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International Space Law for GNSS Civil Liability: *A possible solution?*☆

Dejian Kong*

China University of Political Science and Law, Beijing, China

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ABSTRACT

GNSS-related activities qualify as 'space activities', and it thus make international space law applicable. However, it is quite reticent to broadly interpret GNSS signals under the term 'space object', due to the lack of material and physical properties. The discussions on whether GNSS damage qualifies as indirect damage, and whether the Liability Convention cover that indirect damage, are irrelevant to the applicability of GNSS damage to the outer space treaties. GNSS damage may apply Article VII of the Outer Space Treaty and the Liability Convention as long as the causal link between the damage and GNSS satellites (not GNSS signals) is unbroken, logical, foreseeable and not too remote under the sense of general international law.

1. Introduction

The benefits of Global Navigation Satellite System (GNSS) have integrated into all walks of people's normal life in terms of public and commercial services based on the Positioning, Navigation and Timing (PNT) parameters.[1] However, the opportunities for increased safety, security and efficiency presented by GNSS shall not cover the risks behind its application. The best way to understand those risks is to imagine what would happen if GNSSs were turned off out of the blue [2]. The inevitable nature of GNSS risks due to its technical vulnerability, financial pressure, institutional challenges, and legal inadequacy makes the necessity for a GNSS uniform governance structure [3]. From a legal viewpoint, one of the most complex issues lies in civil liability for damage caused by GNSS (GNSS civil liability) [4]. The oligopoly of the GNSS market leads that user States have to rely on certain GNSS which is out of their control. User States thus attempt to secure their national interests through the establishment of a clear civil liability regime [5]. Also, GNSS is inherently labelled by a global nature because of its worldwide deployment, coverage, and application, which lead to the fact of transnational litigant parties with damage in multi-jurisdictions. Therefore, it is necessary to call for an effective and uniform solution in international law for the issue of GNSS civil liability.

Considering the fact that GNSS is a key element of space systems, international space law deserves to be the first try, compared with other branches of modern international law, for example, international air law. Against this background, this article first attempts to link GNSS with the legal sources of international space law; then it tries to figure out the relationship between those sources and the issue of GNSS civil liability, basically through answering the following two key questions: (1) do GNSS signals qualify as 'space objects'? and (2) is GNSS damage covered by the term 'damage' under the Liability Convention? Afterwards, the matter of causation in the context of GNSS civil liability is tested under the theory of general international law. Finally, concluding remarks are made.

For the purpose of this article, the term 'GNSS civil liability' is defined as 'the obligation to make reparation for any damage caused, especially in the form of monetary payment, by the inappropriate

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* Corresponding author.
E-mail address: kong.dejian@aerospacelaw.cn.

[1] For the general technical background of GNSS, please see NovAtel Inc., *An Introduction to GNSS* (NovAtel Inc., 2010).

[2] Scott Madry, *Global Navigation Satellite Systems and Their Applications* (Springer, 2015), at 1.

[3] See Dejian Kong, *Shaping a uniform governance structure over Global Navigation Satellite System (GNSS): The way of risk management*, 21 (2-3) Uniform Law Review 2016, at 396-400.

[4] This is particularly true in the aviation community where the International Civil Aviation Organization (ICAO) has been dealing with the legal aspects of a GNSS including the issue of civil liability since 1980s. See Ludwig Weber, *The Global Navigation and Communications Satellite Systems and the Role of ICAO*, in: ESA/ECSL, et al., Proceedings of the Third ECSL Colloquium- International Organisations and Space Law (European Space Agency, 1999), at 99.

[5] Kong, *supra note* 3, at 411.

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PNT signals provided by core GNSS, augmentation system and regional system, but excluding GNSS value-added service and malfunction of user equipment.' [6] The terms 'GNSS contractual liability', 'GNSS tort liability (without product liability)', and 'GNSS product liability' constitute three pillars of the regime of GNSS civil liability [7].

Notably, this article only checks the possibility of applying the regime of civil liability in international space law to the issue of GNSS civil liability, but it does not analyse how the burden of compensation is allocated among different parties based on the fault factors of activities in outer space. Also, the term 'damage' used in this article is limited to those presented in Article I (a) of the Liability Convention.

2. GNSS under international space law

As the name implies, space law is the law that regulates space-related activities [8]. As space activities commonly occur in an international domain [9], most parts of space law fall within international law [10], thereby forming the term 'international space law'. However, international space law may be ambiguous when applying its general rules on responsibility and liability to specific space activities such as satellite remote sensing and satellite navigation [11]. It appears that few legal documents and provisions of international space law focus on satellite navigation [12]. Therefore, what we first need to check is whether the provisions of GNSS services or signals could be qualified as international space activities, and only then international space law is applicable [13].

2.1. The term 'space activity' in the context of GNSS

The term 'space activity' frequently appears in treaties, domestic legislation and academic papers. By referring to the definition of space law [14] and the wording of outer space treaties [15] and national legislation [16] as well as other relevant international documents [17], the author believes that it is reasonable to define the term 'space activity' as follows:

> *The human activity for the purpose of exploration of outer space including the Moon and other celestial bodies, ranging from the research, development, manufacture, operation and use of space infrastructure.*

Furthermore, GNSS is a space-based system [18] and a space asset [19], whose characteristics are similar to those of satellite remote sensing systems and satellite communication systems. Even though the operation activities are purely terrestrial undertakings, this does not reduce the space-based characteristics of a space system [20]. Therefore, GNSS-related activities ranging from launching navigation satellites to operating the whole navigation system qualify the term 'space activities' as defined previously, and it thus makes international space law applicable. This line of reasoning can be confirmed by the fact that (1) most of the GNSS powers incorporate activities associated with satellite navigation to the authorization and supervision scope of national space agencies, and (2) GNSS constitutes one of the competence items of the United Nations Office for Outer Space Affairs (UNOOSA) [21]. Also, UNISPACE III recognized GNSS application as one of the great space applications [22]. However, *'merely receiving signals or information in some other form from objects in outer space is not designated as space activities*' [23], and this is also consistent with the argument that GNSS civil liability excludes liability for malfunction of the user equipment receiving signals from the regime of GNSS civil liability [24].

2.2. Sources of international space law concerning GNSS civil liability

Compared with other branches of international law such as the law of the sea, international space law, the body of law governing

[6] See Dejian Kong, *Civil Liability for Damage Caused by Global Navigation Satellite Systems: A Conceptual Analysis*, XLI Annals of Air and Space Law 2016, at 334-335.

[7] *Ibid*, at 335.

[8] UNOOSA, *Space Law*, http://www.unoosa.org/oosa/ourwork/spacelaw/, accessed 2nd May 2017.

[9] Armel Kerrest and Caroline Thro, *Liability for damage caused by space activities*, in Ram S. Jakhu and Paul Stephen Dempsey (Eds.), Routledge Handbook of Space Law (Routledge, 2017), at 59.

[10] Gabriella Catalano Sgrosso, *International Space Law* (LoGisma editore, 2011), at 27.

[11] Assuyo Ito, *Legal Aspects of Satellite Remote Sensing* (Koninklijke Brill NV, 2011), at 244.

[12] All the United Nations treaties, principles and related General Assembly resolutions on Outer Space even do not mention satellite navigation directly. See UNOOSA, *United Nations Treaties and Principles on Outer Space and related General Assembly resolutions* (United Nations,2008), ST/SPACE/11/Rev.2.

[13] Whether a GNSS provider provides *services* or *signals* to users shall be discussed further. Regardless of the classification, GNSS *service* is of course not within the scope of the space *object*.

[14] E.g., Francis Lyall and Paul B. Larsen, Space Law: A Treatise (Ashgate, 2009), at 2: "At its broadest space law comprises all the law that may govern or apply to.

[15] E.g., Article I of the Outer Space Treaty: "Outer space . . . shall be free for exploration and use by all States . . . in accordance with international law." Article III of the Outer Space Treaty: *"States Parties to the Treaty shall carry on activities in the exploration and use of outer space, including the moon and other celestial bodies, in accordance with international law."*

[16] For example, Section 103 of the U.S. National Aeronautics and Space Act of 1958: "the term 'aeronautical and space activities' means (A) research into, and the solution of, problems of flight within and outside the Earth's atmosphere, (B) the development, construction, testing, and operation for research purposes of aeronautical and space vehicles, (C) the operation of a space transportation system including the Space Shuttle, upper stages, space platforms, and related equipment, and (D) such other activities as may be required for the exploration of space." Article 2 of the Law of the Russian Federation on Space Activities defines the term 'space activity' as 'any activity connected with direct operations to explore and use outer space, including the Moon and celestial bodies'. For more comprehensive discussion of the definition of 'space activities' in national legislation, please see Irmgard Marboe, *National Space Law*, in Frans von der Dunk and Fabio Tronchetti (Eds.), Handbook of Space Law (Edward Elgar Publishing, 2015), at 127-204.

[17] E.g., OECD, Handbook on Measuring the Space Economy (OECD, 2012), at 19: "The space sector includes all actors involved in the systematic application of engineering and scientific disciplines to the exploration and utilisation of outer space, an area which extends beyond the Earth's atmosphere."

