LEUPHANA
UNIVERSITÄT LÜNEBURG

09.07.2018

Bachelor Thesis

LL.B. Law (Corporate and Business Law)

Space Sustainability and Connectivity

Selected Aspects of Large Satellite Constellations - a Legal Analysis

Table of Contents

List of Abbreviations

ARSIWA	Draft Articles on Responsibility of States for Internationally Wrongful Acts
ARRA	Agreement on the Rescue of Astronauts, the Return of Astronauts and the Return of Objects Launched into Outer Space
Art.	Article
Arts.	Articles
CNES	Centre national d'études spatiales
COPUOS	Committee on the Peaceful Use of Outer Space
Doc.	Document
Ed.	Edition
Eds.	Editors
EU	European Union
GEO	Geostationary Earth Orbit
IADC	Inter-Agency Space Debris Coordination Committee
ICAO	International Civil Aviation Organization
ICJ	International Court of Justice
ICJ Statute	Statute of the International Court of Justice
JSpOC	Joint Space Operations Center
LEO	Low Earth Orbit
LIAB	Convention on International Liability for Damage Caused by Space Objects
LTS Guidelines	Long-term Sustainability Guidelines
MOON	Agreement Governing the Activities of States on the Moon and Other Celestial Bodies
OST	Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies
Par.	Paragraph
REG	Convention on Registration of Objects Launched into Outer Space
Res.	Resolution
SDG	Sustainable Development Goal
Ser.	Series
SSN	Space Surveillance Network
TCBM	Transparency and Confidence Building Measures
UN	United Nations
UN Charter	United Nations Charter
UNGA	General Assembly of the United Nations
UNSC	Security Council of the United Nations
U.N.T.S.	United Nations Treaty Series
US	United States of America
VLCT	Vienna Convention on the Law of the Treaties
Vol.	Volume

Abstract

The increasing perils of connectivity technologies in the context of large satellite constellations come alongside with legal aspects concerning the protection of the space environment. The interplay of connectivity and sustainability must be regulated. To analyse the legal measures and tools regulating the risks, both sides of the problem are taken into consideration. The technological side of large satellite constellations is summarized under the term cybersecurity. Cyber is a code-based system, i.e. at first sight it requires a specialized field of law. This holds true on space sustainability as well. Large satellite constellations raise the discussion on space debris and junk. The consensus on the LTS guidelines by COPUOS at UNISPACE+50 in 2018 constitutes a milestone in Space Law. Space sustainability requires a particular adoption of legal norms: the idea is very similar to the subject of cybersecurity. Since both areas of issue are internationally driven and have multilateral impact, self-regulation proves ineffective. The genesis of reliable and uniform legal rules requires a different approach considering the multi-level systems of obligations with different binding authority.

This thesis evaluates the balance between the future of connectivity and space sustainability in the context of large satellite constellations by considering the impact of legal rules with different binding authority.

Keywords: space sustainability, connectivity, large satellite constellations, LTS guidelines, cyberlaw, space debris.

Introduction/Background

Today, states and citizens are highly dependent on networks. Networks consist of satellites processing a large number of data packages containing information.[1] The volume of data being collected, analysed and stored is highly increasing.[2] In an inter-connected world the amount of possible entry points into a network multiplies with the number of devices. The dependency on networks does not only affect the technological level of cybersecurity but also the level of sustainability in Outer Space. To support the advancing network access and connectivity, large scale satellite services and space applications were needed.

Large satellite constellations are launched or are intended to be launched in order to cope with the demand of connectivity.[3] By launching satellite constellations of more than 100 satellites per constellation into the Low Earth Orbit (LEO) the orbit has become jammed with satellites. Coming with it, space debris such as non-functional space objects occur with an increasing density.[4] A sustainable approach on using and operating satellites is recently discussed at a high-level forum.[5] The Outer Space environment has already changed due to the intervention of humankind in space orbits. The question is how to prevent further disruption and achieve a sustainable environment in Outer Space for future generations.[6] This study analyses selected legal challenges and the currently discussed legal approaches (especially the LTS Guidelines) for implementing a future of connectivity in a sustainable space.

The balance between the future of connectivity and space sustainability in the context of large satellite constellations is evaluated in this thesis. To do so, the impact of legal rules with different binding authority is analysed. Part A introduces the current development of cyber-technology in the field of connectivity. This aspect then leads to part B. The occurring threats to connectivity technologies are discussed by taking into consideration that space is a limited resource and sustainable usage is needed in order to make space accessible and usable for future generations. These two distinct major parts elaborate on the subject and are eventually concluded in part C consisting of an outlook.

Even though the elements of cybersecurity and sustainable space seem to be very distinct at first sight this thesis will explore that they are common in one aspect: the legal implementation of norms and obligations follows an equal process. The analysis of this theory follows a repeated structure: First, rules falling under International Law are discussed. Second, the thesis

---

[1] Ali Atia & Huiwen Yao, *Communications Systems, in* THE INTERNATIONAL HANDBOOK ON SPACE TECHNOLOGY 397, 399 (Malcom Macdonald & Viorel Badescu eds., 2014).
[2] Thomas C. Wingfield, *Legal aspects of offensive information operations in space*, Report of the Defense Technical Information Center, 1, 2 (2005).
[3] Ram S. Jakhu, *Sixty Years of Development of Space Law, in* AIR LAW, SPACE LAW, CYBER LAW – THE INSTITUTE OF AIR AND SPACE LAW AT THE AGE OF 90, 75, 88 (Stephan Hobe ed., 2016).
[4] Alexander Soucek, Historical Background and Context COPUOS SDM Guidelines, in III COLOGNE COMMENTARY ON SPACE LAW, 2 (Stephan Hobe, Bernhard Schmidt-Tedd & Kai-Uwe Schrogl eds. 2015).
[5] UNISPACE+50 (18th -23rd June 2018) UNOOSA and UNCOPUOS as international forum.
[6] UN sustainable development goal 2030: Report of the World Commission on Environment and Development, *Our Common Future*, U.N. Doc. A/42/427 (1987).

analyses the Customary International Law status of distinct conventions and regimes. Third, selected national legislation tools are reviewed as exemplary models. Fourth, general principles of International Law, namely the principles of international co-operation and due regard are discussed.

The thesis concludes in a perspective and finishes with the recommendation to combine different tools of technology, political diplomacy and legal regulatory measures to hold balance between the increasing need of connectivity yet ensuring a sustainable space environment. This mixture should orientate on the process of National Law implementation. By doing so, a reliable framework for the handling of threats in large satellite constellations is built and supported by mandatory technical means, such as impact assessments and authorization processes.

Space Sustainability and Connectivity

A. Current aspects of cyber technologies for future connectivity

Today's society becomes increasingly smart. Beginning with smartphones, smart homes, smartwatches and smart computing, the 21st century has become the turning point towards a ubiquitous computing world.[7] Mark Weiser propagated in 1991 the development towards computer-systems that follow alongside the everyday life helping people, simplifying life and gathering data.[8] This evolution of an 'Internet of Things' (IoT) describes the phenomenon of interconnected systems and objects which share data and are thus communicative.[9] Such connectivity is driven by the development of data analysis, technological evolutions and the accessibility of space by non-governmental entities.

Related legal challenges chiefly concern data privacy and data protection, intellectual property rights and cybersecurity.[10] The aspects of transmission (telecommunication) and storage (big data and cloud computing) are most vulnerable points in cybersecurity. This growing impact is caused by the large datasets and the lack of awareness by users. Connectivity does not only concern governmental levels but is becoming essential in the everyday life of every citizen. In the next sections, the thesis explores the various questions and legal interests involved.

[7] Stephen Mason, *The internet and privacy: some considerations*, 21 Computer and Telecommunications Law Review 68, 71 (2010).
[8] Mark Weiser, *The Computer for the 21st century,* 265 Scientific American, September 94, 95 (1991); Mark H. Wittow & Daniel J. Buller, *Cloud Computing – emerging legal issues for access to data, anywhere, anytime*, 14 Journal of Internet Law 1, 6 (2010).
[9] Julia J.A. Shaw, *From homo economicus to homo roboticus: an exploration of the transformative impact of the technological imaginary*, 11 International Journal of Law in Context 245, 256 (2015); Mark Taylor & Jennifer Richardson*, 5G wireless technology,* 23 Computer and Telecommunications Law Review 152, 152 (2017).
[10] This thesis focusses on the aspect of cybersecurity relating to space technologies in large satellite constellations.

I. Large Satellite Constellations leading towards 5G

Connected systems that generate, transmit, process and store space data are the main driver for the digital economy and society.[11] The trade-off between the importance of a developing market for future technologies of connectivity on the one hand and legal certainty on the other hand must be recognised and acknowledged for the implementation of legal tools. Therefore, these tools shall be flexible and well-balanced to fit the fast development in the (cyber-) space technology sector. Regulation and the implementation of legal rules on national level are needed to match the technological tools to their legal counterparts.

Large satellite constellations are built to connect the world and to ensure equal access to internet, data and telecommunication.[12] The objective is dual: on the one side, the benefit for the international community is sought whilst on the other side the economic interest is a driver for the operation. Smart technology is the main pillar of economy and society today. To enhance reliability of connectivity, large satellite constellations were launched. Current examples are the 'Starlink' operation by SpaceX and the 'OneWeb' operation designed to achieve worldwide access to the internet. To operate such large constellations of approximately 100 to 1500 satellites per constellation (depending on the objective and operation)[13], a secure network communication is equally important as the hardware, mainly consisting of small satellites or 'CubeSats'. A constellation of such small satellites with dimensions of around 10 cm x 10 cm x 10 cm have the same or better technological and physical feasibilities as conventional satellites measuring the size of a motor vehicle.[14] The need for world-wide connectivity is the driver for enhanced system capacities and technological development.

Beginning in the early 20th century with the first telephones, fast developing towards land mobile radio in 1929, the two-way mobile radio voice system was introduced in the United States in 1933. The invention of the transistor in 1947 reduced the power consumption of these 1G communication systems based on analogue frequency modulation. The second generation of mobile communication had improved characteristics and relied on digital frequency modulation. The third-generation standard (3G) profited of growing bandwidth and operated at a radiofrequency level of approximately 2 GHz. This development wass supported by increasing usage of WLAN and LTE networks in the beginning of the 21st century. This led to the current 4G standard with a high data rate whilst allowing high mobility.[15] The step further is the fifth generation of communication standards, namely the 5G development. This development includes the effective use of satellite constellations for improving the mobility level. A world-wide coverage with resilient communication networks is needed to achieve this

[11] Bert-Jaap Koops, *Megatrends and Grand Challenges of Cybercrime and Cyberterrorism Policy and Research, in* 4-6 COMBATTING CYBERCRIME AND CYBERTERRORISM - CHALLENGES, TRENDS AND PRIORITIES (Babak Akhgar & Ben Brewster eds. 2016); David Bollier, *The promise and peril of Big Data*, The Aspen Institute, Communications and Society Program, 20-25 (2010).
[12] Lajos Hanzo et al., *Wireless Myths, Realities, and Futures: From 3G/4G to Optical and Quantum Wireless*, 100 Proceedings of the IEEE 1853, 1853 (2012); ITU-T Working Group 13, *Framework of IMT-2020 network*, Recommendation Y.3102 (2018).
[13] Paul B. Larsen, *Small Satellites Legal Issues*, 82 Journal of Air Law and Commerce 275, 279 (2017).
[14] Ibid., 280.
[15] Lajos Hanzo et al., *Wireless Myths, Realities, and Futures: From 3G/4G to Optical and Quantum Wireless*, 100 Proceedings of the IEEE 1853, 1854 (2012).

objective. Large satellite constellations are built to establish the conditions for world-wide connectivity.

II. Connectivity as a Sustainable Development Goal

The UN Sustainable Development Goals 2030 describe the objectives set by the UN in achieving a sustainable future. The goals consist of 17 target issues that are very distinct and shall cover the aspects of the global commons for ensuring a sustainable Earth environment. These goals include inter alia industry, innovation and infrastructure, reduced inequalities and climate action.[16] Through large satellite constellations these goals are attainable since a connected world lowers inequality and raises a reliable infrastructure. Climate action targets are already under discussion at a high-level forum. Large satellite constellations imply that a high number of additional space objects are launched in Outer Space which will increase the debris density in the Earth orbits.

The Committee on the Peaceful Uses of Outer Space is developing guidelines for the long-term sustainability of Outer Space much like the Sustainable Development Goals 2030 set by the UN. The SDG's are based on the Brundtland Report 1987: "limited resources shall be protected and managed in order to safeguard them for future generations". Outer Space is such a secured resource.[17] The functional value of orbits is to safeguard the ability of satellite operations. It has economic and social value as systems, either economic systems or social systems, are dependent on networks and satellite operations. Space debris is depleting the non-renewable natural resource orbit. This implies that Outer Space and the Earth's orbits are limited resources.

This is equally true on the radio spectrum. The radio spectrum is non-renewable, it cannot be stored or limited. It is specified for a particular territory, but it does not stop at a specific border. It is only an imaginary construct. The radio spectrum is limited in its exertion since only distinct frequencies allow certain activities and communications. Some frequencies are more demanded than spectrum bands are available. Therefore, the radio spectrum constitutes a limited resource and is to be guarded under the SDG's for ensuring a sustainable future.[18]

Large satellite constellations are a measure to cope with the need of overall connectivity. The necessary bandwidths for communication can only be guaranteed in a sustainable space environment as radio frequencies are a limited resource.[19] Interference is a common phenomenon and increases with the number of space objects and the number of operator's that can access the network. The uncertainties of an interlinked world come with the increased demand for connectivity. Two distinct threats are analysed in this thesis. At first sight they

---

[16] David Le Blanc, *Towards Integration at Last? The Sustainable Development Goals as a Network of Targets*, 23 Sustainable Development 176, 178 (2015).
[17] Fabio Tronchetti, *Legal aspects of space resource utilization, in* HANDBOOK OF SPACE LAW, 803 (Frans von der Dunk & Fabio Tronchetti eds. 2015).
[18] Committee on the Peaceful Uses of Outer Space, *Guidelines for the long-term sustainability of outer space Activities,* Guideline 4.2, UN Doc. A/AC.105/2017/CRP.23.
[19] Hiroyuki Kishindo, *Launch Contracts for Small Satellites – The Essential Elements, in* SMALL SATELLITES: REGULATORY CHALLENGES AND CHANCES 317, 330 (Irmgard Marboe ed. 2017).

might seem to be unequal. In regard of the legal rules that can be applied, the similarities become evident. Both aspects, distinct in their nature, are regulated by law in the same way.

B. Ensuring the Future of Connectivity in a Sustainable Space

To balance connectivity and sustainability of space operations, the status of optimal connectivity must be reached. This point is defined as marginal benefits of connectivity crossing marginal risk. This optimum is called smartness.[20] Smartness depends on several structural decisions and is part of an analytical approach considering the system dynamics, patch decisions, economic value and the associated factors.[21] For a reliable connectivity system the aspect of sustainable use of space objects must not be neglected. Space sustainability is one of the main pillars of international co-operation and capacity building. COPUOS as high-level forum currently develops uniform guidelines on sustainability of Outer Space, a milestone in diplomacy, scientific development and international co-operation.

