective action, and thus likely to be less willing to be bound by international law rules addressing the issue. Therefore, the initial stage of the future mechanism's construction will need to afford serious consideration to the interests and preferences of the U.S. It is possible to discern those preferences through various official documents issued by the U.S. government.

Of the three mechanisms discussed above, the U.S., taking into account its own interests, may well support only the preventive mechanism, rejecting the avoidance mechanism and compensation mechanism. As noted, Article IX of the Outer Space Treaty, without differentiating military and

civilian activities,[52] serves as the legal basis for the preventive mechanism,[53] and is in fact the legal basis for the safety zone system proclaimed by the U.S.[54] Therefore, the U.S. may propose the establishment of safety zones to prevent satellite collisions. Doing so would enhance both the legitimacy of the concept of safety zones and the impact of the U.S. version in interpretation of Article IX of the Outer Space Treaty. In addition, the duties of notification and consultation in the preventive mechanism overlap to a large extent with the issues of STM and the code of conduct for responsible space conduct that the U.S. currently focuses on. The U.S. may thus push ahead with developing relevant international norms through the preventive mechanism and amplify its own voice on these issues.

The U.S. is likely to be less incentivized to support the establishment of the avoidance mechanism. Although the owner of most space objects in orbit, the U.S. is less vulnerable to satellite collisions than other states. Moreover, under the avoidance mechanism, it would become the main bearer of the avoidance obligation, which would dramatically increase the cost of its own space activities. For these reasons, the U.S. is likely to oppose the explicit formulation of an avoidance obligation at the international level.

Nevertheless, both Space Policy Directive-3 of the National Space Traffic Management Policy[55] and U.S.

52. Robert Ramey, *Armed Conflict on the Final Frontier: The Law of War in Space*, 48 Air Force L. Rev. 76-77 (2000).

53. Sergio Marchisio, *Article IX*, in 1 Cologne Commentary on Space Law 176 (Stephan Hobe et al. eds., 2009).

54. Nat'l Aeronautics and Space Admin., The Artemis Accords: Principles for Cooperation in the Civil Exploration and Use of the Moon, Mars, Comets, and Asteroids for Peaceful Purposes § 11.7 (Oct. 13, 2020), https://www.nasa.gov/wp-content/uploads/2022/11/Artemis-Accords-signed-13Oct2020.pdf?emrc=653a00.

55. Space Policy Directive-3, National Space Traffic Management Policy, https://trumpwhitehouse.archives.gov/presidential-actions/space-policy-directive-3-national-space-traffic-management-policy/.

submissions[56] in response to UN General Assembly (UNGA) Resolution 75/36[57] clearly show that the U.S. supports and intends to take a leading role in the establishment of both preventive and avoidance mechanisms.

As far as the preventive mechanism is concerned, Space Policy Directive-3 endorses the sharing of information on potential collisions and does not exclude the disclosure of key data to avoid collisions. The document's emphasis is on space debris collisions, with most of its sections touching on space debris mitigation rather than satellite collisions.[58] Nevertheless, the directive does support the establishment of an open architecture space situation awareness data repository, including "the inclusion of satellite owner-operator ephemerides to inform orbital location and planned maneuvers."[59] It further emphasizes the maintenance of U.S. leadership in space.[60] The U.S. will no doubt make full use of its advantages in spatial data to ensure its dominant position in the construction of the preventive mechanism.

When it comes to the avoidance mechanism, Space Policy Directive-3 makes it clear that the U.S. "should develop a set of standard techniques for mitigating the collision risk."[61] In its submissions in response to UNGA Resolution 75/36, the U.S. suggests that all states should consider the adoption of best practices and responsible behaviors to avoid potential collisions or harmful interference.[62] These submissions once

56. United States of America, National Submission to the United Nations Secretary General Pursuant to UN General Assembly Resolution 75/36, Reducing Space Threats through Norms, Rules and Principles of Responsible Behaviors, https://front.un-arm.org/wp-content/uploads/2021/05/04292021-US-National-Submission-for-UNGA-Resolution-75.36.pdf.