[18] GNSS was defined as follows in UNISPACE III Report: "Global navigation satellite systems sare space-based radio positioning systems that provide 24-hour three-dimensional position, velocity and time information, in any weather conditions, to suitably equipped users anywhere on the surface of Earth, as well as airborne and space users." UN, Report of the Third United Nations Conference on the Exploration and Peaceful Uses of Outer Space (Vienna, 19-30 July 1999), 18 October 1999, A/CONF.184/6, at 49.

[19] Joan Johnson-Freese, *Space Warfare in the 21st Century* (Routledge, 2017), at 5.

[20] For example, 'remote space activities' is defined as "the operation of remote sensing space systems, primary data collection and storage stations, and activities in processing, interpreting and disseminating the processed data." Although all the above activities are ground-based, this does not run counter to the nature of space-based systems of satellite remote sensing systems as they fall within the reach of 'Principles Relating to Remote Sensing of the Earth from Outer Space', which is an important element of international space law. See Principle I of the Principles Relating to Remote Sensing of the Earth from Outer Space, adopted by the United Nations General Assembly in its resolution 41/65 of 3 December 1986; Fabio Tronchetti, *Legal aspects of satellite remote sensing*, in Frans von der Dunk and Fabio Tronchetti (Eds.), Handbook of Space Law (Edward Elgar Publishing, 2015), at 520.

[21] See UNOOSA, *Our work*, http://www.unoosa.org/oosa/en/ourwork/index.html, accessed 14th September 2017.

[22] *The Space Millennium: Vienna Declaration on Space and Human Development*, adopted by the Third United Nations Conference on the Exploration and Peaceful Uses of Outer Space (UNISPACE III) at its 10th plenary meeting, 30th July 1999; Nie Jingjing, *The Future of Uniform International Rules on GNSS Liability*, 54 Proceedings of the International Institute of Space Law 2011, at 339.

[23] Section 1 of the Swedish Act on Space Activities.

[24] Kong, *supra note* 6, at 318.

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space-related activities [25], is much younger and adapted much less legal instruments. The development of international space law has been deadlocked for several decades since the Cold War. Currently, only the five treaties, with legally binding effect, on outer space address the issue of fundamental rules on the exploration of outer space, namely the 1967 Outer Space Treaty [26], the 1968 Rescue Agreement [27], the 1972 Liability Convention [28], the 1975 Registration Convention [29] and the 1979 Moon Agreement [30]. Nevertheless, international liability was placed in a quite important position in the drafting history of the Outer Space Treaty and the Liability Convention [31]. Back then the positions of the Soviet Union and the U.S. were unusually aligned on whether to include the issue of responsibility and liability into the discussion, even though they were widely divergent on many other issues [32].

As the foundation of outer space, the Outer Space Treaty lays down the basic regulations and framework of international space law, including liability for damage caused by space objects. Article VII of the Outer Space Treaty provides the legal basis to international claims for compensation [33]. Article VII states that each *launching State* shall be *'internationally liable for damage to another State Party to the Treaty or to its natural or juridical persons by such object or its component parts on the Earth, in air space or in outer space, including the Moon and other celestial bodies.'* [34]

The Liability Convention establishes specific provisions and categories of legal liability for injury or damage arising out of space activities with a legislative basis of Article VII of the Outer Space Treaty which was considered to be not sufficiently explicit about liability beyond its general provisions [35]. The international space law community recognizes the inherently ultra-hazardous nature of space activities [36]. To favour the interests of victims on the surface of the Earth or in the aircraft in flight, the Liability Convention regulates a strict/absolute liability for damage, where claimants do not share the burden of proof of fault [37]. Liability under the Outer Space Treaty and the Liability Convention is geographically and financially unlimited, and it provides maximum protection to potential victims [38]. What is more, those two treaties impose international liability squarely and only on those States qualifying as launching States [39], which ensures an efficient scheme for identifying the liable party and defendant. Also, the Liability Convention elaborates relevant definitions, settlement of disputes procedure, joint liability regime and other specific elements.

The aforementioned victim-oriented civil liability regime established by the Outer Space Treaty and the Liability Convention constitutes a legal source to analyse the matter of GNSS civil liability in international space law. Furthermore, as it seems increasing State practice has made the necessary *opinio juris*, the author supports the viewpoint to assert the status of the customary international law of Article VII of the Outer Space Treaty [40], in which case nonmember States could also apply a civil liability regime based on this provision [41].

Besides international treaties, the source of international law recognized by the International Court of Justice (ICJ) also includes (1) customary international law, (2) general principles of law, and (3) works of highly qualified publicists [42]. Items (1) and (2) are usually presented by general practice and national legal systems; item (3) works as subsidiary means for the determination of rules of law. Scholars generally hold that the source of international space law should be the same as general international law [43].

3. Do GNSS signals qualify as 'space objects'?

There was not any generally accepted legal definition of the term 'space object' at the time when the Liability Convention was concluded [44]. Article I of the Liability Convention regulates that 'the term "space object" includes component parts of a space object as well as its launch parts thereof', but most scholars recognize this provision as an *expression* rather than a full definition of the term 'space object' [45], or as a partial definition [46]. From a legal standpoint, it is without question that navigation satellites including their components are space objects here [47], but it is questionable whether a *signal* transmitted by those navigation satellites could fall within the term 'space object' according to that expression.

[25] UNOOSA, *supra note* 8.

[26] Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial (the 'Outer Space Treaty'), done 27th January 1967, entered into force on 10th October 1967; United Nations, *Treaty Series*, vol. 610, No. 8843.

[27] Agreement on the Rescue of Astronauts, the Return of Astronauts and Return of Objects Launched into Outer Space (the 'Rescue Agreement'), done 22nd April 1968, entered into force on 3rd December 1968; United Nations, *Treaty Series*, vol. 672, No. 9574.

[28] Convention on International Liability for Damage Caused by Space Objects (the 'Liability Convention'), done 29th March 1972, entered into force on 1st September 1972; United Nations, *Treaty Series*, vol. 961, No. 13810.

[29] Convention on Registration of Objects Launched into Outer Space (the 'Registration Convention'), done 14th January 1975, entered into force on 15th September 1976; United Nations, *Treaty Series*, vol. 1023, No. 15020.

[30] Agreement Governing the Activities of States on the Moon and Other Celestial Bodies (the 'Moon Agreement'), done 18th December 1979, entered into force on 11th July 1984; United Nations, *Treaty Series*, vol. 1363, No. 23002.

[31] Stephan Hobe, Bernhard Schmidt-Tedd and Kai-Uwe Schrogl (Eds.), *Cologne Commentary on Space Law: Volume I (Carl Heymanns Verlag, 2009)*, at 130.

[32] UNOOSA, LSC Summary Records - 7th Session, 1962, A/AC.105/C.2/SR.1.

[33] Hobe, Schmidt-Tedd and Schrogl, *supra note* 31, at 142.

[34] Article VII of the Outer Space Treaty.

[35] Hobe, Schmidt-Tedd and Schrogl, *supra note* 31, at 136.

[36] I. H. Ph. Diederiks-Vershoor and V. Kopal, *An Introduction to Space Law* (Kluwer Law International, 2008), at 37; Hobe, Schmidt-Tedd & Schrogl, *supra note* 31, at 143-144.

[37] Article VII of the Outer Space Treaty; Article II of the Liability Convention.

[38] Hobe, Schmidt-Tedd and Schrogl, *supra note* 31, at 136.

[39] Article VII of the Outer Space Treaty; Article II of the Liability Convention.

[40] Ram S. Jakhu and Steven Freeland, *The Relationship between the Outer Space Treaty and Customary International Law*, 59 Proceedings of the International Institute of Space Law 2016, at 183.

[41] It should be noted here that (1) the status of customary international law only increases the scope of application to nonmember States, but does not affect the applicability of the Outer Space Treaty to the damage caused by GNSS; (2) the question of whether the status of customary international law of Article VII of the Outer Space Treaty extends to the Liability Convention remains open and needs further discussion, but it is out of the scope of this research.

[42] Article 38 of the Statute of the International Court of Justice, annexed to the UN Charter.

[43] Article 38(1) of the Statute of the International Court of Justice, annexed to the UN Charter; N. M. Matte, *Space Activities and Emerging International Law* (McGill University, 1984), at 74; HE Qizhi, *Outer Space Law* (Law Press·China, 1992), in Chinese, at 21.

[44] E Carpanelli and B Cohen, *Interpreting "Damage Caused by Space Objects" under the 1972 Liability Convention*, 56 Proceedings of International Institute of Space Law 2013.

[45] Bin Cheng, *International Responsibility and Liability for Launch Activities*, 20(6) Air and Space Law (1995), at 297; Hobe, Schmidt-Tedd & Schrogl, *supra note* 31, at 139-140; Stephan Hobe, Bernhard Schmidt-Tedd and Kai-Uwe Schrogl (Eds.), *Cologne Commentary on Space Law: Volume II* (Carl Heymanns Verlag, 2013), at 110 and 115; W. F. Foster, *The convention on international liability for damage caused by space objects*, 10 The Canadian Yearbook of International Law 1972, at 144-145; Carl Q. Christol, *The Modern International Law of Outer Space* (Pergamon Press, 1982), at 108; Ra Michael Chatzipanagiotis & Konstantina Liperi, *Regulation of global navigation satellite systems*, in Ram S. Jakhu & Paul Stephen Dempsey (Eds.), Routledge Handbook of Space Law (Routledge, 2017), at 165; B.D. Kofi Henaku, *The International Liability of the GNSS Space Segment Provider*, XXI (1) Annals of Air and Space Law 1996, at 165.