Both, technological development and space sustainability are increasingly demanded fields of regulation. The discussion is especially driven by the growth of large satellite constellations. The legal tools and existing regulatory mechanisms regarding either technology or sustainability are to be analysed in this thesis. For neither subject exists a uniform framework of law yet. To analyse the question both subjects are separately analysed according to the impact of the legal rules with different binding authority. This way, this thesis will explore whether the existent legal tools are sufficient to handle new developments in technology and sustainability in the context of large satellite constellations.

I. Cybersecurity and Space Security

Cybersecurity is interlinked with Space Security, but the terms are to be distinguished. The principles of cybersecurity regulations can be applied in the context of space security as well. Cyber-risk analysis is possible today and will become a growing factor for future connectivity technologies. In this context, the interoperability of systems needs to be analysed with respect to the importance of data. The criteria for such analysis are confidentiality, integrity, availability, authentication, authorisation, access control, trustworthiness and auditing.[22] In future, security of the Internet of Things and connected systems is crucial and a challenging aspect. The paradigm of connectivity will no longer be restricted to the virtual world of the internet but will have direct influence and impact on the physical world. This bridge constitutes

---

[20] Mattew Smith & Elizabeth Paté-Cornell, *Cyber risk analysis for a smart grid, in* A SYSTEMS APPROACH TO CYBER SECURITY: PROCEEDINGS OF THE 2ND SINGAPORE CYBER-SECURITY R&D CONFERENCE, 53 (Abhik Roychoudhury & Yang Liu eds. 2017).

[21] R. M. D' Szousa et al., *Modeling Interdependent Networks as Random Graphs: Connectivity and Systemic Risk, in* NETWORK OF NETWORKS: THE LAST FRONTIER OF COMPLEXITY, 73, 88 (GREGORIO D'AGOSTINO & ANTONIO SCALA, eds., 2014).

[22] Sarfraz Alam & Mohammad M. R. Chowdhury & Josef Noll, *Interoperability of Security-Enabled Internet of Things*, 61 Wireless Personal Communications 567, 571-3 (2011); United States Joint Chiefs of Staff, *Joint Pub 3-13: Joint Doctrine for Information Operations*, I-9 (1998), available: https://www.hsdl.org/?view&did=3759 (last accessed: 02.07.2018).

a development towards a more complex system with numerous variables and security challenges. Therefore, a basic and uniform security standard must be implemented to manage the development of connectivity.[23] No such common legal regime exists on data analysis in connected systems yet.[24] At international level, a different approach is used to analyse the threats occurring in cyberspace.[25] Cyber activities used for disrupting/interrupting, spoofing/jamming, or intercepting the communication is an increasing risk for satellite operators.

The challenge of securing connected systems is highly demanding as it is a developing technical and economic field. Law has always been rather reactive then proactive.[26] There is no common framework on remediation and response to cyber operations.[27] This lack of clear and comprehensive guidance leads to legal uncertainty. To prevent and overcome these *lacunae*, international law is to be applied as the most general legal ground.[28] Supporting the application of rules of International Treaty Law, Customary International Law obligations have binding character on the states.[29] Additionally, general rules of International Law must be taken into consideration for the interpretation of cyber operations against other states.[30]

1. *Regulation of cyber-related activities under the UN Charter and Space Law*

The term 'cyber' does not exist in the wording of the UN Charter[31] or the UN Space Treaties. Still, operations in cyberspace follow regulatory instruments. These instruments have their predecessors in the UN Charter and the Space Treaties. The International Law obligations frame the most fundamental ideas for the regulation of cyber.[32]

a. Cyber-operations under the UN Charter

The Charter of the United Nations was signed on 26 June 1945 and had the recent objective of peacekeeping after the end of the 2nd World War.[33] At the time of the adoption, cyber had not

---

[23] Sarfraz Alam & Mohammad M. R. Chowdhury & Josef Noll, *Interoperability of Security-Enabled Internet of Things*, 61 Wireless Personal Communications 567, 571 (2011).
[24] Thomas Hoppner & Anastasia Gubanova, *Regulatory challenges of the Internet of Things*, 21 Computer and Telecommunications Law Review 227, 230 (2015).
[25] Whether the concerned operations are malicious or not is not to be discussed in this thesis.
[26] P. J. Blount, *Renovating Space: The future of international space law*, 40 Denver Journal of International Law and Policy 515, 515 (2012).
[27] Michael N. Schmitt, *Cyber operations and the jus ad bellum revisited*, 56 Villanova Law Review 569, 571 (2011).
[28] JAN ANNE VOS, THE FUNCTION OF PUBLIC INTERNATIONAL LAW 138 (2013).
[29] Farhad Talaie, *The Importance of Custom and the Process of its Formation in Modern International Law*, 5 James Cook University Law Review 27, 42 (1998).
[30] Art. 38 (I) (c) ICJ Statute: Statute of the International Court of Justice, *entered into force* Oct. 24, 1945, 15 U.N.C.I.O. 355; JAN ANNE VOS, THE FUNCTION OF PUBLIC INTERNATIONAL LAW 111 (2013).
[31] Charter of the United Nations, *entered into force* Oct. 24, 1945, 892 U.N.T.S. 119.
[32] BERT-JAAP KOOPS & MORAG GOODWIN, CYBERSPACE, THE CLOUD, AND CROSS-BORDER CRIMINAL INVESTIGATION - THE LIMITS AND POSSIBILITIES OF INTERNATIONAL LAW 1, 65 (2014); Titiriga Remus, *Cyber-attacks and International law of armed conflicts - a "jus ad bellum" perspective,* 8 Journal of International Commercial Law and Technology 179, 180 (2013).
[33] Rüdiger Wolfrum, *Art. 1 UN Charter, in* I THE CHARTER OF THE UNITED NATIONS: A COMMENTARY 21 (Bruno Simma et al. eds., 3rd Ed. 2012); additionally, but later enshrined: UNGA Res 377 (V) (3 November 1950); UNGA Res 1815 (XVII) (18 December 1962).

the impact of being acknowledged equivalent to conventional weapons. For this reason, the UN Charter does not (and could not) mention cyber. The idea of enlarging the UN Charter provisions and "update" them to current developments contradicts the telos of the treaty and the effect of the UN Charter which is applicable through means of analogy.[34] The treaty obligations have binding force on the actors. Through supplementary means such as Customary International Law and the application of general principles of law International Law remained applicable throughout the time since the adoption of the UN Charter.

The wording and history of the UN Charter do not specifically mention cyber. The systematic position of the UN Charter in the hierarchy of International Law obligations demonstrates the predominance of the UN Charter in relation to different norms. The UN Charter frames the corresponding treaties. In this regard, the application of UN Charter obligations on cyber operations is supported by a systematic approach of interpretation. Cyber-related jurisdiction does not exist at international level. The systematic approach therefore does not directly affect the interpretation of cyber operations. In the context of cyber the telos of the UN Charter is the predominant means of interpretation. According to Arts. 31 & 32 VCLT[35] the purpose and objective of treaties are the guiding principles for the interpretation. The purpose of the UN Charter is to maintain peace and security.[36] Cyber is a new and unforeseen development. It brings the possibility to threaten peace and security that is contained in Art. 1 UN Charter. The interference in systems leading to limitations or loss of functionality, either permanent or temporary, is a disruptive event. In line with the object and purpose of the UN Charter, cyber can meet the threshold of Art. 2 (4) UN Charter in specific cases.

Three common distinctions are made between the concept of cyber-attack, cyber-warfare and cyber operations. This thesis will restrict the analysis on the regulation of cyber operations in large satellite constellations.

'Cyber operations' are economically driven and have their target mostly in sabotage, theft, fraud or extortion.[37] Some forms of cyber operations meet the threshold of use of force. These operations fall under the definition of 'cyber-attacks'.[38] The use of force is prohibited in International Law according to Art. 2 (4) UN Charter.[39] Only in the case of self-defence (Art. 51 UN Charter) or in the case of lawful countermeasures the use of force can be justified. Art.

[34] Article 32 of the Vienna Convention on the Law of Treaties states that for interpretation recourse may be had to supplementary means of interpretation to confirm or determine the meaning of a provision. Analogy is such a supplementary means.
[35] Vienna Convention on the Law of Treaties, *entered into force* Jan. 27, 1980, 1155 U.N.T.S. 331; Case concerning Kasikili/Sedudu Island (Botswana v. Namibia), Judgement, I.C.J. Report 1999, par. 1045, The ICJ confirmed that Art. 31 VCLT on the treaty interpretation reflected customary international law. Therefore, it is applicable despite the fact that both, Botzwana and Namibia were not party to the VCLT and the treaty between the parties entered into force in 1890. The VCLT is applicable, even though not retrospectively, as being custom such as were the rules of interpretation.
[36] Rüdiger Wolfrum, *Art. 1 UN Charter, in* I THE CHARTER OF THE UNITED NATIONS: A COMMENTARY 2 (Bruno Simma et al. eds., 3rd Ed. 2012).
[37] Babak Akhgar et al., *Consolidated Taxonomy and Research Roadmap for Cybercrime and Cyberterrorism, in* 295, 297 COMBATTING CYBERCRIME AND CYBERTERRORISM - CHALLENGES, TRENDS AND PRIORITIES (Babak Akhgar & Ben Brewster eds. 2016).
[38] Marco Benetar, *The Use of Cyber Force: Need for Legal Justification?*, 3 Goettingen Journal of International Law 375, 387 (2009), Oona Hathaway, *The Law of Cyber-Attack*, 100 California Law Review 817, 826 (2012).
[39] Corfu Channel (UK v. Albania) (Merits) 1949, I.C.J. 4 (Apr. 9).

39 UN Charter in conjunction with Arts. 41 & 42 UN Charter contains an entry point for the application of International Law on cyber operations. Measures of "complete or partial interruption of economic relations and of rail, sea, air, postal, telegraphic, radio, and other means of communication […]"[40] can be involved in the response to actions with respect to threats to the peace, breaches of the peace, and acts of aggression. The Security Council decides on the measures. The interruption of (radio) communication is thus included in the provisions of the UN Charter. Cyber operations that target the communication networks of large satellite constellations fall under the measure. This means that such cyber operations must be declared by the Security Council and can only be taken in response to a previous wrongful act by the state against which they are taken. In that case the cyber operation constitutes a lawful countermeasure in accordance with Art. 22 ARSIWA in conjunction with Arts. 49ff. ARSIWA.[41]

'Cyber-warfare' oversteps this level and rises cyber to the level of war.[42] The use of force according to Art. 2 (4) UN Charter in conjunction with Common Art. 2 Geneva Convention[43] is required to fulfil the further requirements of a precise scope, duration and intensity of the action to constitute a means of warfare. These three criteria were introduced by Jean Pictet, who is known for his workings on the Commentary on the Geneva Conventions.[44]

The distinction of cyber-operations and cyber-attacks is highly discussed in the international community. The consented line of the threshold of the use of force is met when it produces effects comparable to those of a kinetic attack that falls under the definition of Art. 2 (4) UN Charter.[45] If the action is equivalent to a use of force, it may only be undertaken pursuant to Chapter VII of the UN Charter, or as a lawful exercise of self-defence (Art. 51 UN Charter).[46]

b. Cyber operations under International Space Law

Art. III OST [47]states that International Law is applicable on space activities. Cyber operations (whether or not they meet the threshold of the use of force) are conducted in Outer Space. They are network-based and need frequency communication for accessing the network.[48] Large satellite constellations build an interconnected network and the satellites contained in the

[40] Art. 41 UN Charter.
[41] Responsibility of States for Internationally Wrongful Acts: Compilation of Decisions of International Courts, Tribunals and Other Bodies, UNGA, 62nd Sess. U.N. Doc. A/62/62 (2007); Responsibility of States for Internationally Wrongful Acts: Compilation of Decisions of International Courts, Tribunals and Other Bodies, UNGA, 65th Sess. U.N. Doc. A/65/76 (2010).
[42] P.J. Blount, *The Preoperational Legal Review of Cyber Capabilities: Ensuring the Legality of Cyber Weapons*, 39 Northern Kentucky Law Review 211, 212 (2012).
[43] Geneva Convention Relative to the Protection of Civilian Persons in Time of War (Fourth Geneva Convention), *entered into force* 12 August 1949, 75 U.N.T.S. 287.
[44] Thomas C. Wingfield, *Legal aspects of offensive information operations in space*, Report of the Defense Technical Information Center, 1, 11 (2005).
[45] MARCO ROSCINI, CYBER OPERATIONS AND THE USE OF FORCE IN INTERNATIONAL LAW 46-7 (2014).
[46] Thomas C. Wingfield, *Legal aspects of offensive information operations in space*, Report of the Defense Technical Information Center, 1, 14 (2005).
[47] Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies, *entered into force* Oct. 10, 1967, 610 U.N.T.S. 205.
[48] Oona Hathaway, *The Law of Cyber-Attack*, 100 California Law Review 817, 823 (2012).

constellation are communicative. Satellites are operated remotely. This means that frequencies transmitted from Earth are used to operate the satellite.[49] A network consists of several single entities that interact with each other and exchange information. Outer Space networks are not based on a wired connection but on radio communication. Each entity is sender and/or recipient and sends or receives electromagnetic waves. The information that is transmitted by the radio waves is usually encrypted within the system to unravel the information that is sent or received.[50] Such communication processes are regulated under International Space Law. Cyber as distinct form of communication raises the question if there is a need for different regulation than the application of International Law of the UN Charter or Space Law as general basis.

2. *Rules establishing Customary International Law*

Customary International Law consists of two elements, *opinio iuris* and state practice.[51] *Opinio iuris* is the subjective element of customary law.[52] It consists of the understanding that certain behaviour is legally obligatory.[53] A legal substitute can be used to deduce *opinio iuris*.[54] State practice in customary law is the objective element of custom.[55] A principle or the application of norms is to be considered as state practice when the behaviour in question is covered by usual state activities, *i.e.* that various sources give evidence that the behaviour of a state is repeated and not singular.[56]

As previously discussed, there is no legally binding rule in International Law which directly concerns cyber operations and the regulation of cyber operations in the context of new technologies. Different forms of customary rules exist which are multi-level rules with distinct status and different implementation. The analysis focusses on the most common rules that contain principles of Customary International Law. The value of different legal tools and guidelines is considered. This way, measures with different binding authority will be highlighted in order to explore their impact on new developments and technologies such as interconnected large satellite constellations.

a. ITU Constitution and ITU Conventions

The International Telecommunications Union (ITU) is the recognized agency to control and manage the frequency bands in the Earth orbits.[57] Communication depends on signals

[49] Frans von der Dunk, *Legal aspects of satellite communications, in* 456, 456-7 HANDBOOK OF SPACE LAW (Frans von der Dunk & Fabio Tronchetti eds. 2015).
[50] Ibid.
[51] Case Concerning Military and Paramilitary Activities in and against Nicaragua (Nicaragua v. United States of America) (Merits) (Judgment) 1986 I.C.J. 13 (June 27), par. 183-188; Legality of the Threat or Use of Nuclear Weapons (Advisory Opinion) 1996, I.C.J. 226 (July 8), par. 64; Case Concerning the Continental Shelf (Libya v. Malta) (Judgment) 1985, I.C.J. 13 (June 3), par. 27.
[52] Farhad Talaie, *The Importance of Custom and the Process of its Formation in Modern International Law*, 5 James Cook University Law Review 27, 31 (1998).
[53] MALCOLM SHAW, INTERNATIONAL LAW 60 (7th ed. 2014).
[54] Farhad Talaie, *The Importance of Custom and the Process of its Formation in Modern International Law*, 5 James Cook University Law Review 27, 37 (1998).
[55] Ibid.
[56] MALCOM SHAW, INTERNATIONAL LAW 58 (7th ed. 2014).
[57] Frans von der Dunk, *Legal aspects of satellite communications, in* 456, 463 HANDBOOK OF SPACE LAW (Frans von der Dunk & Fabio Tronchetti eds. 2015).

transmitted to and received from satellites. The signal transmission takes place via radio waves and is managed by the ITU to avoid harmful interferences. The management of signals is realized through the establishment of distinct frequency bands that are allocated by the ITU to the state operators. Radio communication relies not only on the aspect of available frequency bands but also on satellite service in a stable orbit. The Geostationary Earth Orbit (GEO) proves most suitable for communication. This is, because space objects in the GEO have a synchronous orbit to Earth and thus "stay" in one position which simplifies the signal receipt and transmission.[58] The ITU is distinguished in three sectors: Radiocommunication (ITU-R), Telecommunication Standardization (ITU-T) and Telecommunication Development(ITU-D). For spectrum management and allocation, ITU-R and ITU-T are the most important references.