57. Resolution adopted by the United Nations General Assembly on December 7, 2020, December 16, 2020, A/RES/75/36, https://documents-dds-ny.un.org/doc/UNDOC/GEN/N20/354/39/PDF/N2035439.pdf?OpenElement.

58. *See e.g.*, supra note 56.

59. Space Policy Directive-3, § 5(a)(ii).

60. *Id* at §1.

61. *Id.* at § 5(c)(i).

62. USA submission, supra note 56, at 6.

again reiterate U.S. leadership in promoting shared norms and forging new agreements on outer space.[63]

The U.S. may lack sufficient interest in establishing a compensation mechanism, which would likely increase the operating costs of its commercial space enterprises and adversely affect the commercial space industry as a whole. At the moment, the U.S. is home to a large number of commercial aerospace enterprises, which would be required by the compensation mechanism, once instituted, to assume compensatory liability for damages arising from a collision. As emphasized by Space Policy Directive-3, a new approach to STM that encourages the growth of the U.S. commercial space sector must be developed.[64] Naturally, the U.S. would not favor a compensation mechanism that imposed huge economic costs on its commercial space enterprises.

3.2. Preferences of Other States for Future Mechanism

Other states have stronger incentives than the U.S. to establish an international mechanism. They have higher degrees of vulnerability and dependence with respect to satellite collisions, and, moreover, their unilateral measures and/or cooperation between or among themselves are less effective in resolving the issue.

Other states thus have a greater need for the preventive and avoidance mechanisms than the U.S. Owing to the insufficiency of their space situational awareness technologies, these states tend to rely on information sharing and joint consultation for early planning to avoid potential collisions. As early planning saves avoidance costs, the preventive mechanism is likely to be preferable to the avoidance mechanism. However, with the number of space objects increasing, not all collision risks can be detected in advance.[65] Therefore, the avoidance mechanism remains

63. *Id.* at 1.

64. Space Policy Directive-3, supra note 55, at § 1.

65. F. Letizia, C. Colombo & H.G. Lewis, *Collision Probability Due to Space Debris Clouds through a Continuum Approach*, 39 J. of GUIDANCE, CONTROL, & DYNAMICS 2240, 2240-49 (2015).

indispensable. Explicit provisions on avoidance obligations would not only help to reduce avoidance costs, but would also encourage states to reasonably arrange space object orbits in advance to discharge their avoidance obligation.

These states may similarly lack enthusiasm for establishing a compensation mechanism in view of the difficulties of such a mechanism in the negotiation process and its potentially limited effects in practice. On the one hand, the deficiency of the compensation mechanism stems from the shortcomings of the Liability Convention. It would undoubtedly be unrealistic and unreasonable to formulate a compensation mechanism solely for the issue of collision avoidance. Improvement of the compensation mechanism is closely associated with the further development and improvement of the Liability Convention, tasks that are proving to be rather difficult at this stage.[66] On the other hand, as an *ex post* remedy, the compensation mechanism cannot effectively resolve the root cause of the issue, and thus its actual function is more limited than those of the other two mechanisms. The primary goal of all states in designing the future mechanism should be on how to avoid collisions, not on how collisions should be compensated after the fact. Moreover, existing space technologies are able to avoid most collision risks. Hence, the establishment of a compensation mechanism may play only a deterrent role in reality.

3.3. Approaches and Path Based on Common Preferences

It is clear from the foregoing discussions that the U.S. and other states share common interests in the prevention and avoidance mechanisms,[67] which should thus be used as the starting point for construction of the future mechanism at the international level, with the aim of gradually reaching

66. Alexander P. Reinert, *Updating the Liability Regime in Outer Space: Why Spacefaring Companies Should Be Internationally Liable For Their Space Objects*, 62 WM. & MARY L. REV. 327, 339-45 (2020-2021).