[46] Stephen Gorove, *Toward a Clarification of the Term "Space Object": An International Legal and Policy Imperative?*, 21(1) Journal of Space Law 1993, at 12.

[47] Cheng, *supra note* 45, at 297–310.

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For the aforementioned confusion, there are three schools of thought. The first school insists that a space object itself would have both material and physical properties which excludes a signal [48]; the second school argues that damage from intangible electromagnetic waves was not absolutely excluded in the interpretation of the Liability Convention even though physical damage caused by tangible parts of a space object was of foremost concern [49]; the third school directly recognizes that the signal emitted from the space object is indeed a space object [50]. Therefore, a proper interpretation to see whether a space object must be tangible or material is essential for applying the issue of GNSS civil liability to the Outer Space Treaty and the Liability Convention.

Unlike the United Nations Convention on the Law of the Sea [51] and the Convention on International Civil Aviation (the 'Chicago Convention') [52], the treaties on outer space neither offer a mechanism for the interpretation of their provisions in general nor design a remedy for the settlement of disputes in understanding those provisions [53]. In this regard, we have to make reference to the rules of interpretation laid down in general international law: Article 31–33 of the Vienna Convention on the Law of Treaties (the 'Vienna Convention') [54], which represents the final and authoritative achievement of decades of efforts on treaty interpretation [55].

The interpretation rules set down by the Vienna Convention stipulate that a treaty must be interpreted by the *ordinary meaning* of treaty terms with reference to *the context* and *the object and purpose* of the treaty [56]. In other words, the three primary means of interpretation that can be used by an interpreter citing Article 31 are as follows: (1) conventional language, (2) the context, and (3) the object and purpose of a treaty [57].

3.1. Interpretation by the conventional language

Determining the ordinary meaning of the term 'object' is the point of departure for understanding the term 'space object'. The term 'object' is in daily usage [58], and it usually refers to a material thing that can be seen and touched with a fixed shape or form [59]. However, nontangible radiations, which include GNSS signals, are a series of radio waves with electronic information [60], and it is, hence, not even an *object*, let alone a *space object* [61]. Also, although the author agrees that Article 1(d) of the Liability Convention does not qualify as a definition of the term 'space object', it indeed may serve as a basis to understanding the real meaning of that term [62]. The nondefinition is the result of the Legal Subcommittee of the UNOOSA believing that the term 'space object' had a reasonably clear meaning, and it was the only necessary to emphasise that all the component parts and launching devices were included besides a space object itself [63]. In this sense, the minimum requirement of a space object is physical nature otherwise no component parts or launching devices thereof could be included.

3.2. Interpretation by the conventional context

The terms of a treaty are not drafted in isolation, and we must consider their normal meaning within the entire treaty text [64]. In the context of Article VII of the Outer Space Treaty and the Liability Convention, such phrases as 'the launching of an object to outer space' [65], 'a space object is launched' [66], 'launch a space object' [67], and 'the operation of that space object' [68] are frequently used. It seems that a space object is usually connected with *launching* and *operating* activities, even though those activities may not be essential for each space object [69]. This argument could also be supported by the academic definition, offered by Professor Bin Cheng, of the term 'space object', that is 'anything that human beings *launch* or attempt to *launch* into space' [70]. Besides the Liability Convention, the Registration Convention shares the same expression and meaning of the term 'space object' word for word [71]. Article 4 (d) of the Liability Convention regulates that the basic orbital parameters including nodal period, inclination, apogee and perigee concerning each space object shall be carried on the registry of each State. In this sense, it seems clear that the term 'space

[48] Carl Q. Christol, *International Liability for Damage Caused by Space Objects*, 74 American Journal of International Law 1980, at 354; Hobe, Schmidt-Tedd & Schrogl, *supra note* 31, at 139; Kerrest & Thro, *supra note* 9, at 64.

[49] Lesley Jane Smith, *Legal aspects of satellite navigation*, in Frans von der Dunk and Fabio Tronchetti (Eds.), Handbook of Space Law (Edward Elgar Publishing, 2015), at 585.

[50] Henaku, *supra note* 45, at 165.

[51] Part XV of the United Nations Convention on the Law of the Sea.

[52] Article 84, Chapter XVIII of the Chicago Convention.

[53] Hanneke van Traa-Engelman, *Settlement of Space Law Disputes*, 3(3) Leiden Journal of International Law 1990, at 139-155.

[54] Here, there may arise a question of how the interpretation of a preceding treaty could (for example, the Outer Space Treaty taking effect in 1967) apply rules codified by a later treaty (the Vienna Convention taking effect in 1980). For this question, certain scholars have already made a convincing point of view and case analysis by the following words: *The ICJ (International Court of Justice) has on several occasions confirmed that both Article 31 and Article 32 of the VCLT (Vienna Convention) reflect customary international law and has applied these rules to treaties that predated the VCLT. For example, in 1999, the Court interpreted and applied the rules codified in Arti that predated the VCLT. For example, in 1999, the Court interpreted and applied the rules codified in Article 31 and 32 of the VCLT, when considering the meaning of a treaty was concluded in 1890.* Ram S. Jakhu & Steven Freeland, *The Relationship between the United Nations Space Treaties and the Vienna Convention on the Law of Treaties*, 55 Proceedings of the International Institute of Space Law 2012, at 386-387.

[55] Ulf Linderfalk, *Is the hierarchical structure of article 31 and 32 of the Vienna convention real or not? interpreting the rules of interpretation*, 54 (1) Netherlands International Law Review 2007, at 134; Evan Criddle, *The Vienna Convention on the Law of Treaties in U.S. Treaty* Interpretation, 44 (2) Virginia Journal of International Law 2004, at 433.

[56] Article 31 of the Vienna Convention reads as follows: *A treaty shall be interpreted in good faith in accordance with the ordinary meaning to be given to the terms of the treaty in their context and in the light of its object and purpose.*

[57] Linderfalk, *supra note* 55, at 153.

[58] Gorove, *supra note* 46, at 25.

[59] *Collins COBUILD Advanced Learner's Dictionary* (Harper Collins Publishers, 2001), at 1058; *The Concise Oxford Dictionary* (Foreign Language Teaching and Research Press & Oxford University Press, 1999), at 938; *Longman Dictionary of Contemporary English* (Foreign Language Teaching and Research Press, 2002), at 973; *Webster's New World College Dictionary* (Liaoning Education Press & Hungry Minds Inc.), at 994; *Macmillan English Dictionary for Advanced Learners of American English* (Foreign Language Teaching and Research Press, 2002), at 958.

[60] Collins, *supra note* 59, at 1448; Oxford, *supra note* 59, at 1291; Longman, *supra note* 59, at 1335; Webster's, *supra note* 59, at 1333; Macmillan, *supra note* 59, at 1306.

[61] Gorove, *supra note* 46, at 25.

[62] Hobe, Schmidt-Tedd & Schrogl, *supra note* 45, at 115.

[63] Foster, *supra note* 45, at 145; UNOOSA, LSC Summary Records - 7th Session, 1968, A/AC.105/C.2/SR.106

[64] Mark E. Villiger, *Commentary on the 1969 Vienna Convention on the Law of Treaties* (Martinus Nijhoff Publishers, 2009), at 427.

[65] E.g., Article VII of the Outer Space Convention.

[66] E.g., Article I of the Liability Convention.

[67] E.g., Article V of the Liability Convention.

[68] E.g., Article VII of the Liability Convention.

[69] Gorove, *supra note* 46, at 17-18.

[70] Cheng, *supra note* 45, at 297. Professor Vladimir Kopal also made a similar but a bit complicated definition to the term "space object" as follows: *As "space object" should be considered any object launched by man for a mission into outer space, be it into orbit around the Earth or beyond/i.e. into interplanetary space, to and around the Moon and other celestial bodies of the Solar system, or into deep space.* Vladimir Kopal, *Some Remarks on Issues Relating to Legal Definitions of "Space Object", "Space Debris" and "Astronaut"*, 37 Proceedings of the International Institute of Space Law 1999, at 101.

[71] Article 1 (b) of the Registration Convention.

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object' excludes GNSS signals as it has nothing to do with those orbital parameters. Another similar situation in the Moon Agreement is phrases such as 'land their space objects on the moon and launch them from the Moon' [72]. The author does not argue that each space object must be able to be 'launched', 'operated', 'registered', 'returned' and 'landed', but at least these expressions show a strong implication for the physical needs of a space object within the context of UN outer space treaties, particularly the Outer Space Treaty and the Liability Convention.