Spectrum management includes the prohibition of harmful signal interference. Harmful interference is considered under different legal regimes and uses distinct mechanisms. The constantly increasing demand for both the radio frequency spectrum and orbital slot allocations leads to a growing risk of interference.[59] The limited resources of orbital slots and frequencies effects the usage of frequency bands.[60] Several satellites share orbital slots in order to cope with the demand. The drawback of this practice is the risk of signal interference which is explicitly prohibited under Arts. 44 & 45 ITU Constitution[61]. The frequency management and control are exercised by the ITU.[62] Following from the number of member states to the ITU that (except for one state) equals the number of member states of the UN[63], the ITU reached international acceptance considering its authority. Both elements of custom are present. State practice is given through the general acceptance of the ITU frameworks and the reliance on the practices of the ITU. Spectrum management is a core responsibility of the ITU-R. Its mission is to ensure "rational, equitable, efficient and economic use of the radio frequency spectrum by all radio communication services, including those using satellite orbits, and to carry out studies and adopt recommendations on radio communication matters"[64]. Opinio iuris consists of the understanding that certain behavior is legally obligatory. The obligations published by the ITU are accepted and implemented. The element of opinio iuris is realized. It follows that the ITU as authority and its regulations and constitution attained the status of custom.

The regulation of the radiofrequency bands is translated into European and National Law. The Radio Spectrum Decision (676/2002/EC)[65] is the main document in the field of spectrum management at European Union level. On national level, independent regulatory authorities

[58] LOTTA VIIKARI, THE ENVIRONMENTAL ELEMENT IN SPACE LAW: ASSESSING THE PRESENT AND CHARTING THE FUTURE, 41 (2008).
[59] Ibid., 42.
[60] GEORGE T. HACKET SPACE DEBRIS AND THE CORPUS IURIS SPATIALIS 214-5 (1994).
[61] Constitution of the International Telecommunication Union, *entered into force* Dec. 22, 1992, 1825 U.N.T.S. 331.
[62] INTERNATIONAL ACADEMY OF ASTRONOMICS, COSMIC STUDY ON SPACE TRAFFIC MANAGEMENT 65 (Corinne Contant - Jorgenson et al., eds. 2006).
[63] Both the ITU and the UN count 193 member states. Additional to that figure the ITU has more than 700 Sector Members and Associates: https://www.itu.int/en/ITU-R/terrestrial/fmd/Pages/administrations_members.aspx and https://www.itu.int/online/mm/scripts/gensel11 (both last accessed: 05.07.2018).
[64] Art. 4.1 ITU-R: Mission of ITU-R.
[65] Decision No 676/2002/EC of the European Parliament and of the Council of 7 March 2002 on a regulatory framework for radio spectrum policy in the European Community (Radio Spectrum Decision), O.J. (L108) 1.

exercise the tasks of spectrum allocation, frequency assignment, licensing and certification.[66] In Germany the 'Bundesnetzagentur' is the responsible authority. Through translation of international or multilateral obligations into National Law the obligations become binding on the parties.

The application of the ITU norms demonstrates a coherent way of implementing international obligations with non-legally binding character into regulations with binding force. The enforcement of the regulations is transferred to national telecommunication regulatory authorities.[67] Through the translation into National Law and the development of a standardised basis, unambiguous legal certainty is achieved.

b. Convention on Cybercrime - Budapest Convention

The Convention on Cybercrime (ETS No. 185)[68], known as the Budapest Convention, serves as a guideline for the development of a comprehensive national legislation against cybercrime and is binding on the parties. Chapter II of the Convention introduces measures that shall be implemented under National Law. This approach simplifies the enforceability of obligations. The convention is applicable on intergovernmental level and has its main emphasis on criminal law. This highlights the aspect that the convention concerns economically and socially driven crimes in cyberspace. The concerned parties must be state actors in order to apply the Budapest Convention. The question is whether the Budapest Convention constitutes custom in International Law. Cyber is a new field of law and widens the scope of legal obligations to a new level. The Budapest Convention entered into force on 01.07.2004 and has 57 Member States up to today.[69] The states that ratified the Budapest Convention are not only 32 European countries but also 24 states that are not party to the Council of Europe. It is a multilateral treaty with binding force on the parties.[70] The states consented on the need for a uniform regime concerning cybercrime. Opinio iuris as the first element of custom exists. State practice in casu is in question. The majority of all space-faring nations ratified the Budapest Convention. However, Brazil and India have did not participate in the drafting and decline the ratification.[71] Russia states that the Budapest Convention violates national sovereignty and is thus not a member of the convention. Each of the three countries undertakes space activities. They are important actors in space. The fact that they decline the adoption of the Budapest Convention indicates a lack of state practice considering the uncertain status of custom.

---

[66] Report ITU-R SM. 2093-2, *Guidance on the regulatory framework for national spectrum management* (2015), available: https://www.itu.int/dms_pub/itu-r/opb/rep/R-REP-SM.2093-2-2015-PDF-E.pdf (last accessed: 05.07.2018)

[67] Report ITU-R SM. 2093-2, *Guidance on the regulatory framework for national spectrum management* (2015).

[68] Convention on Cybercrime, *entered into force* July 1, 2004, 185 ETS.

[69] Chart of Signatures and Ratifications of Treaty 185, Jul. 5, 2018, https://www.coe.int/en/web/conventions/full-list/-/conventions/treaty/185/signatures (last accessed 05.07.2018).

[70] Babak Akhgar et al., *Consolidated Taxonomy and Research Roadmap for Cybercrime and Cyberterrorism, in* 295, 298 COMBATTING CYBERCRIME AND CYBERTERRORISM - CHALLENGES, TRENDS AND PRIORITIES (Babak Akhgar & Ben Brewster eds. 2016).

[71] Chart of Signatures and Ratifications of Treaty 185, Mar. 1, 2018, https://www.coe.int/en/web/conventions/full-list/-/conventions/treaty/185/signatures?desktop=false (05.07.2018).

The Budapest Convention is binding on the member states that adopted (and ratified) the convention. The measures contained in the convention have guiding character and imply the will of the international community to harmonize national laws.[72] Cybercrimes with a cross-border element lead to judicial hurdles in the law enforcement process. By adopting a common basis among the member states the hurdles diminish. International co-operation and the implementation of obligations in National Law are the key factors.

c. Tallinn Manual on International Law applicable on Cyber Operations

The Tallinn Manual on International Law applicable on Cyber Operations is a NATO Handbook. It has influence on guideline setting and interpretation because the handbook offers a wide range of scholarly opinions on cyber operations.[73] These scholars have insights in the practice of actors in cyberspace and were confronted with cyber operations against governments. International Law lacks case law for cyber operations.[74] The Tallinn Manual demonstrates examples and responses for such incidents. The existence of best practice ideas does not alone rise state practice. State practice consists of repeated state activities.[75] The threshold of state practice may be met fast in technological fields of law[76] but it is higher than the pure availability of guidelines. Even if the Tallinn Manual constitutes state practice it lacks a legal basis. It is neither lex lata nor lex ferenda.[77] Opinio iuris as subjective element of custom is not evidently given. The consented understanding that NATO guidelines are binding on state actors or private entities lacks approval. This is underlined by the fact that the Tallinn Manual consists military shaped opinions. Private actors in Outer Space without military connection might not rely on obligations raised by a NATO Handbook. Taking these thoughts into consideration it remains inconclusive whether the Tallinn Manual on International Law applicable on Cyber Operations represents rules of custom. Thus, it is not legally binding until the International Community decides on its status. As can be seen in the case of the VCLT, it is possible that only some of the obligations contained in a convention or guideline achieve legally binding character. This procedure might equivalently lead to the adoption of the most common obligations and recommendations of the Tallinn Manual because of its insight knowledge on the practice of cyber operations.

d. Impact of Customary International Law on large satellite constellations

None of the above-mentioned instruments of Customary International Law have directly applicable force on state actors. Both elements of custom must exist to create internationally

[72] Oona Hathaway, *The Law of Cyber-Attack*, 100 California Law Review 817, 862 (2012).
[73] See: List of Contributors Tallinn Manual, CCDCOE, TALLINN MANUAL 2.0 ON THE INTERNATIONAL LAW APPLICABLE TO CYBER OPERATIONS (2017).
[74] Cyber operations as the Estanian incidence in 2007, the WannaCry operation or the Stuxnet cyber-attack were not brought in front of the ICJ or a different Court.
[75] Farhad Talaie, *The Importance of Custom and the Process of its Formation in Modern International Law*, 5 James Cook University Law Review 27, 37 (1998).
[76] Bin Cheng, *United Nations Resolutions on Outer Space: 'Instant' International Customary Law?, in:* STUDIES IN INTERNATIONAL SPACE LAW 139 (1997).
[77] Lex lata: the current law, lex ferenda: future law in the sense of what the law should be, as proposal for legislative improvement.

binding obligations. Still, the contained rules of law are binding on the states that adopted the rules. If states do not implement them in their National Law, they cannot be remedied. Legal ruling at international level impacts governments. Economically driven operators, private and legal persons, are only indirectly affected. The regulation of the activities of non-state actors are still lacunae in International Law. National Law uses distinct mechanisms of regulation to translate the legal rules on national level. This way, they impose binding force on all actors equally.

3. *Cyber operations regulated under National Law*

Even though Customary International Law is binding on the states, the current situation lacks compliance with the rules.[78] To have effective impact on states, national legislature is needed. Once rules are implemented on national level, non-compliance can be remedied. Such measures and regulation enforce the authority and enhance the performance of tools.

The impact of data and especially the impact of connected systems containing critical infrastructure increases the need for legal rules with binding force on the operators. Cyber as a field of law is increasingly perceived and implemented under National Law. Critical infrastructure is one of the target issues.[79] Critical infrastructure is an asset or system which is essential for the maintenance of vital societal functions.[80] Satellite constellations constitute critical infrastructure because they build the frame of all essential communication systems that are connected. In an increasingly "smart" world, connectivity is the driver and backbone of the economic stability and society.

At the level of the EU the NIS Directive 2016/1148 is concerned.[81] The NIS Directive 2016/1148 contains risk management and auditing of incidents.[82] The directive does not rise remedies or legal consequences. Through the translation of the obligations into National Law (IT-SicherheitsG and IT-KritisVO in Germany) legal certainty is achieved and can be enforced.[83]

The legal tools and regulatory measures concerning cyber operations in the context of connectivity and large satellite constellations are a spreading sphere. International Law gives a framework of applicable rules but the impact on current activities remains limited. Customary International Law rises a more defined layer on the law applicable but has restricted binding force on private actors. The surrounding law and distinct rules on cyber operations have to be implemented in National Law to achieve legal certainty and remediation tools for non-performance and non-compliance on state level.

---

[78] Stephan A. Kaiser, *Comment on Cyber Security, in* AIR LAW, SPACE LAW, CYBER LAW – THE INSTITUTE OF AIR AND SPACE LAW AT THE AGE OF 90, 137, 139 (Stephan Hobe ed., 2016).
[79] Ibid., at 140.
[80] Kirsten Eichensehr, *The Cyber-law of Nations*, 103 The Georgetown Law Journal 117, 324 (2015).
[81] Directive (EU) 2016/1148 of the European Parliament and of the Council of 6 July 2016 concerning measures for a high common level of security of network and information systems across the Union, O.J. (L194) 1.
[82] PAUL VOIGT & AXEL VON DEM BUSSCHE, THE EU GENERAL DATA PROTECTION REGULATION (GDPR): A PRACTICAL GUIDE 42 (2017).
[83] Ibid.

II. Environmental Impact and Space Sustainability

This section will explore the environmental impact of connectivity systems on space sustainability. The interaction of guidelines and legal mechanisms is analysed in regard of their implementation and profit towards a sustainable use of Outer Space.

A high number of satellites is needed to create a reliable data network. The orbits around the Earth are increasingly in demand. Not only new satellites launched into Outer Space but also functioning and defunct space objects as well as a massive amount of space debris is existent in the Earth orbits. This development leads to dangerous collision situations that can end in the malfunctioning or complete destruction of space objects and their component parts. Jammed orbits additionally increase the probability of signal interferences. The international community has not yet defined common regulations to avoid such development.[84] This is very similar to the previously discussed lack of legal mechanisms to encounter issues in cyberspace in the context of connectivity systems.

To expand on the subject of space sustainability a common definition of space debris is required. There is no common definition at international level and the term space debris is not mentioned in International Law.[85] In Art. 1 (I) (b) Treaty Banning Nuclear Weapon Test in the Atmosphere, in Outer Space and under Water (1963) the term debris is mentioned.[86] Space debris is not uniformly defined but its various definitions are common in essential parts.

UNCOPOUS defines: "Space debris are all manmade objects, including their fragments and parts, whether their owners can be identified or not, in Earth orbit or re-entering the dense layers of the atmosphere that are non-functional with no reasonable expectation of their being able to assume or resume their intended functions or any other functions for which they are or can be authorized"[87] The Inter-Agency Space Debris Coordination Committee (IADC) definition is: "[s]pace debris are all man-made objects including fragments and elements thereof, in earth orbit or re-entering the atmosphere, that are non-functional"[88] The Draft Convention on Space Debris adopted by the International Law Association in 1994 defines "man-made objects in outer space, other than active or otherwise useful satellites, when no change can reasonably be expected in these conditions in the foreseeable future"[89] as space debris.

---

[84] Richard Tremayne-Smith, *Reforming National Licensing and Agency Structures: A Current Overview of the UK Space Agenda, in* 111, 114 CONTRACTING FOR SPACE: CONTRACT PRACTICE IN THE EUROPEAN SPACE SECTOR (Lesley Jane Smith & Ingo Baumann eds. 2016).

[85] Bernhard Schmidt-Tedd & Stephan Mick, *Art. VIII, in* I COLOGNE COMMENTARY ON SPACE LAW, 33 (Stephan Hobe, Bernhard Schmidt-Tedd & Kai-Uwe Schrogl eds. 2009).

[86] Art. 1 (I) (b) PTBT: "(b) in any other environment if such explosion causes radioactive **debris** to be present outside the territorial limits of the State under whose jurisdiction or control such explosion is conducted. […]" (*emphasis added*).

[87] UNCOPUOS Report of the Scientific and Technical Subcommittee on its Thirty-Sixth Session, Technical Report on Space Debris, U.N. Doc. A/AC.105/720 para. 6 (1999).