67. Lotta Viikari, THE ENVIRONMENTAL ELEMENT IN SPACE LAW: ASSESSING THE PRESENT AND CHARTING THE FUTURE, 147 (2008).

consensus on a comprehensive framework for collision avoidance in the future.

3.3.1. Existing Rules and Measures

Article IX of the Outer Space Treaty can serve as the legal basis for the preventive mechanism with regard to early notification and consultation for the ultimate goal of protecting space environment. There is no need for states to formulate new international norms for that mechanism. What is needed is the further refinement and clarification of specific duties under the article, which is arguably formulated in very general terms.[68] State practice, including unilateral action or international cooperative measures, can assist in the clarification of such duties, which would in turn strengthen the interpretation and enforcement of Article IX.

Unilateral action is a straightforward choice whereby states take the initiative to invoke Article IX by notifying and initiating consultations, inspiring other states to take similar actions. Such state practices may develop into international customs over time. Interdependence theory dictates that states with fewer vulnerabilities in interdependent relationships can exert greater influence over other states. Accordingly, unilateral actions taken by space powers such as the U.S., China and Russia have a more significant international impact. On the one hand, space powers can be encouraged to actively assume international responsibilities by taking the initiative to fulfil their notification and consultation obligations to avoid collisions. On the other hand, such unilateral actions would also be conducive to enhancing the international credibility and influence of these space powers.

However, state practice takes time to develop and cannot effectively address the urgent issue of satellite collisions. The adoption of either a soft law document or binding

68. Anel Ferreira-Snyman, ENVIRONMENTAL RESPONSIBILITY FOR SPACE DEBRIS, IN OUTER SPACE LAW: LEGAL POLICY AND PRACTICE 415 (Yanel A. Failat and Anel Ferreira-Snyman eds., 2d ed., 2022).

international document clarifying a state's relevant duties would be a better choice. Such adoption could be achieved through the UN platform or through bilateral or multilateral negotiations beyond that platform.

Consequently, in addition to unilateral actions, space-faring nations could also clarify their notification and consultation obligations through bilateral or multilateral agreements by defining the specific content and enforcement processes of those obligations. Bilateral agreements are relatively easier to conclude than multilateral arrangements. A good bilateral agreement can also set a good example for other states to follow, ensuring that more bilateral cooperation is achieved. The texts of these bilateral agreements could serve as an important reference for the construction of an international mechanism in future.

Multilateral agreements will face more challenges and take longer to negotiation. It would be advisable for the Legal Subcommittee of the UN Committee on the Peaceful Uses of Outer Space (UNCOPUOS) to add a new item to Article IX under the title "General Exchanges of Views on the Interpretation and Application of Article IX of the Outer Space Law" in its agenda to allow the international community to reach consensus on the understanding and implementation of this article. States should be given an opportunity to communicate on such key concepts as harmful interference, advance notification and advance consultation, allowing the international community to reach consensus on the obligations of notification and consultation. On the basis of such consensus, states can then gradually transform the preventive mechanism envisaged by Article IX into practice.

Although Article IX does not directly mention the avoidance mechanism, the principle of cooperation and mutual assistance in its provisions can provide a solid legal basis for the establishment of the avoidance mechanism and obligation. Discussions of the aforementioned agenda item could also lay the groundwork for an avoidance mechanism, allowing states to explore ways of understanding the principle of cooperation and mutual assistance and how it

can be applied in different contexts. Accordingly, the principle could be effectively implemented in reality, which would in turn lay the foundation for implementation of the avoidance mechanism and obligation.

The application of Article IX provides the initial steps for the international community to devise relevant mechanisms for dealing with satellite collisions. It also provides the necessary consensus and an institutional prototype for further development. As discussed above, unilateral actions and international cooperative agreements can help states to understand such obligations as notification, consultation and avoidance, which would be conducive to further discussion of how to improve space collision avoidance rules.