3.3. Interpretation by the conventional object and purpose

The aim of the regime of civil liability under international space law is to ensure the prompt, adequate and equitable compensation to victims for damage caused by space objects [73]. Based on this victim-oriented character, someone may argue that a broad interpretation to encompass damage from 'intangible electromagnetic waves' would be reasonable [74]. The author does not share this view. The purpose of interpretation is to determine the original meaning of terms or provisions, so that interpreters may not make new rules or revise the convention without the approval of all the contracting States. It should be noted that only when a particular treaty provision is ambiguous would an interpretation be necessary. To reflect what *should* be, particularly as such rules go beyond the normal meaning within the treaty context as required by Article 31.1 of the Vienna Convention, a treaty must be interpreted under the principle of good faith, and it would be inappropriate to 'read into' that provision certain rules [75].

Literally speaking, a space *object* should be physical, which thus excludes a GNSS signal. However, if we look at Article 31.4 of the Vienna Convention which allows a *special* meaning of a treaty term, a question may arise as to whether it is possible to understand in this way that a nonmaterial object, including a GNSS signal, was intentionally put into a special meaning of the term 'space object' by the drafters. The answer to that question depends on whether 'the parties so intended' [76]. The intention to give an unusual meaning to a treaty term must be evidenced by *travaux préparatoires* (the official record of a negotiation) [77]. The past tense of the term 'intended' used in Article 31.4 of the Vienna Convention directs us to examine the historical materials as well.

Even though the Outer Space Treaty (Article VII) and the Liability Convention finally use the term 'object' or 'space object', the starting point in their draft documents submitted by individual member States were terms such as damage caused by 'space vehicles' [78], 'space devices' [79] and 'the launching of objects into outer space' [80], and liability for 'space vehicle accident' [81]. It implies that what the delegations looked into was the civil liability for damage resulting from a physical object itself [82], rather than the intangible data, application or product emanating from that object [83], particularly at the moment of launching [84]. The author found no evidence indicating the drafters' intention to establish a connection between an intangible signal with a liability mechanism in the historical context of international space law. Taking a step back, even though the early GNSS, namely TRANSIT had been in operation at the time of drafting the liability provisions of international space law [85], the large-scale application, particularly in such safety-of-life fields as aviation, was more like science fiction at that very beginning of the space era. Against this background, the author believes that there were few possibilities for the drafters of the Liability Convention to even recognize the necessity to make civil liability regulations for an intangible GNSS signal [86]. The author does not deny the possibility of applying old law to new technology and developed situations [87], but the aforementioned arguments show that no historical context supports the intention to add a special meaning to the treaty term 'space object'.

When taking a further step towards State practice, the facts are found that (1) the majority of States do not define the term 'space object' in their national laws, (2) certain space powers simply copied the expression of space object from Article I of the Liability Convention, and (3) only a few States give a specific definition [88]. Like international treaties on outer space activities, national legislation and academic viewpoints thereof also make the term 'space object' as a collective term that includes 'space vehicle', 'spacecraft', 'spaceship', 'satellite', and 'space station' [89]. Also, seven common elements of the definition of the term 'space object' in national laws could be concluded, namely: (1) object, (2) intent to launch, (3) launched, (4) launch vehicle, (5) payload, (6) physical component

[72] E.g., Article 8 of the Moon Agreement.
[73] Preface of the Liability Convention.
[74] Chatzipanagiotis and Liperi, *supra note* 45, at 165; Smith, *supra note* 49, at 585.
[75] Jakhu and Freeland, *supra note* 54, at 387.
[76] Article 31.4 of the Vienna Convention.
[77] Richard K. Gardiner, *Treaty Interpretation* (Oxford University Press, 2015), at 70.
[78] See UN Doc. A/4141, *Report of the Ad Hoc Committee on the Peaceful Use of Outer Space*, 14 July 1959, GA Official Records, Fourteenth Session, Agenda Item 25, Annexes, at 23; UN Doc. A/AC.105/C.2/L.4, *USA: Proposal-Liability for Space Vehicle Accidents*, 4 June 1962, in UN Doc. A/AC. 105/6, Report of Legal Sub-Committee on the Work of its First Session (28 May-20 June 1962), 9 July 1962, at 6
[79] UN Doc. A/AC.105/C.2/L.7, *Working Paper Submitted by the Belgian Delegation on the Unification of Certain Rules Governing Liability for Damage Caused by Space Devices*, 29th April 1963, in UN Doc. A/AC. 105/12, *Report of Legal Sub-Committee on the Work of its Second Session* (16 April-3 May 1963), 6th May 1963, Annex 1, C, at 10.
[80] UN Doc. A/AC. 105/C.2/L.8, *United States: Proposal-Convention concerning liability for the launching of objects into outer space*, 9 March 1964, in UN Doc. A/AC.105/19, *Report of the Legal Sub-Committee on the Work of its Third Session* (9-26 March 1964), 26 March 1964, Annex II, Proposals and amendments relating to liability for damage caused by objects launched into outer space, at 2; UN Doc. A/AC. 105/C.2/L.10, *Hungary: Proposed draft agreement - Agreement concerning liability for damage caused by the launching of objects into outer space*, 16 March 1964, in UN Doc. A/AC.105/19, *Report of the Legal Sub-Committee on the Work of its Third Session* (9-26 March 1964), 26 March 1964, Annex II, Proposals and amendments relating to liability for damage caused by objects launched into outer space, at 7.
[81] See UNGA Res. 1802 (XVII), *International co-operation in the peaceful uses of outer space*, 14th December 1962, Article I paragraph 3; UN Doc. A/AC.105/35, *Report of the Legal Sub-Committee on the Work of its Fifth Session* (12th July–4th August and 12th–16th September 1966), 16th September 1966, at 2.
[82] Christol, *supra note* 48, at 355; Roderick D van Dam, *GNSS and Aviation: Eurocontrol's Perspective*, Outer Space Committee Newsletter, 2000, at 48; Henaku, *supra note* 45, at 164.
[83] Stephen Gorove, *Some Thoughts on Liability for the Use of Data Acquired by Earth Resources Satellites*, 15 Proceedings of the International Institute of Space Law 1972, at 109; Hobe, Schmidt-Tedd & Schrogl, *supra note* 45, at 111.
[84] Hobe, Schmidt-Tedd and Schrogl, *supra note* 45, at 102.
[85] The TRANSIT was declared operational in January 1964 by the US military department and was released for civilian use in July 1967. Norman Bonnor, *A Brief History of Global Navigation Satellite Systems*, 65 Journal of Navigation (2012), at 3.
[86] Ruwantissa Abeyratne, *Space Security Law* (Springer-Verlag Berlin Heidelberg, 2011), at 25; Ingrid Lagarrigue, *Are Existing Navigation Satellite Liability Provisions Adequate to Govern Navigation Satellite Malfunction*, 3 (1) Outer Space Committee Newsletter 2000, at 32.
[87] The author agrees that old law could be applied to new technology, but the key point is to see whether the new technology is merely a change in degree (an improved version of something that already exists), or a change in kind (something else entirely with a new capability). See Rebecca J. Rosen, *The Thorny Combination of Old Laws and New Tech*, https://www.theatlantic.com/technology/archive/2011/11/the-thorny-combination-of-old-laws-and-new-tech/248111/, accessed 2nd May 2017.
[88] See Christopher M. Hearsey, *Comparative Study of the Definition of Space Object in National Space Laws and Its Legal Effect Under International Law*, https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2072514, accessed 20th July 2017.
[89] *Ibid*.

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parts and parts thereof, and (7) satellite [90]. In this scenario, the author does not see any major difference on the content of regulations between international treaties and State practice, regardless of whether or not those practices constitute customary international law or general principles of law.

Here, we can draw a brief conclusion that neither international treaties on outer space nor State practice shows sufficient support for the viewpoint of interpreting an adding an intangible GNSS signal to the physical term 'space object'.

4. Is GNSS damage covered by the term 'damage' under the Liability Convention?

To apply the Liability Convention in the case of an accident caused by the failure of GNSS, certain scholars try to broadly interpret the term 'damage', which is considered by academics as one of the most controversial aspects of legal history [91], within the context of 'damage caused by space objects'. They incorporate the notion of *indirect damage*, and further argue that (1) damage caused by GNSS qualify as indirect damage, and (2) this kind of indirect damage is covered by the Liability Convention [92].

Even though that the term 'damage' is clearly defined in Article I of the Liability Convention as 'loss of life, personal injury or other impairment of health; or loss of or damage to property of States or of persons, natural or juridical, or property of international intergovernmental organizations', many scholars still insist that this definition is ambiguous, particularly as to the question whether that term includes only direct damage or, *inter alia*, indirect damage too [93]. Actually, during the drafting of the Liability Convention, whether or not to regulate indirect damage was a thorny question which did not result in an agreement [94].

On one hand, the U.S. delegation expressed that the Liability Convention 'does not cover what some delegations earlier called remote or indirect damage and for which there is only at hypothetical causal connection with a particular space activity' [95], and pointed out that the question of indirect damage could cause great difficulties in practice [96]. This argument is confirmed by certain scholars [97], and it is the same true in the context of GNSS damage [98], for example:

> *Neither the language of the Convention, the negotiations leading to this Convention, nor State practice support such a claim the Liability Convention applies to indirect damage arising from the use of navigational satellite services* [99].