[88] Section 3.1. IADC Space Debris Mitigation Guidelines.

[89] Art. 1.c Draft Convention on Space Debris adopted by the International Law Association; LOTTA VIIKARI, THE ENVIRONMENTAL ELEMENT IN SPACE LAW: ASSESSING THE PRESENT AND CHARTING THE FUTURE, 103 (2008).

The common criteria for constituting debris are: manmade objects, situated in Outer Space or in Earth orbits and non-functionality.[90] The sources of space debris are a crucial element in the assessment of the debris population. Operational spacecraft and non-operational payload, mission related objects, component parts and rocket upper stage breakup are the first and main source of debris. This group is paraphrased as initial debris source. Debris also results from wear and tear (solar radiation causes paint damage and fragments), collision (both, debris collisions with other debris and collision with functional space objects) or explosion (fuel left-over in rockets or malfunctional batteries can cause explosions). This second group mainly consists of debris caused by collision. As the amount of debris in Outer Space has exceeded the amount that can be sustained without change the so-called Kessler effect, also known as Kessler syndrome, arises. It describes the domino effect which occurs when debris collides with debris. This means that space debris particles collide with different space debris particles more often and regularly than space debris re-enters lower earth orbits and burns or leaves the orbit caused by atmospheric drag.[91] In this process, debris shatters and originates more (and smaller) debris parts. This has cascading impact and the amount of debris multiplies.[92] In light of the development of large satellite constellations, each constellation containing up to 1500 satellites, the amount of space objects and debris increases.

Debris can have destructive impact on functional space objects and the risk of collision must be assessed. The first step to assess risk of collision is to track debris. JSpOC acts as international tracker and is supported by a network of numerous tracking operations world-wide, the SSN (Space Surveillance Network). The number of small debris (larger than 1 cm) is estimated to amount to at least 750 000 objects.[93] Tracked and identified space objects amount to 18 922 objects (as of 04.05.2018) according to the measurements of the US SSN.[94] Space objects and debris in the lower Earth orbits are closer to the Earth's atmosphere. The gravity causes unstable orbits. The result is that debris has shorter lifetime than objects in the geostationary orbits. The normal lifecycle of space debris expects that debris in low Earth orbits is dragged to the upper atmosphere and burns when re-entering the Earth atmosphere. In higher orbits the atmospheric drag is low (nearly nil) so that debris remains in its current orbit. This effect is reached in orbits higher than 600 km. Space debris situated above 600 km altitude will remain in the orbit for years, decades or centuries.[95]

---

[90] See also: Bin Cheng, *International Liability for Damage caused by Space Objects, in* I MANUAL ON SPACE LAW 297 (Nandasiri Jasentuliyana & Roy Lee eds. 1979).
[91] Donald J. Kessler and Burton G. Cour-Palais, *Collision Frequency of Artificial Satellites: The Creation of a Debris Belt*, 83 Journal of Geophysical Research 2637, 2643 (1978).
[92] Ibid.
[93] ESA Space Sitautional Awareness, Space Surveillance and Tracking: SST Segment, available: http://www.esa.int/Our_Activities/Operations/Space_Situational_Awareness/Space_Surveillance_and_Tracking_-_SST_Segment (last accessed: 02.07.2018).
[94] NASA, *Satellite Box Score*, 22 Orbital Debris Quarterly News 1, 8 (May 2018).
[95] LOTTA VIIKARI, THE ENVIRONMENTAL ELEMENT IN SPACE LAW, 36 (2008); COMMITTEE ON SPACE DEBRIS, AERONAUTICS AND SPACE ENGINEERING BOARD, COMMISSION ON ENGINEERING AND TECHNICAL SYSTEMS, NATIONAL RESEARCH COUNCIL, ORBITAL DEBRIS: A TECHNICAL ASSESSMENT 30 (1995), available: https://www.nap.edu/read/4765/chapter/1 (last accessed: 02.07.2018).

The environmental consequences of a collision in the LEO are less severe since the objects re-enter the atmosphere constantly and burn. Debris in the LEO has higher relevant velocity caused by the Earth's rotation. The accompanied risk is that small debris impacts more severely. This means that the force that debris imposes on a colliding object in the LEO is equally high or higher than in the GEO due to the increased velocity of objects in the LEO.[96] The most demanded orbits are at the altitudes of 800, 1000, 1400, and 1500 km around the Earth.[97]

The term "minefield" in Outer Space impressively describes the current situation in the LEO. Not only increasingly large satellite constellations that are launched into Outer Space but also the space debris that already exists in the orbits endanger space missions and satellite operations. In 1999, the Third United Nations Conference on the Exploration and Peaceful Uses of Outer Space (UNISPACE III) presented a recommendation stating that "[a]ttention should be given to preserving or restoring astronomical observation conditions to a state as close to natural as possible by any practicable means"[98]. Taking the developments of the Kessler syndrome into consideration, mankind already overstepped the point-of-no-return concerning space debris population.[99] The debris population exponentially grows and has no longer a natural counterpart.[100] This development enforces that active removal must be taken into consideration.[101] Additionally, a new setting is required for managing space operations. Here, a similar concept as space traffic management could give first ideas for such implementation.[102] It should be in states' interest to configurate and develop strategies. Technology is based on the limited resource 'space'. Hence, the sustainability of space concerns all mankind. The need for a regulatory assessment is required notwithstanding the development of law and obligations in this area.

Not only collision with space debris is a threat in Outer Space but also signal interference with debris. This is particularly the case in the geostationary orbit (GEO). The development of large

---

[96] Depending on the weight of the colliding object: According to Newton's 3rd law of motion, energy remains balanced in a system, i.e. the energy before the collision is equal to the energy after the collision: *actio=reactio* (Energy = Force * distance). In the chosen system the distance between the objects shall be fixed and thus out of contemplation. Force is a bound vector with the variables mass and acceleration (Force = mass * acceleration). Acceleration is velocity over time (Acceleration= velocity/time). In the example the two very important variables are velocity and mass of space objects. In the LEO space objects have higher velocity but are mainly smaller and lighter in mass. In the GEO space objects are slower but heavier than in the LEO. The intersection between velocity and mass depends on the variables. Space objects and debris in the LEO can have equally high or higher force on colliding objects than debris in the GEO caused by the immense velocity.

[97] INTERNATIONAL ACADEMY OF ASTRONOMICS, COSMIC STUDY ON SPACE TRAFFIC MANAGEMENT 32 (Corinne Contant-Jorgenson et al., eds. 2006); PETER STUBBE, STATE ACCOUNTABILITY FOR SPACE DEBRIS: A LEGAL STUDY OF RESPONSIBILITY FOR POLLUTING THE SPACE ENVIRONMENT AND LIABILITY FOR DAMAGE CAUSED BY SPACE DEBRIS 25 (2017).

[98] Report of the Third United Nations Conference on the Exploration and Peaceful Uses of Outer Space (UNISPACE III) U.N. Doc. A/CONF.184/6 para. 73 (1999).

[99] André Horstmann et al., *Survey of the Current Activities in the Field of Modeling the Space Debris Environment at TU Braunschweig*, 37 Aerospace 1, 11 (2018).

[100] Donald J. Kessler and Burton G. Cour-Palais, *Collision Frequency of Artificial Satellites: The Creation of a Debris Belt*, 83 Journal of Geophysical Research 2637, 2639 (1978).

[101] Lotta Viikari, *Environmental Aspects of Space Activities, in* 717, 757 HANDBOOK OF SPACE LAW (Frans von der Dunk & Fabio Tronchetti eds. 2015).

[102] Mohammed Hussein et al., *Network pruning for extending satellite service life in LEO satellite constellations*, 23 Wireless Networks 117, 120 (2017).

satellite constellations in the LEO and the GEO rise the threat of harmful interference with space signals. The frequency bands for a constellation are specifically described and allocated by the ITU and during the licensing process.[103] Nevertheless, the risk of interferences exists. The probability of interference increases with the number of space objects in the orbits.[104] Additionally, space debris can impact the radio communication between functional space objects. In a wider sense this harms the Outer Space environment and the limited resource of radio spectrum.

These concerns raise the need for a mandatory impact assessment that must be performed before the launch of space objects. An impact assessment reveals the effects and impact of the project on the current situation and environment. The outcome of the impact assessment must be positive. This implies that the advantages of the project are calculated and prevail the negative effects. If the project endangers protected areas of law or nature such as the limited resource Earth orbit, the operator must prove that precautionary measures are taken. This could be achieved through lifecycle analysis or technical implementations. The EU Galileo programme, the European approach for a resilient global navigation system, did an impact assessment in 2011. The "Proposal for a Regulation of the European Parliament and of the Council on further implementation of the European satellite navigation programmes (2014 – 2020)"[105] includes an impact assessment which relies on three distinct positions: benefits, costs and competitiveness.[106] The positions change for different assessments. Considering large satellite constellations, the analysis should include the aspect of environmental sustainability as a long-term target.

1. *Space Sustainability under International Treaty law*

The applicability of International Law in the context of environmental harm is handled multiple times in (international) case law. The applicability of International Law in the environmental context is referred to by the International Court of Justice in its Advisory Opinion on the *Legality of the Threat or Use of Nuclear Weapons.* The International Court of Justice made reference to already existing international treaties relating to the safeguarding of the environment, which prohibit "to cause widespread, long-term and severe damage to the natural environment".[107]

In the *Gabčíkovo-Nagymaros Project Case* the International Court of Justice declared in its judgement the importance of environmental assessments to prevent disruption in environmental conditions. "[I]n the field of environmental protection, vigilance and prevention are required on account of the often-irreversible character of damage to the environment and of the limitations inherent in the very mechanism of reparation of this type of damage".[108] The

[103] FABIO TRONCHETTI, FUNDAMENTALS OF SPACE LAW AND POLICY 12 (2013).
[104] The risk probability is still very low but taking the Kessler syndrome into consideration it is a potential threat.
[105] European Commission, *Proposal for a Regulation of the European Parliament and of the Council on further implementation of the European satellite navigation programmes (2014 – 2020)*, SEC (2011) 1446 final.
[106] Ibid., at 37.
[107] Legality of the Threat or Use of Nuclear Weapons (Advisory Opinion) 1996, I.C.J. 226 (July 8).
[108] Gabčíkovo-Nagymaros Project (Hungary v. Slovakia) (Judgment) 1997, I.C.J. 7 (Sept. 25) at 140.

International Court of Justice accentuated that "owing to new scientific insights and to a growing awareness of the risks for mankind - for present and future generations - of pursuit of such interventions at an unconsidered and unabated pace, new norms and standards have been developed".[109] States are under a duty to refrain from harmful contamination resulting from activities within their jurisdiction or control as stressed in the *Trail Smelter Arbitration.*[110] The International Court of Justice held that under the principles of International Law "no State has the right to […] cause injury by fumes in or to territory [beyond its jurisdiction]".[111] In the context of large satellite constellations, according to the principle of lex specialis derogat legi generali, Space Law is applicable as specialized treaty law.

a. Interface between UN Space Law and International Law: Art. III OST

Art. III OST claims that activities in Outer Space must be coherent with International Law. International Law is the most general basis for the interpretation of activities. The impact on large satellite constellations is to be considered as related to activities in Outer Space because the satellites concerned are space objects. Space objects and their component parts are objects that are launched or intended to be launched into Outer Space.[112] As such space object is concerned in connectivity systems, Art. III OST is applicable and requires the activity on the system to be coherent with international law. Art. IX OST induces an obligation of states to act in accordance with international environmental law as it highlights the prohibition on change in atmosphere of celestial bodies.[113]

International law in the context of sustainable aspects of large satellite constellations are not only related to the five Outer Space Treaties[114] but also concerns several rules of International Environmental Law. These tools with different binding force will be discussed in the following sections taking into consideration their authority and impact on future activities.

b. Principle of jurisdiction and control over space objects: Art. VIII OST

States shall remain jurisdiction and control over their space objects, yet also over space debris as being non-functional space objects or component parts thereof.[115] Arts. VI & VII OST in conjunction with Art. VIII OST introduce the obligation to remain control over launched objects. This counts equally for large satellite constellations. The wording of jurisdiction and control lead to a conceptual distinction. The concept of 'control' can be realized as a technical function. Such a technical measure, e.g. tracking devices in satellites and registered labelling of component parts, is enforceable through legal obligations. The impact of 'control' goes

[109] Ibid.
[110] Trail Smelter Arbitration (U.S. v. Canada) 1938/1941, R.I.A.A. 1905.
[111] Ibid., at 1965.
[112] Armel Kerrest & Lesley Jane Smith, *Art. VII, in* I COLOGNE COMMENTARY ON SPACE LAW, 51 (Stephan Hobe, Bernhard Schmidt-Tedd & Kai-Uwe Schrogl eds. 2009).
[113] Sergio Marchisio, *Art. IX, in* I COLOGNE COMMENTARY ON SPACE LAW, 30 (Stephan Hobe, Bernhard Schmidt-Tedd & Kai-Uwe Schrogl eds. 2009).
[114] OST, ARRA, LIAB, REG, MOON.
[115] Bernhard Schmidt-Tedd & Stephan Mick, *Art. VIII, in* I COLOGNE COMMENTARY ON SPACE LAW, 33 (Stephan Hobe, Bernhard Schmidt-Tedd & Kai-Uwe Schrogl eds. 2009).

beyond the technical capabilities. It is interlinked with the concept of 'jurisdiction' and describes the possibility of supervision.[116] Jurisdiction over the object and compliance with the technical requirements is accordingly included under Art. VIII OST. The conjunct terms jurisdiction and control implement distinct measures but are equal in their purpose. Jurisdiction is not possible without control and vice versa.[117] Art. VIII OST demonstrates a very general but enforceable obligation to perform technical assessments and to take prospective actions to remain jurisdiction and control.

c. Registration of space objects: Art. II REG

The concept of registration of space objects under Art. II REG[118] is interlinked with Art. VIII OST.[119] Launching states[120] must register the space objects in their national register and inform the Secretary General of the UN of launchings and space objects. Following the wording of Art. II REG, a consistent registration practice by states is required. This practice lacks consistency at the level of practice and at the level of ratification of the REG.[121] In order to enhance the number of registered objects different means are discussed. A possible solution is the outsourcing of the obligation to licensed authorities. Licensing of registration obligations by the operators reduces the burden of registration for non-state operators and economically driven launches. Large satellite constellations are chiefly operated by private operators or in co-operation with different authorities. Licensing condenses the obligation to register to one institution. This way, registration can be enforced and remedied in case of non-compliance. Art. IV REG in conjunction with Art. VII REG permits the registration by non-state actors. Only elements of the obligation can be transferred to different (non-agency) actors and organizations but not the entire originate obligation to register.[122] Through the development towards an economically driven society, institutions are not as authoritative as they used to be. This marks the difficulty in a consistent registration process at government level.[123]

d. Prohibition on adverse changes of the environment: Art. 7 MOON

Art. 7 MOON[124] recognizes an obligation not to adversely change the existing balance in the environment of planets of our solar system. The launch of large satellite constellations

[116] Ibid., at 48.
[117] Bernhard Schmidt-Tedd & Stephan Mick, *Art. VIII, in* I COLOGNE COMMENTARY ON SPACE LAW, 48 (Stephan Hobe, Bernhard Schmidt-Tedd & Kai-Uwe Schrogl eds. 2009).
[118] Convention on Registration of Objects Launched into Outer Space, *entered into force* Sept. 15, 1976, 1023 U.N.T.S. 15.
[119] Bernhard Schmidt-Tedd et al., *Art. II REG, in* II COLOGNE COMMENTARY ON SPACE LAW, 39 (Stephan Hobe, Bernhard Schmidt-Tedd & Kai-Uwe Schrogl eds. 2013).
[120] According to Art. I (a) REG a launching state is "[a] State which launches or procures the launching of a space object" and "A State from whose territory or facility a space object is launched".
[121] Bernhard Schmidt-Tedd & Stephan Mick, *Art. VIII, in* I COLOGNE COMMENTARY ON SPACE LAW, 73 (Stephan Hobe, Bernhard Schmidt-Tedd & Kai-Uwe Schrogl eds. 2009).
[122] Bernhard Schmidt-Tedd & Leslie Tennen, *Historical Background and Context REG, in* II COLOGNE COMMENTARY ON SPACE LAW, 8 (Stephan Hobe, Bernhard Schmidt-Tedd & Kai-Uwe Schrogl eds. 2013).
[123] Bernhard Schmidt-Tedd et al., *Art. II REG, in* II COLOGNE COMMENTARY ON SPACE LAW, 59 (Stephan Hobe, Bernhard Schmidt-Tedd & Kai-Uwe Schrogl eds. 2013).
[124] Agreement Governing the Activities of States on the Moon and Other Celestial Bodies, *entered into force* July 11, 1984, 1363 U.N.T.S. 21.

increases the threat of jammed orbits and frequency interferences. The environment of planets depends on their orbital constitution. The contamination of the environment of Outer Space and planetary orbits is not limited to the incorporation of extra-terrestrial matter. Environmental changes according to Art. 7 MOON can emerge from various measures of contamination.[125] The deliberate spread of space debris in Outer Space has long-term environmental effects. Whether these are considered as harmful contamination or adverse changes to the atmosphere is unclear.[126] The installation of satellite constellations is not a deliberate production of space debris in orbits. It is a planned and supervised project that shall not increase the amount of debris.