3.3.2. Future Development

In the long run, the international community will need to look beyond Article IX of the Outer Space Treaty to explore a more comprehensive framework for dealing with the issue of satellite collisions and the protection of space environment. Space-faring nations place a high value on rules such as the Guidelines for the Long-term Sustainability of Outer Space Activities [69] and discussions of the rules on STM and responsible space behaviors, all of which have a close relationship with the space collision avoidance mechanism. Therefore, these three sets of rules could serve as both a starting point and solid foundation for the establishment of more comprehensive preventive and avoidance mechanisms.

At the moment, states have reached consensus on the Guidelines for the Long-term Sustainability of Outer Space Activities, which are being implemented in practice. States can improve their domestic regulatory frameworks for

69. *United Nations Committee on the Peaceful Uses of Outer Space, Guidelines for the Long-term Sustainability of Outer Space Activities*, conference room paper by the Chair of the Working Group on the Long-term Sustainability of Outer Space Activities, Vienna, June 2018, A/AC.105/2018/CPR.20. https://www.unoosa.org/res/oosadoc/data/documents/2018/aac_1052018crp/aac_1052018crp_20_0_html/AC105_2018_CRP20E.pdf.

environmental protection by implementing these guidelines for collision avoidance. The preventive mechanism can be gradually constructed through implementation of Guidelines A.1, B.1 and B.4, which respectively impose the following requirements on states: States should (1) "adopt, revise and amend, as necessary, national regulatory frameworks for outer space activities"[70]; (2) "provide updated contact information and share information on space objects and orbital events"[71]; and (3) "perform conjunction assessment during all orbital phases of controlled flight."[72] In line with these requirements, states should strengthen their supervision of domestic space objects and require relevant entities to conduct assessments of space rendezvous in advance and share key orbital information. Doing so is crucial for the construction and operation of the preventive mechanism.

With STM rules and rules on responsible space behaviors still under discussion, states can incorporate the issue of satellite collisions into their ongoing discussions and gradually establish a more comprehensive collision avoidance mechanism through development of these two sets of rules. The UNCOPUOS Legal Subcommittee provides an excellent platform for discussions of collision avoidance under its agenda item entitled "General exchange of views on the legal aspects of space traffic management." STM has been defined as a "set of regulatory rules to ensure safe access to outer space, safe operations in outer space and safe return from outer space."[73] States can discuss the sharing of spatial data and implementation of the avoidance obligation. As the U.S. supports the establishment of a spatial data repository and technical standards for collision avoidance in outer space under the STM system, states can discuss implementation methods and specific rules along these two directions. The U.S. would then have an incentive

70. *Id.* at A.1.1.

71. *Id.* at B.1.

72. *Id*. at B.4

73. International Academy of Astronautics, *Cosmic Study on Space Traffic Management* 29 (2006).

to participate and cooperate, which would help consensus to be reached among all states. Through this pathway, the international community can establish both preventive and avoidance mechanisms while developing STM rules.

In addition, the 77th session of the UNGA included under the item "Prevention of an arms race in outer space" a sub-item entitled "Reducing space threats through norms, rules and principles of responsible behaviors."[74] This agenda item provides another international platform for states to discuss and develop collision avoidance mechanisms in outer space. Now that all space-faring nations agree on the importance of the preventive and avoidance mechanisms, they can, in line with their common preferences, promote the two mechanisms by including the obligations of notification, consultation and avoidance in the list of responsible behaviors.