On the other hand, a few delegations such as India [100] were not satisfied with such a narrow interpretation as stated previously, which are further supported by certain scholars [101]. They believe that the notion of damage in Article I of the Liability Convention generally covers both direct and indirect damage [102], and only in this way could the Liability Convention live up to its victim-oriented nature. More importantly, the above view is equally shared by many scholars specific to GNSS damage [103], for example:

> *The conclusion that GNSS satellite damage other than collision is covered by the Liability Convention is not only correct from the reading of the provision but is also supported by the travaux préparatoires* [104].

To comment or make a choice between those two opposing arguments, the first necessary thing is to understand what constitutes indirect damage in the context of space law. Indeed, the term 'indirect damage' is opposed to 'direct damage', but the distinction between them, however, has long been criticised for its complexity and confusion. Case law even states that there should be no place for the theory of indirect damage in

[90] *Ibid*.

[91] Anna Masutti, *GNSS: The Basic Principles for a European Legal Framework on TPL*, in Alfredo Roma, Kai-Uwe Schrogl and Matxalen Sanchez Aranzamend (Eds.), *Policy Aspects of Third Party Liability in Satellite Navigation* (ESPI, 2009), at 33.

[92] Carpanelli and Cohen, *supra note* 44, at 45; Henaku, *supra note* 45, at 170; Chatzipanagiotis and Liperi, *supra note* 45, at 165.

[93] Piotr Manikowski, *Examples of space damages in the light of international space law*, 6 (1) The Poznań University of Economics Review 2006, at 60; Andrzej Górbiel, *Outer Space in International Law*(Uniwersytet Łódzki, 1981), at 107; Carpanelli and Cohen, *supra note* 44, at 31; Andreas Loukakis, *Non-Contractual Liabilities from Civilian Versions of GNSS: Current Trends, Legal Challenges and Potential* (Nomos, 2017), at 29.

[94] Report, A/AC.105/37, para. 17; Nandasiri Jasentuliyana and Roy S. K. Lee (Eds.), *Manual on Space Law: Volume I* (Oceana Publications, 1979), at 115; UN, *Yearbook of the United Nations 1967* (United Nations, 1969), at 31; Kerrest and Thro, *supra note* 9, at 67; Carpanelli and Cohen, *supra note* 44, at 44.

[95] Committee on Aeronautical and Space Sciences United States Senate, *Convention on International Liability for Damage Caused by Space Objects: Analysis and Background Data-Staff Report* (U.S. Government Printing Office Washington, 1972), at 24.

[96] Committee on Aeronautical and Space Sciences United States Senate, *Soviet Space Programs, 1966-70: Goals and Purposes, Organization, Resources, Facilities and Hardware, Manned and Unmanned Flight Programs, Bioastronautics, Civil and Military Applications, Projections of Future Plans, Attitudes Toward International Cooperation and Space Law. Staff Report* (U.S. Government Printing Office, 1971), at 481.

[97] Kerrest and Thro, *supra note* 9, at 57; Valerie Kayser, *Launching Space Objects: Issues of Liability and Future Prospects* (Springer Science and Business Media, 2006), at 49; Marco Ferrazzani, *The Role and liabilities of space segment operators*, in European Center of Space Law, Regulation of the Global Navigation Satellite System (GNSS): A Conference to examine Legal and Policy interests involved in the implementation of GNSS (ESTEC, 14–15th November 1996), at 160; Diederiks-Vershoor & Kopal, *supra note* 36, at 39; Frans von der Dunk, *International Space Law*, in Frans von der Dunk with Fabio Tronchetti, Handbook of Space Law (Edward Elgar Publishing Limited, 2015), at 84; Frans von der Dunk, *European Space Law*, in Frans von der Dunk with Fabio Tronchetti, Handbook of Space Law (Edward Elgar Publishing Limited, 2015), at 265; Paul B. Larsen, Joseph Sweeney and John Gillick, *Aviation Law: Cases, Laws and Related Sources* (Martinus Nijhoff Publishers, 2012), at 1052; Edward R. Finch, *Outer Space Liability: Past, Present and Future*, 14 (1) The International Lawyer 1980, at 126; Gorove, *supra note* 83, at 109.

[98] See Abeyratne, *supra note* 86, at 25; Lagarrigue, *supra note* 86, at 32; Francis P. Schubert, *An International Convention on GNSS Liability: When Does Desirable Become Necessary?*, XXIV Annals of Air and Space Law 1999, at 252; UNIDROIT, *An instrument on third party liability for Global Navigation Satellite System (GNSS) services: a preliminary study*, March 2010, at 21; Larsen, Sweeney & Gillick, *supra note* 97.

[99] Lagarrigue, *supra note* 86, at 32.

[100] See UN Doc. A/AC.105/C.2/L.26, *India: Draft Agreement on Liability - Proposal*, 30th June 1967, in UN Doc. A/AC.105/37, Report of the Legal Sub-Committee on the Work of its Sixth Session (19th June 1967–14th July 1967), 14th July 1967, Annex II, Proposals, amendments and other documents relating to liability for damage caused by the launching of objects into outer space, at 20.

[101] Lyall and Larsen, *supra note* 15, at 405; Bruce A. Hurwitz, *State Liability for Outer Space Activities in Accordance with the 1972 Convention on International Liability for Damage caused by Space Objects* (Martinus Nijhoff Publishers, 1992), at 15; Christol, *supra note* 48, at 362; Carpanelli and Cohen, (Martinus Nijhoff Publishers, 1992), at 15; Christol, *supra note* 48, at 362; Carpanelli & Cohen, *supra note* 44, at 39.

[102] Hobe, Schmidt-Tedd and Schrogl, *supra note* 45, at 112; Carpanelli and Cohen, *supra note* 44, at 35.

[103] P. Rodriguez-Contreras Perez, *Damage Caused by GNSS Signals in the Light of the Liability Convention of 1972*, in Michael Rycroft (Eds.), Satellite Navigation Systems: Policy, Commercial and Technical Interaction (Springer-Science+Business Media, B.V., 2003), at 252; Henaku, *supra note* 45, at 170; Chatzipanagiotis and Liperi, *supra note* 45, at 165.

[104] Henaku, *supra note* 45, at 170. It should be noted here that the citation here is not conflict with the above argument that GNSS signal could not be recognized as a space objet. What the *travaux préparatoires* supports here that damage caused by GNSS satellite (vs GNSS signal) is covered by the Liability Convention, and the key term here is 'damage' rather than 'space object'.

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international law [105]. Nevertheless, as the possibility to recognize an intangible GNSS signal as a space object was disconfirmed as discussed previously, the author would like to discover whether the notion of indirect damage could be an alternative solution which is established on a different legal basis [106], with the help of a hypothetical case model as follows:

> *An aircraft with 300 passengers crashed into a farmer's house because the GNSS Landing System broke down due to defective GNSS signals, and all the crew, passengers and the farmer lost their lives [107]. The defective GNSS signals resulted from the malfunction of GNSS satellites because of (1) their collision with a space object (A); (2) the radio interference with a space object (A); or (3) an accounting error, defective components and other defects of GNSS itself.*

This case model could also be illustrated by Fig. 1 [108].

In this case model, what makes GNSS signals defective is not important, but the critical factor is that neither GNSS satellites nor Space Object (A) caused the damage by direct and a physical connection, which is not the usual way of 'damage caused by space objects'. However, it is quite clear that GNSS satellites qualify as the term 'space objects' regulated by Article VII of the Outer Space Treaty and the Liability Convention; damage here includes the personal casualty (passengers, crew and the farmer) and the loss of property (aircraft and house), which do comply with Article I (a) of the Liability Convention. Therefore, the key point here is not the question of whether indirect damage constitutes the term 'damage' as required by the Liability Convention, but whether we could say that damage is 'caused by' those GNSS satellites or Space Object (A), and hence the Liability Convention applies.

Regardless of the difficulty of finding an exact definition of the term 'indirect damage' [109], it is more or less right to say that the

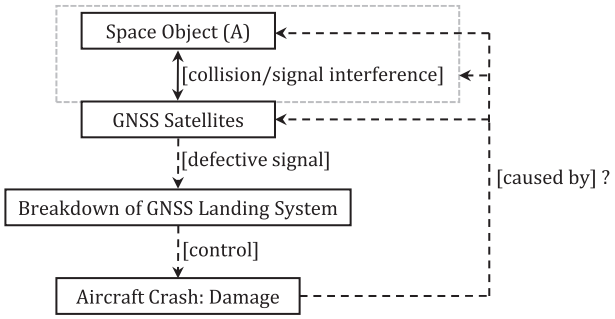

Fig. 1. Case model. GNSS, Global Navigation Satellite System.

term 'indirect damage' refers to the damage which is caused indirectly [110]. Based on this theory, the author holds that the nature of the question of whether 'damage indirectly caused by GNSS satellites' can be regarded as 'damage caused by space objects' depends more on the debate about the causal link between damage and relevant activities and what degree of causality is required to bring about liability [111]. In this regard, it does not matter that whether the definition of damage in outer space treaties covers the indirect damage. This argument is supported by some delegates, evidenced by the *travaux préparatoires* of the Liability Convention [112]. For example, after repeating the uncertainty of the term 'indirect damage' in general international law and the case law of international arbitration, the Japanese delegation believed that:

> all damages which have an adequate relationship of cause and effect with the space activities should be covered in this convention. To avoid endless discussion on whether to include those terms of "indirect damage" or "delayed damage" in the definition of damage, we should discuss the problem of these two terms not in which the damage occurred, by introducing the notion of adequate relationship of cause and effect or so called "the existence of proximity" in the Anglo-American laws[113].