Art. 7 MOON imposes specific obligations in relation to the environmental consequences of space activities. These provisions protecting the space environment exist, but their relevance is limited. The practical effect and binding force of the MOON is contentious. It has a low level of ratification and is not binding on most space-faring nations as they are not party to the treaty.[127]

The treaty norms of the UN Space Treaties are applicable on large satellite constellations because satellites in Earth orbits constitute space objects. According to Art. III OST International Law obligations are relevant for the interpretation of space activities. The obligations under International Law and Space Law are binding on the parties but judicial hurdles in law enforcement minimize the impact. The international community must cope with the shift towards private actors in space. This demands less general obligations but an unambiguous legal framework. In addition to that, case law presents a shift in International Law interpretation: the telos of the law enhances importance. The wording and the traveaux préparatoires of the treaties are still taken into consideration but due to the fast development of technology and the society the aim and purpose of the treaties is highlighted.[128] Customary International Law adapts to new developments in a more flexible way than International Law.

2. *LTS guidelines as obligations under Customary International Law*

Generally, guidelines have no binding character. Only if the application of guidelines becomes custom or if guidelines are implemented in National Law, the rules unfold their binding force. The LTS guidelines are a consented programme by the international high-level forum of COPUOS. They constitute a highly important step towards a regulated and agreed upon set of

[125] RAM S. JAKHU & JOSEPH L. PELTON, GLOBAL SPACE GOVERNANCE: AN INTERNATIONAL STUDY 457 (2017).
[126] Steven Freeland, *Art. 7 MOON, in* II COLOGNE COMMENTARY ON SPACE LAW, 116 (Stephan Hobe, Bernhard Schmidt-Tedd & Kai-Uwe Schrogl eds. 2013); Stephan Hobe*, Future Perspectives MOON*, *in* II COLOGNE COMMENTARY ON SPACE LAW, 300 (Stephan Hobe, Bernhard Schmidt-Tedd & Kai-Uwe Schrogl eds. 2013).
[127] Stephan Hobe, Peter Stubbe & Fabio Tronchetti*, Historical Background and Context MOON*, *in* II COLOGNE COMMENTARY ON SPACE LAW, 1 (Stephan Hobe, Bernhard Schmidt-Tedd & Kai-Uwe Schrogl eds. 2013).
[128] According to Arts. 31 &32 VCLT. The ICJ held in its judgement of the Kasikili/Sedudu Island case that Art. 31 VCLT constitutes custom and is therefore binding: Case concerning Kasikili/Sedudu Island (Botswana v. Namibia), Judgement, I.C.J. Report 1999, par. 1045.

long-term sustainability rules for Outer Space. The extent and concept of the LTS guidelines set by COPUOS in UNISPACE+50 follows in the next sections.

This thesis will analyse whether the LTS guidelines constitute Customary International Law. Sufficient state practice and opinio iuris must exist to establish custom. State practice exists when the behaviour in question is covered by usual and repeated state activities. Opinio iuris has a lower threshold in the context of technology and Outer Space. Technology (and especially technology in Outer Space) is a fast-evolving field. Some of the most recognized scholars in the field of International Law and Space Law constitute that custom can evolve fast in the evolving fields of technology and law.[129]

The consensus on common guidelines is demanded since the beginning of space activities. When the OST entered into force in 1967, the first issues on space sustainability were discussed. Since the very beginning of Space Law, a common regime for space activities and the sustainable use of Outer Space was a contractionary subject.[130] The LTS guidelines therefore constitute a milestone in Space Law. These guidelines, of which 21 do now constitute consented rules, have predecessors. The history of the LTS guidelines is taken into consideration for the existence of opinio iuris. The existence of state practice as the subjective element of custom is in question. In the next sections the impact of the predecessors of the LTS guidelines and the guidelines themselves are explored in light of the existence of opinio iuris and state practice.

a. The Precautionary Principle established in the Rio Declaration (1992)

The Rio Declaration was established in 1992 and leads towards a political and diplomatic based solution for the non-compliance with environmental obligations. The Rio Declaration constitutes soft law and is build upon principles that have been applied in several cases by the International Court of Justice.[131] This way, the application of the principles set in the declaration is binding on the states. This is because case law implies that sufficient opinio iuris and state practice exists to establish customary obligations.

The precautionary principle is established in Principle 15 of the 1992 Rio Declaration which states that "where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent

[129] MALCOM N. SHAW, INTERNATIONAL LAW 58 (8th ed. 2017); ANTHONY A. D'AMATO, CONCEPT OF CUSTOM IN INTERNATIONAL LAW 271 (1971); Bin Cheng, *"United Nations Resolutions on Outer Space: 'Instant' International Customary Law?", in:* STUDIES IN INTERNATIONAL SPACE LAW 139 (1997).; Bruno Simma & Philip Alston, *The Sources of Human Rights Law: Custom, Jus Cogens, and General Principles*, 12 Australian YIL, 82, 99 (Sept. 1988).

[130] The travaux préparatoires of the treaties and the Conference Room Papers of COPUOS sessions demonstrate the difficulties in finding consensus.

[131] Nuclear Tests Case (New Zealand V. France) (Judgment) 1974 I.C.J. 472 (Dec. 20); Dissenting Opinion on the Request for an Examination of the Situation in Accordance with Paragraph 63 of the Court's Judgment of 20 December 1974 in the Nuclear Tests case; Gabčíkovo-Nagymaros Project (Hungary v. Slovakia) (Judgment) 1997, I.C.J. 7 (Sept. 25).

environmental degradation".[132] The precautionary principle establishes that while in threat of serious or even irreversible environmental damage, preventive and immediate actions must be taken.[133] An Environmental Impact Assessment is a procedural obligation of states when undertaking activities that can result in environmental risk.[134] The ICJ held in the Pulp Mills case that "it is for each State to determine in its domestic legislation or in the authorization process for the project, the specific content of the Environmental Impact Assessment required in each case"[135] and that "an Environmental Impact Assessment must be conducted prior to the implementation of a project. Once operations have started and, where necessary, throughout the life of the project, continuous monitoring of its effects on the environment shall be undertaken".[136] The precautionary principle limits interest in pure commercial gain and leads to a set of societal concerns. The application of the precautionary principle shall increase public and societal equality.[137]

These assessments are supported by the hard law tools of Art. 3 (3) Framework Convention on Climate Change[138] and the soft law mechanisms of Art. 194 (1) UN CLOS[139] and Art. 2 i.c.w. Art. 6 Montréal Protocol[140]. The Montréal Protocol does not only impose the need for an assessment of the actions taken but also obliges states to implement a licensing system for the import and export of concerned substances.[141]

The corresponding licensing system for Large Satellite Constellations (SpaceX and OneWeb as examples) in the US is the FCC licensing procedure. Licensing is one form of regulatory measures.[142] It can be implemented and controlled very early in projects. This simplifies the

---

[132] James Cameron & Juli Abouchar *The Status of the Precautionary Principle in International Law, in* THE PRECAUTIONARY PRINCIPLE AND INTERNATIONAL LAW - THE CHALLENGE OF IMPLEMENTATION, 52 (David Freestone & Ellen Hay eds. 1996).

[133] PHILIPPE SANDS ET AL., PRINCIPLES OF INTERNATIONAL ENVIRONMENTAL LAW, 217 (2012); Paul B. Larsen, *Application of the Precautionary Principle to the Moon*, 71 Journal of Air Law and Commerce 294, 296 (2006).

[134] NEIL CRAIK, THE INTERNATIONAL LAW OF ENVIRONMENTAL IMPACT ASSESSMENT, PROCESS, SUBSTANCE AND INTEGRATION, 87 (2009).

[135] Case concerning Pulp Mills on the River Uruguay (Argentina v. Uruguay), Judgment, in ICJ Reports, 2010, par. 205.

[136] Ibid.

[137] Mike Feintuck, *Regulatory Raitionales beyond the Economic, in* 47 THE OXFORD HANDBOOK OF REGULATION (Robert Baldwin et al. eds. 2012).

[138] Art. 3 (3) Framework Convention on Climate Change: "The Parties should take precautionary measures to anticipate, prevent or minimize the causes of climate change and mitigate its adverse effects. Where there are threats of serious or irreversible damage, lack of full scientific certainty should not be used as a reason for postponing such measures, taking into account that policies and measures to deal with climate change should be cost-effective so as to ensure global benefits at the lowest possible cost […]".

[139] Art. 194 (1) UN CLOS: "States shall take, individually or jointly as appropriate, all measures consistent with this Convention that are necessary to prevent, reduce and control pollution of the marine environment from any source, using for this purpose the best practicable means at their disposal and in accordance with their capabilities, and they shall endeavour to harmonize their policies in this connection".

[140] Art. 6 Montréal Protocol: "Beginning in 1990, and at least every four years thereafter, the Parties shall assess the control measures provided for in Article 2 and Articles 2A to 2J on the basis of available scientific, environmental, technical and economic information. At least one year before each assessment, the Parties shall convene appropriate panels of experts qualified in the fields mentioned and determine the composition and terms of reference of any such panels. Within one year of being convened, the panels will report their conclusions, through the Secretariat, to the Parties".

[141] Art. 4B Montréal Protocol.

[142] Leopold Mantl, *The European Union, in* 406, 424 OUTER SPACE IN SOCIETY, POLITICS AND LAW (Christian Brünner & Alexander Soucek eds. 2011).

implementation for satellite operators and is a cost-effective system. It can also be done at the outset of the project. When the licence is not given, costs can be saved, or the proposal can be amended for achieving the necessary licence for the project. The licence contsits of conditions that the operator must fulfil such as compliance with ITU standards and orbital space debris mitigation setups.[143]

b. Space Debris Mitigation Guidelines

In 2002, the Inter-Agency Debris Committee (IADC) proposed Debris Mitigation Guidelines following a recent initiative for space sustainability. The IADC Space Debris Mitigation Guidelines contain a set of technical and legal obligations with the purpose of mitigating debris in Outer Space.[144] The non-binding obligations have guiding character and build the framework for the Space Debris Mitigation Guidelines of COPUOS which are established in 2007 and later the year endorsed by the UN General Assembly in its resolution 62/217 (22 Dec. 2007).[145] The COPUOS Space Debris Mitigation Guidelines target the risk related debris but proved ineffective in the long term because of a lack of application by the member states.[146] The guidelines have no binding force and the principles contained in the COPUOS approach were set vague and general resulting in a lack of implementation by the member states.

In 2007 followed another multilateral standard. The European Code of Conduct for Space Debris Mitigation[147] proposed activities for active removal of debris and chose a more practical approach.[148] Tracking of debris as well as the end-of-life disposal or satellite manoeuvres are taken into consideration. The standards contained in the Code of Conduct relate to the technical element of space debris mitigation but do not relate to the affiliated concerns such as environmental sustainability of Outer Space.

Neither of the Space Debris Mitigation Guidelines meets the threshold of uniform state practice. This is, because there is no common basis for adopting obligations constraining space activities that are not coherent with the Space Debris Mitigation Guidelines. The development of different mitigation guidelines however indicates that there is a common understanding of states for the need of legal obligations regulating space debris. The numerous attempts to find a standard for the mitigation of debris highlights the demand for such legal framework. For this reason, the element of opinio iuris of custom can be perceived.

---

[143] FCC 17-77, WorldVu Satellites Limited, d/b/a OneWeb (OneWeb), *FCC Grants Oneweb Access To U.S. Market For Its Proposed New Broadband Satellite Constellation* (June 21, 2017).
[144] Kai-Uwe Schrogl, *Space and its sustainable uses, in* 604, 605 OUTER SPACE IN SOCIETY, POLITICS AND LAW (Christian Brünner & Alexander Soucek eds. 2011); IADC Space Debris Mitigation Guidelines, IADC 02-01, IADC Action Item number 22.4 (Sep 2007).
[145] UNCOPUOS Space Debris Mitigation Guidelines, GA Res. 62/217 (22 Dec. 2007).
[146] Peter Stubbe & Kai-Uwe Schrogl, *Future Perspectives COPUOS SDM Guidelines - The Legal Significance of the COPUOS SDM Guidelines, in* III COLOGNE COMMENTARY ON SPACE LAW, 23, 25 (Stephan Hobe, Bernhard Schmidt-Tedd & Kai-Uwe Schrogl eds. 2015).
[147] European Code of Conduct For Space Debris Mitigation, Issue 1.0, Jun 28, 2004.
[148] PETER STUBBE, STATE ACCOUNTABILITY FOR SPACE DEBRIS: A LEGAL STUDY OF RESPONSIBILITY FOR POLLUTING THE SPACE ENVIRONMENT AND LIABILITY FOR DAMAGE CAUSED BY SPACE DEBRIS 235-6 (2017).

c. LTS Guidelines

The Long-Term Sustainability Guidelines by COPUOS (under the Scientific and Technical Subcommittee) and UNOOSA originate from the Space Debris Mitigation Guidelines and the European Code of Conduct.[149] The Working Group on the LTS Guidelines developed a consented set of 21 voluntary mitigation guidelines that contain the best-practice measures. At the high-level forum UNISPACE+50 the LTS guidelines were adopted. This way, the long-term sustainability of Outer Space shall be ensured. The framework for the LTS guidelines is set in GA Res. A/Res/72/79[150] which represents the entry point to LTS Guidelines.