It is worth mentioning here that the preventive mechanism and avoidance mechanism should not be bundled together. States should be free to choose the easier topic, i.e., the preventive mechanism, first for discussion and consensus. The core of the preventive mechanism is advance notification and consultation, which are clearly stipulated in Article IX. The Outer Space Treaty does not explicitly mention the avoidance obligation, making it easy for states to diverge on the details of that obligation. Therefore, bundling the two mechanisms together is likely to hinder the construction of both. It might be more sensible to put discussion of the avoidance mechanism on hold for now and give priority to the preventive mechanism, which has a more specific legal basis and is less controversial. The successful establishment of the preventive mechanism could indicate to all states that a considerable degree of consensus has been reached on the issue of collision avoidance, making it easier

74. United Nations General Assembly, Seventy-sixth session, Agenda item 98(d) Prevention of an arms race in outer space: reducing space threat through norms, rules and principles of responsible behaviors, Resolution adopted by the General Assembly on December 24, 2021, A/RES/76/231, https://documents.un.org/doc/undoc/gen/n21/417/21/pdf/n2141721.pd?token=AvYOaG6Hu5FwgAUV6F&fe=true.

for states to resolve their differences on the relevant rules of collision avoidance. If the importance and legitimacy of the avoidance mechanism were widely recognized and accepted by all states, there would be much less resistance to its establishment. The existence of both mechanisms could then effectively deal with the issue of collision avoidance.

Because there are still divergent views among states on the establishment of the compensation mechanism, it is best to begin with the prevention and avoidance mechanisms rather than bundling the three together for discussion. Once the prevention and avoidance mechanisms are in place and have proved to be effective, the international community will have more incentives to continue the discussions. The compensation mechanism may take more time, with the revisiting of the Liability Convention providing a potential impetus for its establishment.[75]

4. CONCLUSION

Outer space is a fragile environment.[76] The issues of environmental protection and space sustainability have been on the forefront, with space debris being one major concern. In light of the urgent need for mechanisms to prevent satellite collisions and protect environment in outer space, this article puts forward a three-stage framework, namely, before the incident (notification and consultation), during the incident (active preventive measures) and after the incident (damage and compensation). In strict legal terms, the following rights, duties and responsibilities are involved: the duty of prior notification and the right to request notification; the duty of prior consultation and the right to request prior consultation; the duty of active collision prevention and the right to request active collision prevention; and the responsibility to provide compensation

75. Caley Albert, *Liability in International Law and the Ramifications on Commercial Space Launches and Space Tourism* (2014) LOYOLA OF LOS ANGELES INT'L AND COMP L. R. 36(2), 244.

76. Paul B. Larsen, *Application of the Precautionary Principle to the Moon*, (2006) J. OF AIR LAW AND COMM. 71, 298.

for collision damages. In the long run, there is a need to look beyond Article IX of the Outer Space Treaty to explore a more comprehensive framework for environmental protection.

The UNCOPUOS Guidelines for the Long-Term Sustainability of Outer Space Activities, discussions on the space traffic management and responsible space behavior could serve as both a starting point and solid foundation for the establishment of more comprehensive mechanisms for prevention of satellite collisions and environmental protection. State can improve their domestic regulatory regime by voluntarily implementing these guidelines.

"The evolving regime of space law is constantly subject to developments from within and outside the law."[77] Relevant theories in the field of international politics or international relations, outside the constraints of legal rules or principles, will be helpful for construction of a legal regime for the avoidance of satellite collisions. By making reference to interdependence theory, this article looks further into the feasibility of and approach to constructing mechanisms to deal with the issue of satellite collisions with the objective of environmental protection in outer space. From a legal point of view and taking into account the aforementioned rights, duties and responsibilities, the future regime should consist of three mechanisms: a prevention mechanism, avoidance mechanism and compensation mechanism. Examination of the preferences of all states suggests that the future regime should start with the prevention mechanism, to be followed by the avoidance mechanism. The compensation mechanism is expected to take longer to agree, but should ideally be in place by the time the Liability Convention is revisited to achieve the ultimate goal of environmental protection in outer space and space sustainability.

77. Gbenga Oduntan, *Sovereignty and Jurisdiction in the Airspace and Outer Space: Legal Criteria for Spatial* Delimitation (Routledge 2012) 280.