Therefore, it is reasonable for us to argue that the difference between direct and indirect damage is a matter of adequate causation which was not expressed in the Liability Convention [114]. This argument has been extended to the context of GNSS civil liability by a few scholars [115], while the majority of scholars were still focussing on the definition of damage itself, i.e., whether GNSS damage could be included in the term 'damage' under the Liability Convention. The author shares the minority view and believes that, if the claim for GNSS damages intends to qualify under the outer space treaties, the key point lies in proving the *causation* between

[105] See F.V. Garcia Amador, Louis Bruno Sohn and Richard R. Baxter, *Recent Codification of the Law of State Responsibility for Injuries to Aliens* (Martinus Nijhoff Publishers, 1974), at 124; UN, *Report by Special Rapporteur of the International Law Commission (Arangio-Ruiz)*, UN Doc. A/CN.4/425, PARA. 36; UN, *Reports of International Arbitral Awards* (UN, 1956), at 62-63; Elihu Lauterpacht, C. J. Greenwood and A. G. Oppenheimer, *International Law Reports (117)* (Cambridge University Press, 2000), at 248.

[106] See Hobe, Schmidt-Tedd and Schrogl, *supra note* 45, at 129.

[107] The author finds a similar case in the context of satellite communication, which is the response to the US delegation who explained that indirect damage does not apply the Liability Convention, and this case and opinion is quite helpful to the research. The original words are as follows: "*Only when damage results from this interference is the Convention applicable: thus, if for example a space object of one state interrupts the transmission of radio signals from a communications satellite to an aircraft in flight, which makes that aircraft veer off course and crash, the first-mentioned state may be held liable by virtue of article II of the Convention.*" Peter van Fenema, *The 1972 Outer Space Liability Convention* (McGill University, 1973), at 62. The opinion which supports to apply the Liability Convention for damage caused by radio interference please see also Hurwitz, *supra note* 101, at 20.

[108] In the pictures used in this article, all full lines refer to the fact that physical connect exists between heading and ending points, and in contrast, all dotted lines mean that no physical connect exists.

[109] The notion of direct damage is emphasized from different perspectives in space law as well as the law of GNSS among international scholars. For example, Professor Smith and Professor Kerrest direct this notion to be "caused after an interval, an intervening event or events that are a consequence of the initial *impact*". Professor Masutti addresses indirect damage from the perspective of 'loss of profit'; Professor Mendes de Leon and Professor van Traa indicate that indirect damage refers to, in the context of GNSS, "damage caused by the signals in contrast with damage caused by the space object"; Dr. Andreas Loukakis holds that indirect cases of damage are resulted from "the use of capabilities of a space object" rather than the space object as such, where damage caused by defective signals emitted by GNSS satellites qualify as a typical example. See respectively: Hobe, Schmidt-Tedd & Schrogl, *supra note* 45, at 127; Masutti, *supra note* 91, at 33; Pablo Mendes de Leon & Hanneke van Traa, *Space Law*, in Jessica Schechinger (Eds.), The Practice of Shared Responsibility in International Law (Cambridge University Press, 2017), at 475 (note 75); Loukakis, *supra note* 84, at 31.

[110] Christol, *supra note* 48, at 360.

[111] Nicolas Mateesco Matte, *Aerospace Law: From Scientific Exploration to Commercial Utilization* (The Carswell Company Limited & Editions A. Pedone, 1977), at 157.

[112] See UNOOSA, LSC Summary Records – 7th Session, 1968, A/AC.105/C.2/SR.103.

[113] UNOOSA, Japan: Working Paper, A/AC/105/C.2/L.61, 1969; Nandasiri Jasentuli

[114] Bin Cheng, *Studies in International Space Law* (Clarendon Press Oxford, 1997), at 323; Pablo Rodriguez-Contreras Perez, *GNSS Liability issues: Possible solutions to a global system* (McGill University, 2002), at 46; Aldo Armando Cocca, *From Full Compensation to Total Responsibility*, 26 Proceedings of the Twenty-sixth Colloquium on the Law of Outer Space 1983, at 158.

[115] E.g., Perez, *ibid*, at 46 and 61; Perez, *supra note* 103, at 252.

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damage and *GNSS satellites/Space Object (A)* [116], particularly in the sense of the phrase '*damage* caused by *space objects*'.

5. The matter of causation in the context of GNSS civil liability: the key point

For the matter of causation, it is quite difficult to agree on a common definition in one specific convention where the conflict between *common law* and *civil law* has to be coordinated. But that difficulty, in turn, leaves broad discretion for the dispute settlement body to identify that causation in light of the intent and purposes of the convention thereof, as well as observing justice and equity, on a case-by-case basis [117]. Unlike the air law system in which the exact meaning or test of the causation is usually for domestic tribunals to decide [118], the outer space law has to deal with the matter of causation in a more international sense, because: on one hand, the outer space treaties do not give a general answer for the causation, but Article XII of the Liability Convention provides that the compensation 'shall be determined in accordance with *international law* and the principles of justice and equity' [119]; on the other hand, claims under the Liability Convention must be based on the model of State-vs-State by a Claims Commission rather than a municipal court [120].

Focussing on the context of GNSS civil liability, the matter of causation depends on the understanding of the term 'caused by' under the phrase 'damage caused by space objects', more specifically, 'damage caused by GNSS satellites' [121]. Actually, the term 'caused by' is greatly favoured by the international legal community as it could resolve the vexing question of causation, so as to 'allow for different tests of remoteness and causality which may be appropriate for different obligations or in different contexts, having regard to the interest sought to be protected by the relevant primary rule.' [122] This means that causation, in the context of GNSS damage, is opened to be examined and tested on the basis of discretion and under the general theory of causation in international law, which mainly refers to the criterion of 'directness' [123], 'foreseeability' [124] or 'proximity' [125 126].

For the criterion of 'directness', the international community, including the United Nations Compensation Commission [127], has started to abandon knowledge accumulated from old arbitral decisions [128], which qualify damage not immediately caused by the wrongful act as 'indirect' [129]. By contrast, the international community has started to hold that the 'directness' only focuses on the presence of a clear and unbroken causal link between cause and effect [130]. Also, the Mixed Claims Commission (the United States and Germany) [131] insisted that "it matters not how many links there may be in the chain of causation ⋯, provided there is no break in the chain ⋯' [132]. In a more academic language, we could say: as long as the damage can be clearly, unmistakably traced back, link by link, to the act as the exclusive cause through a connected, though not necessarily direct, chain of events, the damage must be compensated [133]. In this regard, after checking the cases containing the discussion of direct or indirect damages, Professor Bin Cheng concludes that: 'It is only true to say that in the majority of cases, in which the epithets 'direct' and 'indirect' are applied to describe the consequences of an unlawful act, they are in fact being used synonymously with "proximate" and "remote".' [134] What the author reads out from this conclusion is that: the usage of 'direct' or 'indirect' has nothing to do with the criterion of 'directness' (unbroken causal link) but what matters is the remoteness of damage, i.e., 'proximate' or 'remote'.

For the criterion of 'foreseeability', it is generally required that the existence or type of damage must be reasonably foreseeable at the time of the accident occurred or before by a *reasonable person* (it does not matter whether the liable person has in fact expected that damage or not), even though the extent of that damage could not have been foreseen [135].

The notion of 'proximity' or 'proximate cause' does not have a generally accepted meaning in practice [136], and its definition is still in progress with too many disagreements among courts and scholars, even though this notion is one of ancient 'vintage' in legal history [137]. Judges in the court alternatively determine whether the damage is 'not proximate' or 'too remote' [138]. It should be noted here that the criterion of 'proximity' itself does not exclude all 'remote' causes but only those which are 'too remote'.