The applicability of mitigation guidelines lacks uniformity and consensus. For this reason, the LTS Guidelines represent a milestone in Space Law. The drafting history underlines the difficulties in finding a consensus.[151] Consensus-based decisions have the advantage that the result highlights the current perception of the members. At international level a result in such a decision shows the willingness to co-operate and to build a reliable legal regime. The LTS guidelines constitute a step forward towards space sustainability. Outer Space and the Earth orbits shall be sustained fur future generations by implementing the guidelines. This equals the purpose and objective of the SDG's 2030 and the guidelines.

The answer to the question whether the LTS guidelines constitute Customary International Law depends on the existence of opinio iuris and state practice. Opinio iuris can be perceived because of the long and successful way towards the consensus of the respective LTS guidelines. The element of state practice is doubtful. According to the status of the LTS guidelines[152], the express wording states that the guidelines are voluntary measures. To enhance state practice of the LTS guidelines with the objective of creating a Customary International Law obligation contradicts the purpose of the guidelines.

Still, the LTS guidelines can obtain binding force on states through adoption of the guidelines into National Law. Then they are legally enforceable and enhance compliance to the (private) actors in Outer Space through national jurisdiction. This development would lead to the adoption of National Law of all space-active states that do not yet have a National Space Law, such as Germany.[153] Diverse measures of sustainable development can be implemented in a smart way using authorization and licensing processes. During the processes the compliance with LTS guidelines can be assessed. In case of non-compliance the actors can be forced to implement technological measures to fulfil the standard of the guidelines.

---

[149] UNCOPUOS Legal Subcommittee 57th Session, Vienna, 9 – 20 April 2018, *Agenda Item 11: General exchange of information and views on legal mechanisms relating to space debris mitigation and remediation measures, taking into account the work of the STSC Statement by the German Delegation*, par. 2.

[150] Consideration of the fiftieth anniversary of the United Nations Conference on the Exploration and Peaceful Uses of Outer Space, GA Res. A/Res/72/79 (2017).

[151] Draft Report on National legislation relevant to the peaceful exploration and use of outer space, 40-44 UNGA Doc. A/AC.105/C.2/L.304/Add.4 (2018).

[152] Committee on the Peaceful Uses of Outer Space, *Guidelines for the long-term sustainability of outer space Activities*, 15 UNGA Doc. A/AC.105/L.315 (2018).

[153] UNCOPUOS Legal Subcommittee 57th Session, Vienna, 9 – 20 April 2018, *Agenda Item 6: Status and application of the five United Nations treaties on outer space Statement by the German Delegation*, par. 6.

The LTS Guidelines shall be translated in National Law in order to establish compliance and law enforcement. The French Space Law[154] demonstrates a role model for the translation of the legal issues of space activities under International Law into National Law.

3. *Translation of Guidelines in National law*

The French Space Operations Act (FSOA) entered into force 3rd June 2008 and consists of two implementing decrees: first, the decree on authorization and control regime and second, the decree on the responsibilities of the CNES.[155]

It has a precise adoption of norms and regulation measures. The FSOA relies on two main pillars: registration (Arts. 12, 21 FSOA) and authorization (Arts. 4, 6 FSOA). In the context of large satellite constellations and their environmental impact the authorization practice of the FSOA demonstrates a role-model for other states. According to Art. 4 FSOA, three fundamental aspects must be present in order to achieve authorization for a project. The fundamentals are the moral, financial and professional guarantees.[156] In addition, the applicant for the authorization must approve the technical conformity of the system with the standards set by the ministry of Outer Space Affairs. Art. 4 FSOA particularly mentions that the technical conditions must be coherent with environmental safety.[157] Considering the obligations contained in the LTS guidelines, measures that lead to a sustainable use of Outer Space shall be implemented. Through Art. 4 FSOA such measures for sustainable space environments are assessed by technical means.[158] This paragraph in the FSOA shows the translation of Space Sustainability guidelines into National Law. The technical assessment of projects is delegated to the CNES and is operated according to the current practices of the CNES. This advances procedure profits from the experience of the CNES in space operations.[159] The technical

---

[154] LOI no. 2008-518 du 3 juin 2008 relative aux opérations spatiales.

[155] Bruno Lazare & Jean-Pierre Trinchero, *Regulations and Licensing at the European Spaceport, in:* SPACE SAFETY REGULATIONS AND STANDARDS 177, 181 (Joseph L. Pelton & Ram S. Jakhu, eds. 2017).

[156] Art. 4 FSOA: "Authorizations to launch, to command or to transfer the commanding of a space object launched and to proceed with its return to Earth are granted once the administrative authority has checked the moral, financial and professional guarantees of the applicant, and if necessary of its shareholders, and has ascertained that the systems and procedures that it intends to implement are compliant with the technical regulations set forth, in particular for the safety of persons and property, the protection of public health and the environment. […]".

[157] The French Technical Regulation is consistent with the Space Debris Mitigation Guidelines of the IADC and COPUOS as well as they correspond with the European Code of Conduct for Debris Mitigation. The FSOA is amended by a decree (n° 2009-643 du 9 juin 2009) that specifies the technical regulations for space operators. According to Art. 21 du décret n° 2009-643 du 9 juin 2009: "Le système de lancement mis en œuvre par l'opérateur de lancement doit être conçu, produit et mis en œuvre de façon à respecter les dispositions suivantes pour les éléments évoluant dans l'espace extra-atmosphérique". Art. 21 du décret n° 2009-643 du 9 juin 2009 further elaborates on specific technical requirements for mitigating space debris and rises penalties for non-compliance with the decree. It is possible that no authorization is granted if the operator does not entirely comply with the regulations.

[158] Decree on Technical Regulation issued pursuant to *Act* n°2008-518: Arrêté du 31 mars 2011 relatif à la réglementation technique en application du décret n° 2009-643 du 9 juin 2009 relatif aux autorisations délivrées en application de la loi n° 2008-518 du 3 juin 2008 relative aux opérations spatiales; Cordula Steinkogler, *Small Satellites and Space Debris Mitigation, in* SMALL SATELLITES: REGULATORY CHALLENGES AND CHANCES 211, 228 (Irmgard Marboe ed. 2017).

[159] Phillipe Clerc, *Consequences of the French Space Law on Space Operations (FSOA) on CNES's Mission as a Contracting Space Agency* 117, 125 in CONTRACTING FOR SPACE: CONTRACT PRACTICE IN THE EUROPEAN SPACE SECTOR (Lesley Jane Smith & Ingo Baumann eds. 2016).

requirements are therefore state-of-the-art and do not impose unreasonable disadvantage to the applicant.

The further authorization process can be simplified by licensing. Licenses from administrative authorities can prove that the applicant fulfils the requirements of moral, financial and professional guarantees for a limited time.[160] Each space operation falling under the FSOA is subject to authorization.[161] These two elements lead to a simple and universal application. The licenses count not only as prerequisites for the authorization process but also verify that the project is based on a reliable management. Licenses alone are not sufficient for the authorization of the space operation. A specific and precise justification file containing details on the space mission, space objects and launching details as well as the supplementary documents on financial and managemental processes is required.[162] This way the authorities ensure full coverage and compliance with all requirements for the authorization of the operation.

According to Art. 6 FSOA the financial means must be proven. This includes full compensation for damage to or from space objects. The liability concerned obligations follow the LIAB[163]. Art. III LIAB creates fault-based liability in Outer Space.[164] To enhance the enforcement of claims a universally applicable means is used to cover the costs. The FSOA intends an insurance-based approach in order to provide a reliable financial foundation for damage in Outer Space. This way, the financial assessment can be guaranteed in the authorization process. The registration of space objects is regulated in the FSOA and concerns the decree on the responsibilities of the CNES. According to Arts. 12 & 21 FSOA the registration of space operations is carried out by the CNES. It includes the registration of space objects in the national register and the notification of the Secretary General of the UN as required by Art. II REG.

Through the implementation and enforcement of these measures the FSOA builds a resilient best practice process of space operation authorization and registration. These patterns are contained in the LTS guidelines and fully translated into the French National Law. The FSOA is a role-model on technical and legal implementation of guidelines into National Law.[165] The interplay of technical assessments and legal obligations is realized very specifically and shows

[160] Bruno Lazare & Jean-Pierre Trinchero, *Regulations and Licensing at the European Spaceport, in:* SPACE SAFETY REGULATIONS AND STANDARDS 177, 183 (Joseph L. Pelton & Ram S. Jakhu, eds. 2017).
[161] Giugi Carminati, *French National Space Legislation: A Brief "Parcours" of a long History*, 36 Houston Journal of International Law 11, 12 (2014).
[162] Bruno Lazare & Jean-Pierre Trinchero, *Regulations and Licensing at the European Spaceport, in* SPACE SAFETY REGULATIONS AND STANDARDS 177, 183 (Joseph L. Pelton & Ram S. Jakhu, eds. 2017).
[163] Convention on International Liability for Damage Caused by Space Objects, *entered into force* Oct. 9, 1973, 961 U.N.T.S. 187.
[164] Art. III LIAB: "In the event of damage being caused elsewhere than on the surface of the Earth to a space object of one launching State or to persons or property on board such a space object by a space object of another launching State, the latter shall be liable only if the damage is due to its fault or the fault of persons for whom it is responsible".
[165] The United Kingdom has a similar approach on licensing and authorization processes: Frans G. von der Dunk, *The Origins of Authorisation: Article VI of the Outer Space Treaty and International Space Law, in* 3, 23 NATIONAL SPACE LEGISLATION IN EUROPE (Frans G. von der Dunk ed. 2011).

the advantages of combined mechanisms of law and technology. The use of technology as a practicable means to enforce law is a smart measure to enhance compliance with the norms.

This application can be translated to different fields of law, such as the guidelines on cyber operations. Regulation can be achieved through authorization processes. Authorization can adopt to the different conditions of highly specified areas because distinct assessments can be done. The choice of parameters for the assessments influences the regulatory level. This way, law can be a flexible means to cope with new developments in technology. The target can be achieved by adopting a National Law similar to the FSOA for space operating states.

4. *Application of General Principles of Law*

As a subsidiary means, general principles of law are to be taken into consideration in the interpretation of activities.[166] Such general principles form the backbone of law as they frame activities on a general basis. General principles are widely construed (mostly by case law) and have guiding character.

a. Due regard / due diligence

The principle of due regard/due diligence is well recognised as a general principle of international law,[167] and is specified under Art. 7 MOON and Art. IX OST. The principle of due regard describes the obligation of a state to take into account interests and rights of other states in their activities in outer space.[168] The distinction between due regard and due diligence is only minor. Due regard can be paraphrased with reasonable care and describes the obligation to comply with the standard.[169] The standard depends on the activity and situation. Due diligence is further assessing the gathering of information needed in order to comply with the standard.[170]

The definition of due regard was used for the first time in 1944 in International Conventional Law, when 26 states concluded the Chicago Convention, which chartered the ICAO to develop air navigation principles and procedures for safety of air navigation.[171] The principle of due regard has also been affirmed by the International Court of Justice in the decision of July 25, 1974. In the *Fisheries Jurisdiction case* between the U.K. and Iceland, the International Court of Justice declared that "states have an obligation to pay due regard to the interests of other

[166] According to Art. 38 (I) (c) ICJ Statute.
[167] The United States Diplomatic and Consular Staff in Tehran Case (US v. Iran) (Judgment) 1980, I.C.J. 21 (May 24), par. 63; Pulp Mills (Argentina v. Uruguay) (Judgment) 2010, I.C.J. 14 (Apr. 20), par. 205; Rio Declaration on Environment and Development, U.N. Doc. A/Conf.151/26 (1992), Principle 2; Declaration of the United Nations Conference on the Human Environment, U.N. Doc. A/Conf.48/14/Rev.1 (1972), Principle 21.
[168] Sergio Marchisio, *Art. IX, in* I COLOGNE COMMENTARY ON SPACE LAW, 23, 25 (Stephan Hobe, Bernhard Schmidt-Tedd & Kai-Uwe Schrogl eds. 2009).
[169] Ibid., 175, 176.
[170] Commentary to Art. 2 ARSIWA, at 70; Timo Koivurova, *Due diligence, in* MAX PLANCK ENCYCLOPEDIA OF PUBLIC INTERNATIONAL LAW, 6 (2010).
[171] Sergio Marchisio, *Article IX, in* I COLOGNE COMMENTARY ON SPACE LAW 175, 177 (Stephan Hobe, Bernhard Schmidt-Tedd & Kai-Uwe Schrogl eds. 2009).

States in the conservation and equitable exploitation of the fisheries resources"[172]. There is no common definition of contamination. Article IX OST implies that States shall avoid any contamination which would cause a significant harm and shall exhaust all possible measures beyond any reasonable doubt.[173] This implies that the term contamination should be widely interpreted. Following this logic, due regard has a broad extension. This is supported by the purpose of general rules of International Law according to Art. 38 (I) (c) ICJ Statute. The aim and purpose of "general rules recognized by civilized nations" is to cushion findings that do not fit in hard law or soft law cases of custom. Legal tools that impact the very impetus of International Law shall be acknowledged by the broad principle of Art. 38 (I) (c) ICJ Statute.

The understanding for having due regard to the future interest of Earth's population in Outer Space developed since the beginning of the exploration of Outer Space. As stated in the UN Sustainable Development Goals 2030, future generations must have access to resources in a sustainable environment. The future of accessible Earth orbits is at risk without a common regime for sustainable use of Outer Space resources. Therefore, states are under an International Law obligation to pay due regard for the interest of other states (and other generations) in their (prospective) space activities. The obligation to pay due regard to the interest of other states includes Environmental Impact Assessments.[174]

Space and space-related technology are the main drivers for development in economy and society. In light of the aforementioned, equal rights to have access and possibility to gain advantage from space must be acknowledged in International Law. To do so, the general International Law principles of joint capacity-building and international co-operation are essential.

b. International Co-operation

International co-operation is a main objective of the UN, its institutions and offices.[175] UNOOSA acts as a global player towards achieving the missions of increasing international cooperation and capacity building. To achieve better co-operation between states and non-governmental actors, Transparency and Confidence Building Measures (TCBMs) are implemented.[176] The preamble of the OST recognizes international co-operation as objective. The most popular result of international co-operation is the ISS. The ISS consists of various component parts launched by several countries that co-operate in the use and construction of

[172] Fisheries Jurisdiction Case (United Kingdom of Great Britain and Northern Ireland v. Iceland), (Judgment) 1974 I.C.J. 3 (July 25).
[173] LOTTA VIIKARI, THE ENVIRONMENTAL ELEMENT IN SPACE LAW: ASSESSING THE PRESENT AND CHARTING THE FUTURE, 60 (2008); Aditya Sharma, *Protection of The Outer Space Environmental: Need to Revisit the Law*, 54 PROC. ON L. OUTER SPACE 69, 73 (2011).
[174] Stephen Townley, *The Rise of Risk in International Law*, 18 Chicago Journal of International Law 622 (2018).
[175] Rüdiger Wolfrum, *Art. 1 UN Charter, in* I THE CHARTER OF THE UNITED NATIONS: A COMMENTARY 9 (Bruno Simma et al. eds., 3rd Ed. 2012)
[176] Report of the Secretary General on Transparency and confidence-building measures in outer space activities, U.N. Doc. A/72/65 (2017).

the space station.[177] To promote international co-operation high level forums organise meetings on a regular basis. Discussions on the recent developments are the first step towards approved multilateral agreements. TCBMs are an additional measure to promote co-operative activities in Outer Space. Large satellite constellations raise the need for international co-operation since the high number of satellites launched risk the sustainable use of Earth orbits. Several preventive measures must be taken to avoid interference with other operations and objects. The possibilities to respond to this need are concerned at a more specified level, namely at a regulation level.