Indeed, neither international law nor national law shows a general standard or theory for the matter of causation. There is no clear line to make an exact judgement on the notions of 'directness', 'foreseeability' and 'proximity' respectively. This fact urges us not to focus on one criterion mechanically but remain flexible as long as *the principles of justice and equity*, which are also stipulated by

[116] See Hobe, Schmidt-Tedd & Schrogl, *supra note* 45, at 191.
[117] Kayser, *supra note* 97, at 48-49.
[118] I.H.Ph. Diederiks-Verschoor and Pablo Mendes de Leon, *An Introduction to Air Law* (Kluwer Law International, 2012), at 302; Elmar Giemulla & Ronald Schmid (Eds.), *Montreal Convention* (Kluwer Law International, 2010), at Article 16-4.
[119] Matte, *supra note* 111.
[120] See Article XIV of the Liability Convention.
[121] As discussed previously, there are few possibilities to interpret 'GNSS signal' as 'space object', so here the author will not discuss the causation between 'damage' and 'GNSS signal' under the phrase 'damage caused by space objects'.
[122] See Article 31 (1), Responsibility of States for Internationally Wrongful Acts; James Crawford, *Articles on Responsibility of States for Internationally Wrongful Acts*, http://legal.un.org/avl/pdf/ha/rsiwa/rsiwa_e.pdf, accessed 16th August 2017.
[123] See para. 16 of the Security Council resolution 687 (1991).
[124] See *Portuguese Colonies case (Naulilaa incident)*, in United Nations, Reports of International Arbitral Awards: vol. II (Sales No. 1949.V.1), at 1031.
[125] See William Lloyd Prosser, *Selected Topics on the Law of Torts: Five Lectures Delivered at the University of Michigan* (William S. Hein, 1982), at 191.
[126] United Nations, *Yearbook of the International Law Commission 2000: Volume II Part One* (United Nations, 2009), at 18.
[127] The United Nations Compensation Commission (UNCC) was created in 1991 as a subsidiary organ of the United Nations Security Council under Security Council resolution 687 (1991) to process claims and pay compensation for losses and damage suffered as a *direct* result of Iraq's unlawful invasion and occupation of Kuwait in 1990-91. For more information, please visit http://www.uncc.ch/, accessed 16th August 2017.
[128] See United Nations, *Yearbook of the International Law Commission 1989: Volume II Part One* (United Nations, 1992), at 12 (note 63).
[129] Damage not immediately related to the wrongful act such as loss of earnings or profits has been clearly stated to be compensated by the UNCC. See paras. 5 and 20 of the Governing Council Decision no. 7, S/AC.26/1991/7/Rev.1, 17th March 1992.
[130] Marco Frigessi di Rattalma & Tullio Treves (Eds.), *The United Nations Compensation Commission: A Handbook* (Kluwer Law International, 1999), at 21.
[131] The Mixed Claims Commission (United States and Germany) was set up to deal with the compensation of the U.S. nationals for damage caused in Lusitania disaster from the German Government, under the Treaty of Berlin, signed August 25, 1921.
[132] United Nations, *Report of International Arbitral Awards: Mixed Claims Commission (United States and Germany) (November 1, 1923-October 30, 1939): Volume VII* (United Nations, 2006), at 29.
[133] Clyde Eagleton, *The Responsibility of States in International Law* (Kraus Reprint, 1970), at 202.
[134] Bin Cheng, *General Principles of Law as Applied by International Courts and Tribunals* (Cambridge University Press, 1987), at 243.
[135] Helen Gubby, *English legal terminology* (Eleven International Publishing, 2016), at 133.
[136] See William Lloyd Prosser, *Prosser and Keeton on the law of torts* (West Pub. Co., 1984), at 263-280.
[137] William C. Bryson, *Cause and Consequence in the Law*, in Rom Harre and Fathali M. Moghaddam (Eds.), Questioning Causality: Scientific Explorations of Cause and Consequence across Social Contexts (ABC-CLIO, 2016), at 331.
[138] H. L. A. Hart & Tony Honore, *Causation in the Law* (Oxford University Press, 1985), at lii.

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Article XII of the Liability Convention, have been duly observed. Therefore, the author holds that while the criterion of 'directness' intends to establish a factual causation, the criteria of 'foreseeability' and 'proximity' transfer that factual causation to a legal one with some limitations, to avoid there being no end to the possible liable parties for even minor acts of negligence and to restrict it from going too far beyond what the generally shared sense of justice would support [139].

Based on the previously performed analysis, we could now try to test causation in aforementioned hypothetical case where three possible causes are summarised as below. The author believes that these causes cover most of the cases concerning GNSS civil liability.

(1) *Collision with Space Object (A)*: In this case, the damage is caused actually by the collision between Space Object (A) and GNSS satellites, and therefore the causal link between Space Object (A)/GNSS satellites and damage must be established to claim for compensation. The fact of whose fault it is that caused the collision is critical to the identification for the liable party and the division of compensation in outer space [140], but it only makes a small difference to the causation test, namely: if the collision was caused by Space Object (A), then the causal link shall be illustrated in Fig. 2A [141]; if GNSS satellites caused that collision, the causal link would be illustrated in Fig. 2B; if that collision is caused jointly by Space Object (A) and GNSS satellites, the causal link would be illustrated in Fig. 2C.

Compared with the typical case in space law, Fig. 2 does not show any physical connection between the space object in question and damage caused by that space object, but the causal link is unbroken, which complies with the criterion of 'directness'. If there is no other factor intervening in this causal link, a reasonable person would be aware that the collision between a space object and GNSS satellites may interrupt the generation of GNSS signals [142], especially after the accident of the *Iridium 33 and Cosmos 2251 Collision* which indicated the possible communication service interruption [143]. Therefore, the criterion of 'foreseeability' also fits here. The only thing that needs to be further discussed is whether the causal link is 'too remote' or not under the criterion of 'proximity'. As there is no clear standard for the notion of 'proximity', we have to make a weighing of interests between victims and potentially liable parties through the principles of justice and equity.

The Liability Convention is in favour of *third* parties who are the most innocent party in the highly dangerous space activities [144], and requires the liable party to make compensation to the extent as if the damage had not occurred [145]. Even though it would be not fair to hold the party liable for any consequence which is not very closely related to the starting point of the causal link, the author believes that since all the causal links in Fig. 2 are simple, proximate and not too remote, it is fair enough to hold the party who or whose fault (in the sense of joint liability in outer space as shown by Fig. 2C) caused that collision to make prompt and full compensation to the victims in this case.

(2) *Signal interference with Space Object (A)*: In this case, the damage is caused by the signal interference between GNSS satellites and Space Object (A), and what is required for the claim is the causal link between the space object/GNSS satellites making unlawful interference and damage, as shown in Fig. 3. The structure and remoteness of a causal link in this case are similar to the one in Fig. 2, and the only big difference is between *collision* and *interference*, i.e., *physical connection* and *remote effect*. However, the matter of causation never requires a 'physical' link as an essential element. For example, in the *Cosmos 954 Claim*, the nuclear damage was not caused by a direct hit and connection but radiation contamination, which was accepted as the proximate cause of harm [146]. It seems too narrow to be fair enough if we restrict the notion of damage to the damage caused exclusively by direct contact [147]. It is not the key point whether the damage is suffered through physical impact with a space object or results from biological, chemical or radiological contamination emanating from a space object [148].

Therefore, the author believes that if the causal link could be established for the damage caused by the *collision* between Space Object (A) and GNSS satellites (see above), there is no reason to deny the causal link for the damage caused by *radio interference* between GNSS satellites and Space Object (A), as the remoteness of them is almost the same [149].

(3) Malfunction of GNSS itself. In this case, the damage is caused by the GNSS itself including its satellites [150], where the causal link between GNSS satellites and damage has to be established for a relevant claim for compensation. Admittedly, the case of this model has already existed in practice [151], and the author believes that it would continue to be the most probable way to happen in practice, compared with the *collision* and *radio interference* in outer space. In contrast with the two models mentioned previously, the difference in this case is that no other space object but GNSS satellites could be blamed for the damage, and this makes the causal link (see Fig. 4) even simpler and less remote, which is a good point for the victim.

It is clear that there is no physical connection between space objects (GNSS satellites) and damage, but as discussed previously,

[139] Bryson, *supra note* 137, at 330.

[140] Article III and IV of the Liability Convention.

[141] In this case, whether Space Object (A) or the liable party shall be obligated to pay the compensation Space Object (A).

[142] The space segment is a constellation of more than 20 satellites, and the collision or malfunction of a few satellites may not interrupt the GNSS service as a whole, but it is still not impossible. The lack of enough satellites that function well at least makes a difference to the performance of GNSS signals, which may cause an air accident.

[143] See Iridium Satellite LLC, *Update on Iridium Satellite Constellation*, http://investor.iridium.com/releasedetail.cfm?ReleaseID=429190, accessed 17th August 2017.

[144] Marietta Benko, Kai-Uwe Schrogl, Denise Digrell and Esther Jolley, *Space Law: Current Problems and Perspectives for Future Regulation* (Eleven International Publishing, 2005), at 92.

[145] Article XII of the Liability Convention.

[146] Christol, *supra note* 48, at 359; Q. C. Edward G. Lee & D.W. Sproule, *Liability for Damage Caused by Space Debris: The Cosmos 954 Claim*, 26 Canadian Yearbook of International Law 1988, at 276.

[147] See Diederiks-Verschoor and Leon, *supra note* 118, at 302.

[148] Foster, *supra note* 45, at 155.

[149] Kayser, *supra note* 97, at 48.

[150] One may argue in this case that the problem may arise from the ground control segment crashing rather than the failure of GNSS satellites themselves, but this does not affect the civil liability issues of GNSS satellites under international space law, as all the users get (defective) signals from those satellites rather than ground transmitters. However, defective signals solely from ground-based augmentation system do not in any way apply to the outer space treaties, but it may be involved into legal disputes as the operator or provider has to prove its innocence, which is quite difficult.