General principles of law grant a very broad understanding of legal obligations. The applicability of these general norms can be enforced if the obligations are translated in National Law or performed by a regulatory medium.

C. Perspectives

The development towards an interlinked world requires a reliable network of connectivity. As discussed, pure legal regimes and regulation on International Level is limited by the factors of compliance enforcement and technical implementation of common standards. Considering the impact and importance of satellite constellations for the economy, society and sustainable development it is important to base the system on diverse pillars. Technology serves as a solution, but it must be supported by a political consensus. This trade-off shall result in diplomatic consultations and consented solutions. Classic treaty norms do not comply with the needs of a fast-developing community which relies on flexible adjustments in regulation. The International Community has decided not to rank tools because the states aim to avoid hard law obligations because of the long and difficult treaty making process. Therefore, soft law mechanisms such as regulation is preferred and the most flexible answer. The component of technological development is interlinked with regulation. Such technological process can result in smarter regulation and faster adaption to changes. Examples for the technological developments in the future are the use of Artificial Intelligence and Quantum Technologies. Whilst the concept of Artificial Intelligence is already implemented in some areas of economy, the evolution of quantum technology is a future idea whose ancestors[178] are recently implemented.

Artificial Intelligence is still in in the process of development and will result in a step forward toward resilient connectivity technologies.[179] Artificial Intelligence describes the phenomenon that machines can learn and develop independently from human data input. Such independent development of code is possible with today's technological standards. A computer is "fed"

[177] Bernhard Schmidt-Tedd & Stephan Mick, *Art. VIII, in* I COLOGNE COMMENTARY ON SPACE LAW, 59 (Stephan Hobe, Bernhard Schmidt-Tedd & Kai-Uwe Schrogl eds. 2009); FRANCIS LYALL & PAUL B. LARSEN, SPACE LAW - A TREATISE 123 (2009).
[178] Such as glass fibre connectivity.
[179] Julia J. A. Shaw, *From homo economicus to homo roboticus: an exploration of the transformative impact of the technological imaginary*, 11 International Journal of Law in Context 245, 255 (2015).

with data from databanks, mathematical formula or physical theorems.[180] The machine saves the information and can request delivery of the information at any time. By repeating this data input multiple times, the machine develops a reliable data basis. At some stage during the process of data input the operator includes simple "questions" to the machine. The computer finds a solution relying on the given data.[181] The machine will find the solution to the question through data analysis. This procedure is repeated various times. The crucial point is when the operator poses a question with an unknown solution. The computer analyses the known data and formula. Through the previous processes the machine developed an algorithm to deal with solution-finding. This algorithm has constantly been altered and improved.[182] This process demonstrates Artificial Intelligence. It is code-based and relies on a resilient basis of data. Artificial Intelligence could be used to improve communication between the satellites within the constellation. This way, a reliable connectivity system can be implemented on Earth.

As one different possible alternative to large satellite constellations, quantum technologies could offer new possibilities in the sector of connectivity.[183] However, this quantum leap is not yet foreseeable. With the emergence of quantum technologies, the basis of connectivity would change drastically and would allow new spheres of connectivity.[184] Such would transform today's world in utmost ways. The theory of physics, mathematics and information technology would have a new foundation allowing a different way of reasoning.[185] In the context of large satellite constellations, quantum technology offers an independent solution as it does not rely on radiofrequency. Quantum communication is an optical solution and thus has a different spectrum requirement.[186] The optical frequency bands are less demanded today so that quantum technology is an alternative for radiofrequency communication.[187]

Glass fibre technology (as an example of optical frequency technology) gives a first insight on how quantum technology could enhance possibilities of communication and connectivity. The throughput of optical frequency systems is higher and faster than is the radiofrequency technology.

[180] Herbert A. Simon, *Why should machines learn?, in* 25, 32-5 I MACHINE LEARNING -AN ARTIFICIAL INTELLIGENCE APPROACH (R. S. Michalski, J. G. Carbonell & T. M. Mitchell eds., 2016).
[181] Ibid.
[182] Ibid.
[183] Lajos Hanzo et al., *Wireless Myths, Realities, and Futures: From 3G/4G to Optical and Quantum Wireless*, 100 Proceedings of the IEEE 1853, 1877 (2012).
[184] David Deutsch & Artur K. Ekert, *Introduction to Quantum Computation, in* PHYSICS OF QUANTUM INFORMATION 93 (D. Bouwmeesters et al. eds. 2010).
[185] Christopher Gordon Timpson, Quantum Information Theory and The Foundations of Quantum Mechanics 29 (Trinity Term 2004) (unpublished Doctoral Thesis Trinity College).
[186] Lajos Hanzo et al., *Wireless Myths, Realities, and Futures: From 3G/4G to Optical and Quantum Wireless*, 100 Proceedings of the IEEE 1853, 1877 (2012).
[187] Ibid. at 1875.

Conclusion

Law is reactive rather than proactive.[188] This is caused by the fast development of technology and the implicated dangers a proactive law-making process would have. It is evident that law cannot foresee technological development and even if it could, there would always be technology that finds and uses a loophole in law whilst developing. Soft law tools are smarter and more flexible thus a reactive answer to technical evolution. It can (and shall) be applicable to the predecessors of technology as well as to the current technologies. Still, law can foresee the very next stages of development and shall be flexible enough to have regulatory impact.[189] This is possible through establishment of customary law or the application of similar measures or obligations by analogy in order to prevent *lacunae* in law. This way, international law and diplomacy have developed over decades and proved their flexibility to deal with new, unforeseen and even abstract developments of humankind.[190] It cannot and must not be the objective of the responsible entities to rely on technology in order to overcome an urgent problem and threat. Risks that arise by large/mega constellations must be analysed and regulated immediately and not in the future.

The objective of the implementation of legal tools is to regulate this upcoming development. This way, the needs of recent developments in connectivity technology and sustainability approaches in Outer Space are fulfilled. States fail to comply with implemented rules and regulations at international level. Regulatory systems alone cannot cope with the problems arising. The objective must be to implement a semi-extra-terrestrial applicability of systems and rules. This results in a sustainable mixture of terrestrial- and extra-terrestrial systems to ensure global connectivity. A reliable system of connectivity yet ensuring sustainable developments in Outer Space can only be guaranteed by a composition of distinct measures that result in a common rule.

This thesis presents two distinct fields of concern realized by large satellite constellations. First, the need of increasing cybersecurity. Second, the threat of unsustainable use of Outer Space caused by a high number of satellites and debris. Both subjects are critical in nature and concern governmental levels, national security, (inter-) national economy and society. Self-regulation has had a limited effect in restricting the concerned threats.[191] As has been laid out, the genesis of a cyber- and a sustainability regime for large satellite constellations is significant. The formation of the recent set of guidelines, either in cybersecurity issues and in sustainability questions, is a milestone in the further generation of legal measures. The development of a common legal approach for cybersecurity is further developed than is the sustainability aspect in Outer Space.

---

[188] P.J. Blount, *Renovating Space: The future of international space law*, 40 Denver Journal of International Law and Policy 515, 515 (2012).
[189] Jürgen Feick & Raymund Werle, *Regulation of Cyberspace, in* 523 THE OXFORD HANDBOOK OF REGULATION (Robert Baldwin et al. eds. 2012)
[190] P.J. Blount, *Renovating Space: The future of international space law*, 40 Denver Journal of International Law and Policy 515, 527 (2012).
[191] IAN BROWN & CHRISTOPHER T. MARSDEN, REGULATING CODE – GOOD GOVERNANCE AND BETTER REGULATION IN THE INFORMATION AGE 163 (2013).

The examples of cybersecurity and space security demonstrate a way of implementing a common standardization and legal framework regime in high-technology sector. The LTS guidelines have gone through a long process of discussion at international level. The result of which is the consensus on a set of LTS guidelines at UNISPACE+50. Following the example of the cyber-regime, standards and compliance guidelines must be translated into enforceable rules. This can be implemented at the level of a national space law or at technological level through the establishment of compulsory licensing, tracking or insurance means.

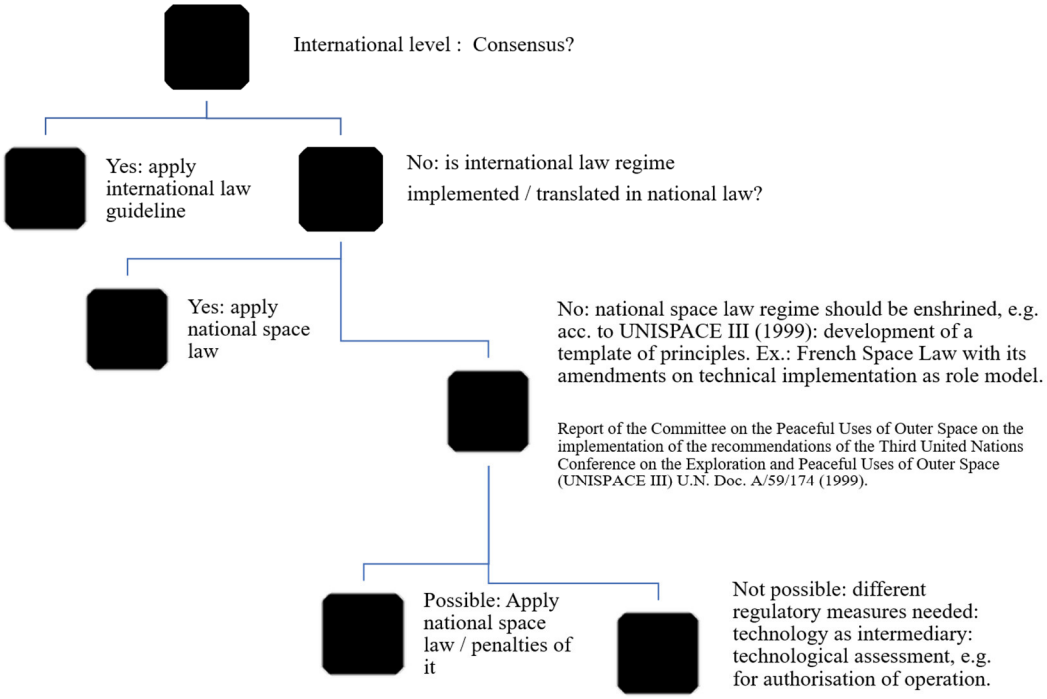

Figure 1: Process Flow (Source: Ronja Christiansen)

Figure 1 shows an idea of a process flow that should be established to overcome the missing elements that are outlines in this thesis. It contains the aspects of structural development of obligations and the need for a regulation regime at all levels.

Bibliography / Table of Authorities

1. IMPORTANT LEGAL DOCUMENTS

Statute of the International Court of Justice, *entered into force* Oct. 24, 1945, 15 U.N.C.I.O. 355.

Charter of the United Nations, *entered into force* Oct. 24, 1945, 892 U.N.T.S. 119.

2. TREATIES AND INTERNATIONAL AGREEMENTS

Agreement Governing the Activities of States on the Moon and Other Celestial Bodies, *entered into force* July 11, 1984, 1363 U.N.T.S. 21.

Constitution of the International Telecommunication Union, *entered into force* Dec. 22, 1992, 1825 U.N.T.S. 331.

Convention on Cybercrime, *entered into force* July 1, 2004, 185 ETS.

Convention on International Liability for Damage Caused by Space Objects, *entered into force* Oct. 9, 1973, 961 U.N.T.S. 187.

Convention on Registration of Objects Launched into Outer Space, *entered into force* Sept. 15, 1976, 1023 U.N.T.S. 15.

Geneva Convention Relative to the Protection of Civilian Persons in Time of War (Fourth Geneva Convention), *entered into force* Aug. 12, 1949, 75 U.N.T.S. 287.

Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies, *entered into force* Oct. 10, 1967, 610 U.N.T.S. 205.

Vienna Convention on the Law of Treaties, *entered into force* Jan. 27, 1980, 1155 U.N.T.S. 331.

Agreement on the Rescue of Astronauts, the Return of Astronauts and the Return of Objects Launched into Outer Space, entered into force Dec. 3, 1968, 19 U.S.T. 7570, 672 U.N.T.S. 119.

3. INTERNATIONAL LAW CASES

I. International Court of Justice (I.C.J.)

Case Concerning Military and Paramilitary Activities in and against Nicaragua (Nicaragua v. United States of America) (Merits) (Judgment) 1986 I.C.J. 13 (June 27);

Case Concerning the Continental Shelf (Libya v. Malta) (Judgment) 1985, I.C.J. 13 (June 3)

Corfu Channel (UK v. Albania) (Merits) 1949, I.C.J. 4 (Apr. 9).

Fisheries Jurisdiction Case (United Kingdom of Great Britain and Northern Ireland v. Iceland), (Judgment) 1974 I.C.J. 3 (July 25).

Gabčíkovo-Nagymaros Project (Hungary v. Slovakia) (Judgment) 1997, I.C.J. 7 (Sept. 25).

Kasikili/Sedudu Island (Botswana v. Namibia), Judgement, I.C.J. Report 1999.

Legality of the Threat or Use of Nuclear Weapons (Advisory Opinion) 1996, I.C.J. 226 (July 8)

Nuclear Tests Case (New Zealand V. France) (Dissenting Opinion) (1974 I.C.J. 472 (Dec. 20);

Nuclear Tests Case (New Zealand V. France) (Judgment) 1974 I.C.J. 472 (Dec. 20);

Pulp Mills (Argentina v. Uruguay) (Judgment) 2010, I.C.J. 14 (Apr. 20)

The United States Diplomatic and Consular Staff in Tehran Case (US v. Iran) (Judgment) 1980, I.C.J. 21 (May 24),

II. International Tribunals

Trail Smelter Arbitration (U.S. v. Canada) 1938/1941, R.I.A.A. 1905.

4. UNITED NATIONS MATERIALS

Committee on the Peaceful Uses of Outer Space, *Guidelines for the long-term sustainability of outer space Activities*, 15 UNGA Doc. A/AC.105/L.315 (2018).

Consideration of principles of international law concerning friendly relations and co-operation among States in accordance with the Charter of the United Nations, UNGA Res 1815 (XVII) (18 December 1962).

Consideration of the fiftieth anniversary of the United Nations Conference on the Exploration and Peaceful Uses of Outer Space, GA Res. A/Res/72/79 (2017).

Declaration of the United Nations Conference on the Human Environment, U.N. Doc. A/Conf.48/14/Rev.1 (1972), Principle 21.

Draft report on National legislation relevant to the peaceful exploration and use of outer space, 40-44 UNGA Doc. A/AC.105/C.2/L.304/Add.4 (2018).

Montréal Protocol on Substances that Deplete the Ozone Layer, 1522 U.N.T.S. 3; 26 ILM 1550 (1987).

Report of the Committee on the Peaceful Uses of Outer Space on the implementation of the recommendations of the Third United Nations Conference on the Exploration and Peaceful Uses of Outer Space (UNISPACE III) U.N. Doc. A/59/174 (1999).

Report of the Secretary General on Transparency and confidence-building measures in outer space activities, U.N. Doc. A/72/65 (2017).