[151] See *Glonass Failure Caused by Faulty Software*, http://www.gpsdaily.com/reports/Glonass_Failure_Caused_by_Faulty_Software_999.html, accessed 21 August 2017.

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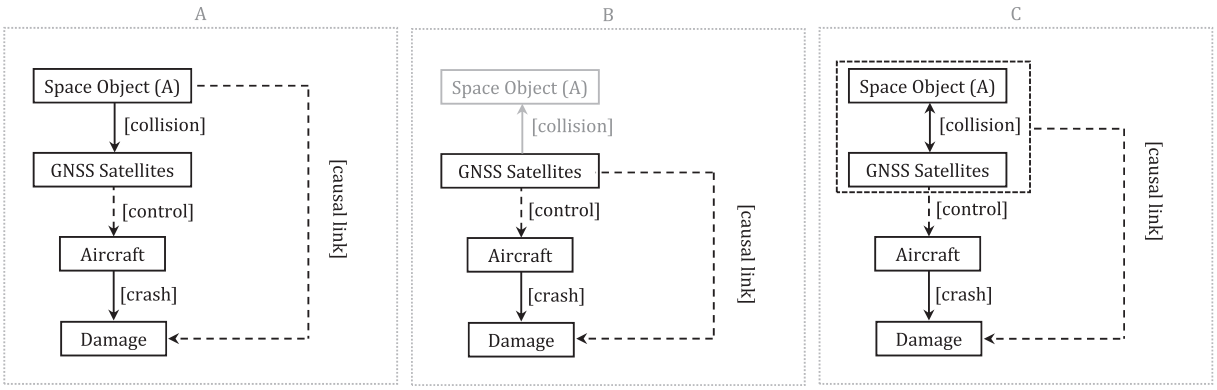

Fig. 2. Causation (I). GNSS, Global Navigation Satellite System.

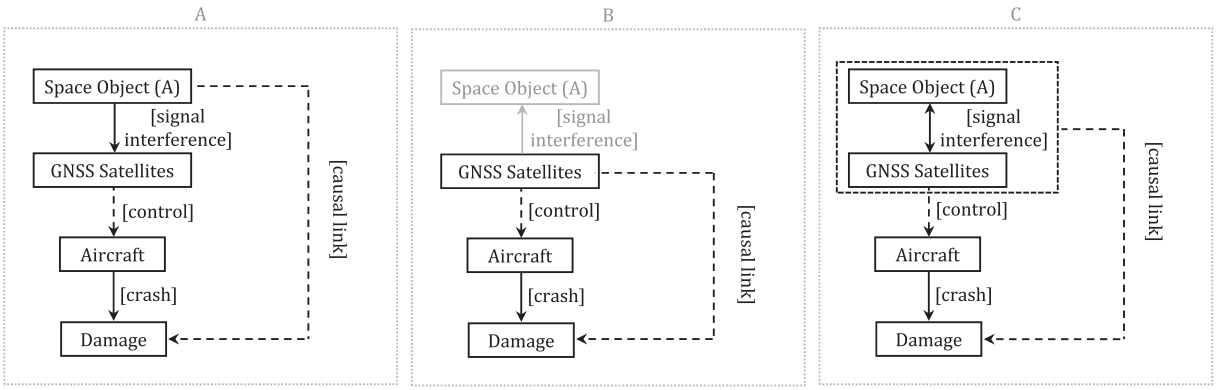

Fig. 3. Causation (II). GNSS, Global Navigation Satellite System.

it does not affect the establishment of the causal link. To support the author's argument, an analogy of the causal link between the case of damage caused by GNSS and that by Air Traffic Control (ATC) could be made with reference to the well-known *2002 Überlingen mid-air collision,* in which case the main cause was attributed to the ATC service provider [152]. The main causal link in the *2002 Überlingen mid-air collision* could be simply illustrated as in Fig. 5A.

It is quite apparent that the structure and remoteness of the causal link in Fig. 5A is almost the same as the one in Fig. 5B (Fig. 4). The only difference lies in the fact that ATC controls an aircraft by the 'command' to 'pilot-in-command', and GNSS satellites control an aircraft by the 'signal' or 'data' to the 'GNSS Landing System', which could be regarded as an 'auto-pilot'. Therefore, if air law practitioners could widely accept the causation in Fig. 5A [153], that will be no reasonable excuse for space law experts to deny the one in Fig. 5B (Fig. 4).

6. Conclusion

It is beyond question that the development and operation of GNSS qualify as space activities and hence international space law applies. Yet the author believes that international space law is quite reticent to broadly interpret GNSS *signals* under the term 'space object'. The questions of (1) whether indirect damage is covered by Article VII of the Outer Space Treaty and the Liability Convention and (2) whether GNSS damage qualifies as indirect

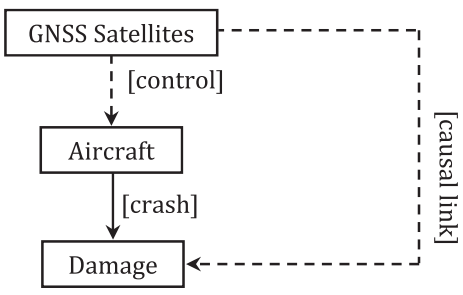

Fig. 4. Causation (III). GNSS, Global Navigation Satellite System.

[152] See German Federal Bureau of Aircraft Accidents Investigation, *Investigation Report*, AX001-1-2/02, May 2004, http://cfapp.icao.int/fsix/sr/reports/02001351_final_report_01.pdf, accessed 21st August 2017.

[153] The compensation issues between Bashkirian Airlines (whose aircraft was crashed and who paid compensation to most victims in the crash according to air law) and the Federal Republic of Germany (which transferred its part of sovereignty in terms of ATC service to Skyguide and which is legally responsible for the ATC civil liability) reached an out of court settlement around 2013. See F. Schubert, *The Liability of Air Traffic Control Agencies - The Ueberlingen Midair Collision Case Study*, Presentation to the Institute of Air and Space Law, McGill University, October 2014, at 51.

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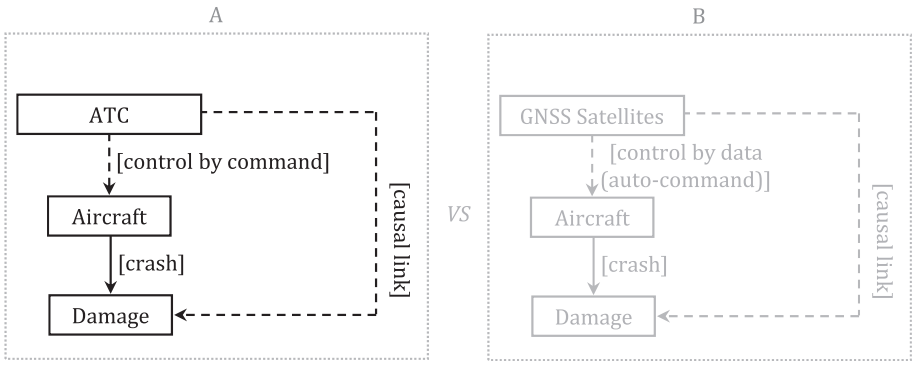

Fig. 5. Causation (IV). ATC, Air Traffic Control; GNSS, Global Navigation Satellite System.

damage have troubled the space community for quite a while. But the answers of those two questions are not a case in point in applying civil liability regime under the Outer Space Treaty and the Liability Convention to the issue of GNSS civil liability. What matters lies in the establishment of causation, on a case-by-case basis, between damage and space objects where GNSS satellites are included, with reference to the criterion of 'directness', 'foreseeability' and/or 'proximity' under the sense of general international law. Technically speaking, the author also admits that it will be quite challenging in practice to prove the matter of causation in the case concerning GNSS damage, but it is still not impossible with the help from, for example, technical experts.

Nevertheless, the author does not deny the fact that when both the Outer Space Treaty and the Liability Convention were formulated, it was far too early to handle or even foresee such 'new' (comparatively speaking) space technology concerns as the issue of GNSS civil liability. Despite the possibility to apply international space law (Article VII of the Outer Space Treaty and the Liability Convention) for the issue of GNSS civil liability, the adequacy, feasibility and fairness of this solution remain to be further studied [154].

[154] The present international space law does provide a possible solution to deal with the issue of GNSS civil liability, but its adequacy and fairness are questionable for several reasons. For example: (1) the regime of civil liability regulated by Article VII of the Outer Space Treaty and the Liability Convention is actually a State-vs-State liability system, where claims must be brought by a 'State' against another 'State', but it does not give a legal cause on the court for the private parties; (2) according to the current civil liability regime under international space law, the identification of the liable party is focused on the launching activities, but this may not fit the issue of GNSS civil liability, because GNSS damage is actually caused by the *operation* of GNSS rather than the *launching* activities of GNSS satellites; (3) neither Article VII of the Outer Space Treaty nor the Liability Convention set limits in terms of compensation, and this may be against GNSS sustainable development and (4) as to the matter of causation, different understandings may exist in different cases, and this legal uncertainty raises challenges when dealing with the issue of GNSS civil liability to some extent. All those factors will be further researched by the author in another article.

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