Report of the Third United Nations Conference on the Exploration and Peaceful Uses of Outer Space (UNISPACE III) U.N. Doc. A/CONF.184/6 para. 73 (1999).

Responsibility of States for Internationally Wrongful Acts: Compilation of Decisions of International Courts, Tribunals and Other Bodies, UNGA, 62nd Sess. U.N. Doc. A/62/62 (2007).

Responsibility of States for Internationally Wrongful Acts: Compilation of Decisions of International Courts, Tribunals and Other Bodies, UNGA, 65th Sess. U.N. Doc. A/65/76 (2010).

Rio Declaration on Environment and Development, U.N. Doc. A/Conf.151/26 (1992), Principle 2.

UNCOPUOS Legal Subcommittee 57th Session, Vienna, 9 – 20 April 2018, *Agenda Item 6: Status and application of the five United Nations treaties on outer space Statement by the German Delegation.*

UNCOPUOS Legal Subcommittee 57th Session, Vienna, 9 – 20 April 2018, *Agenda Item 11: General exchange of information and views on legal mechanisms relating to space debris mitigation and remediation measures, taking into account the work of the STSC Statement by the German Delegation*.

UNCOPUOS Report of the Scientific and Technical Subcommittee on its Thirty-Sixth Session, Technical Report on Space Debris, U.N. Doc. A/AC.105/720 para. 6 (1999).

UNCOPUOS Space Debris Mitigation Guidelines, UNGA Res. 62/217 (22 Dec. 2007).

UNGA Res 377 (V) (3 November 1950) (“Uniting for Peace”).
United Nations Convention on the Law of the Sea 1833 U.N.T.S. 3; 21 ILM 1261 (1982).

United Nations Framework Convention on Climate Change 1771 UNTS 107; S. Treaty Doc No. 102-38; U.N. Doc. A/AC.237/18 (Part II)/Add.1; 31 ILM 849 (1992).

United Nations sustainable development goal 2030: Report of the World Commission on Environment and Development, *Our Common Future*, U.N. Doc. A/42/427 (1987).

5. DOCUMENTS OF THE EUROPEAN UION AND INTERNATIONAL ORGANIZATIONS

Directive (EU) 2016/1148 of the European Parliament and of the Council of 6 July 2016 concerning measures for a high common level of security of network and information systems across the Union, O.J. (L194) 1.

European Commission, *Proposal for a Regulation of the European Parliament and of the Council on further implementation of the European satellite navigation programmes (2014 – 2020)*, SEC (2011) 1446 final.

IADC Space Debris Mitigation Guidelines, IADC 02-01, IADC Action Item number 22.4 (Sep 2007).

ITU-T Working Group 13, *Framework of IMT-2020 network*, Recommendation Y.3102 (2018).

Decision No 676/2002/EC of the European Parliament and of the Council of 7 March 2002 on a regulatory framework for radio spectrum policy in the European Community (Radio Spectrum Decision), O.J. (L108) 1.

Report ITU-R SM. 2093-2, *Guidance on the regulatory framework for national spectrum management* (2015), available: https://www.itu.int/dms_pub/itu-r/opb/rep/R-REP-SM.2093-2-2015-PDF-E.pdf (last accessed: 05.07.2018).

Report ITU-R SM. 2093-2, *Guidance on the regulatory framework for national spectrum management* (2015).

6. LITERATURE

I. Books

IAN BROWN & CHRISTOPHER T. MARSDEN, REGULATING CODE – GOOD GOVERNANCE AND BETTER REGULATION IN THE INFORMATION AGE (2013).

CCDCOE, TALLINN MANUAL 2.0 ON THE INTERNATIONAL LAW APPLICABLE TO CYBER OPERATIONS (2017).

COMMITTEE ON SPACE DEBRIS, AERONAUTICS AND SPACE ENGINEERING BOARD, COMMISSION ON ENGINEERING AND TECHNICAL SYSTEMS, NATIONAL RESEARCH COUNCIL, ORBITAL DEBRIS: A TECHNICAL ASSESSMENT (1995), available: https://www.nap.edu/read/4765/chapter/1 (last accessed: 02.07.2018).

NEIL CRAIK, THE INTERNATIONAL LAW OF ENVIRONMENTAL IMPACT ASSESSMENT, PROCESS, SUBSTANCE AND INTEGRATION (2009).

ANTHONY A. D'AMATO, CONCEPT OF CUSTOM IN INTERNATIONAL LAW (1971).

INTERNATIONAL ACADEMY OF ASTRONOMICS, COSMIC STUDY ON SPACE TRAFFIC MANAGEMENT (Corinne Contant - Jorgenson et al., eds. 2006).

RAM S. JAKHU & JOSEPH L. PELTON, GLOBAL SPACE GOVERNANCE: AN INTERNATIONAL STUDY (2017).

BERT-JAAP KOOPS & MORAG GOODWIN, CYBERSPACE, THE CLOUD, AND CROSS-BORDER CRIMINAL INVESTIGATION - THE LIMITS AND POSSIBILITIES OF INTERNATIONAL LAW (2014).

FRANCIS LYALL & PAUL B. LARSEN, SPACE LAW - A TREATISE (2009).

MARCO ROSCINI, CYBER OPERATIONS AND THE USE OF FORCE IN INTERNATIONAL LAW (2014).

PHILIPPE SANDS ET AL., PRINCIPLES OF INTERNATIONAL ENVIRONMENTAL LAW (2012).

MALCOLM SHAW, INTERNATIONAL LAW (7th ed. 2014).

MALCOM N. SHAW, INTERNATIONAL LAW 58 (8th ed. 2017).

PETER STUBBE, STATE ACCOUNTABILITY FOR SPACE DEBRIS: A LEGAL STUDY OF RESPONSIBILITY FOR POLLUTING THE SPACE ENVIRONMENT AND LIABILITY FOR DAMAGE CAUSED BY SPACE DEBRIS (2017).

FABIO TRONCHETTI, FUNDAMENTALS OF SPACE LAW AND POLICY (2013).

LOTTA VIIKARI, THE ENVIRONMENTAL ELEMENT IN SPACE LAW: ASSESSING THE PRESENT AND CHARTING THE FUTURE (2008).

PAUL VOIGT & AXEL VON DEM BUSSCHE, THE EU GENERAL DATA PROTECTION REGULATION (GDPR): A PRACTICAL GUIDE (2017).

JAN ANNE VOS, THE FUNCTION OF PUBLIC INTERNATIONAL LAW (2013).

II. Shorter works of author(s) in a collection of various authors (chapters in books):

Babak Akhgar et al., *Consolidated Taxonomy and Research Roadmap for Cybercrime and Cyberterrorism, in* 295 COMBATTING CYBERCRIME AND CYBERTERRORISM - CHALLENGES, TRENDS AND PRIORITIES (Babak Akhgar & Ben Brewster eds. 2016).

Ali Atia & Huiwen Yao, *Communications Systems, in* THE INTERNATIONAL HANDBOOK ON SPACE TECHNOLOGY 397 (Malcom Macdonald & Viorel Badescu eds., 2014).

James Cameron & Juli Abouchar *The Status of the Precautionary Principle in International Law, in* THE PRECAUTIONARY PRINCIPLE AND INTERNATIONAL LAW - THE CHALLENGE OF IMPLEMENTATION, 52 (David Freestone & Ellen Hay eds. 1996).

Bin Cheng, *International Liability for Damage caused by Space Objects, in* I MANUAL ON SPACE LAW 297 (Nandasiri Jasentuliyana & Roy Lee eds. 1979).

Bin Cheng, *United Nations Resolutions on Outer Space: 'Instant' International Customary Law?, in:* STUDIES IN INTERNATIONAL SPACE LAW 139 (1997).

Phillipe Clerc, *Consequences of the French Space Law on Space Operations (FSOA) on CNES's Mission as a Contracting Space Agency* 117 in CONTRACTING FOR SPACE: CONTRACT PRACTICE IN THE EUROPEAN SPACE SECTOR (Lesley Jane Smith & Ingo Baumann eds. 2016).

R. M. D' Szousa et al., *Modeling Interdependent Networks as Random Graphs: Connectivity and Systemic Risk, in* NETWORK OF NETWORKS: THE LAST FRONTIER OF COMPLEXITY, 73 (GREGORIO D'AGOSTINO & ANTONIO SCALA, eds., 2014).

David Deutsch & Artur K. Ekert, *Introduction to Quantum Computation, in* PHYSICS OF QUANTUM INFORMATION 93 (D. Bouwmeesters et al. eds. 2010).

Jürgen Feick & Raymund Werle, *Regulation of Cyberspace, in* 523 THE OXFORD HANDBOOK OF REGULATION (Robert Baldwin et al. eds. 2012).

Mike Feintuck, *Regulatory Raitionales beyond the Economic, in* 47 THE OXFORD HANDBOOK OF REGULATION (Robert Baldwin et al. eds. 2012).

Steven Freeland, *Art. 7 MOON, in* II COLOGNE COMMENTARY ON SPACE LAW, 116 (Stephan Hobe, Bernhard Schmidt-Tedd & Kai-Uwe Schrogl eds. 2013).

Stephan Hobe*, Future Perspectives MOON*, *in* II COLOGNE COMMENTARY ON SPACE LAW, 300 (Stephan Hobe, Bernhard Schmidt-Tedd & Kai-Uwe Schrogl eds. 2013).

Stephan Hobe, Peter Stubbe & Fabio Tronchetti*, Historical Background and Context MOON*, *in* II COLOGNE COMMENTARY ON SPACE LAW, 1 (Stephan Hobe, Bernhard Schmidt-Tedd & Kai-Uwe Schrogl eds. 2013).

Ram S. Jakhu, *Sixty Years of Development of Space Law, in* AIR LAW, SPACE LAW, CYBER LAW – THE INSTITUTE OF AIR AND SPACE LAW AT THE AGE OF 90, 75 (Stephan Hobe ed., 2016).

Stephan A. Kaiser, *Comment on Cyber Security, in* AIR LAW, SPACE LAW, CYBER LAW – THE INSTITUTE OF AIR AND SPACE LAW AT THE AGE OF 90, 137 (Stephan Hobe ed., 2016).

Armel Kerrest & Lesley Jane Smith, *Art. VII, in* I COLOGNE COMMENTARY ON SPACE LAW, 51 (Stephan Hobe, Bernhard Schmidt-Tedd & Kai-Uwe Schrogl eds. 2009).

Hiroyuki Kishindo, *Launch Contracts for Small Satellites – The Essential Elements, in* SMALL SATELLITES: REGULATORY CHALLENGES AND CHANCES 317 (Irmgard Marboe ed. 2017).

Timo Koivurova, *Due diligence, in* MAX PLANCK ENCYCLOPEDIA OF PUBLIC INTERNATIONAL LAW (2010).

Bert-Jaap Koops, *Megatrends and Grand Challenges of Cybercrime and Cyberterrorism Policy and Research, in* 4-6 COMBATTING CYBERCRIME AND CYBERTERRORISM

- CHALLENGES, TRENDS AND PRIORITIES (Babak Akhgar & Ben Brewster eds. 2016).

Bruno Lazare & Jean-Pierre Trinchero, *Regulations and Licensing at the European Spaceport, in* SPACE SAFETY REGULATIONS AND STANDARDS 177 (Joseph L. Pelton & Ram S. Jakhu, eds. 2017).

Leopold Mantl, *The European Union, in* 406 OUTER SPACE IN SOCIETY, POLITICS AND LAW (Christian Brünner & Alexander Soucek eds. 2011).

Sergio Marchisio, *Art. IX, in* I COLOGNE COMMENTARY ON SPACE LAW (Stephan Hobe, Bernhard Schmidt-Tedd & Kai-Uwe Schrogl eds. 2009).

Sergio Marchisio, *Article IX Principle of Due Regard and Protection of Space Environment, in* I COLOGNE COMMENTARY ON SPACE LAW (Stephan Hobe, Bernhard Schmidt-Tedd & Kai-Uwe Schrogl eds. 2009).

Bernhard Schmidt-Tedd et al., *Art. II REG, in* II COLOGNE COMMENTARY ON SPACE LAW (Stephan Hobe, Bernhard Schmidt-Tedd & Kai-Uwe Schrogl eds. 2013).

Bernhard Schmidt-Tedd & Stephan Mick, *Art. VIII, in* I COLOGNE COMMENTARY ON SPACE LAW (Stephan Hobe, Bernhard Schmidt-Tedd & Kai-Uwe Schrogl eds. 2009).

Bernhard Schmidt-Tedd & Leslie Tennen, *Historical Background and Context REG, in* II COLOGNE COMMENTARY ON SPACE LAW (Stephan Hobe, Bernhard Schmidt-Tedd & Kai-Uwe Schrogl eds. 2013).

Kai-Uwe Schrogl, *Space and its sustainable uses, in* OUTER SPACE IN SOCIETY, POLITICS AND LAW 604 (Christian Brünner & Alexander Soucek eds. 2011).

Herbert A. Simon, *Why should machines learn?, in* I MACHINE LEARNING -AN ARTIFICIAL INTELLIGENCE APPROACH 25 (R. S. Michalski, J. G. Carbonell & T. M. Mitchell eds., 2016).

Mattew Smith & Elizabeth Paté-Cornell, *Cyber risk analysis for a smart grid, in* A SYSTEMS APPROACH TO CYBER SECURITY: PROCEEDINGS OF THE 2ND SINGAPORE CYBER-SECURITY R&D CONFERENCE 53 (Abhik Roychoudhury & Yang Liu eds. 2017).

Alexander Soucek, Historical Background and Context COPUOS SDM Guidelines, in III COLOGNE COMMENTARY ON SPACE LAW 2 (Stephan Hobe, Bernhard Schmidt-Tedd & Kai-Uwe Schrogl eds. 2015).

Peter Stubbe & Kai-Uwe Schrogl, *Future Perspectives COPUOS SDM Guidelines - The Legal Significance of the COPUOS SDM Guidelines, in* III COLOGNE COMMENTARY ON SPACE LAW (Stephan Hobe, Bernhard Schmidt-Tedd & Kai-Uwe Schrogl eds. 2015).

Richard Tremayne-Smith, *Reforming National Licensing and Agency Structures: A Current Overview of the UK Space Agenda, in* CONTRACTING FOR SPACE: CONTRACT PRACTICE IN THE EUROPEAN SPACE SECTOR 111 (Lesley Jane Smith & Ingo Baumann eds. 2016).

Fabio Tronchetti, *Legal aspects of space resource utilization, in* HANDBOOK OF SPACE LAW, 803 (Frans von der Dunk & Fabio Tronchetti eds. 2015).

Lotta Viikari, *Environmental Aspects of Space Activities, in* HANDBOOK OF SPACE LAW 717 (Frans von der Dunk & Fabio Tronchetti eds. 2015).

Frans von der Dunk, *Legal aspects of satellite communications, in* HANDBOOK OF SPACE LAW 456 (Frans von der Dunk & Fabio Tronchetti eds. 2015).

Frans G. von der Dunk, *The Origins of Authorisation: Article VI of the Outer Space Treaty and International Space Law, in* NATIONAL SPACE LEGISLATION IN EUROPE 3 (Frans G. von der Dunk ed. 2011).

Rüdiger Wolfrum, *Art. 1 UN Charter, in* I THE CHARTER OF THE UNITED NATIONS: A COMMENTARY (Bruno Simma et al. eds., 3rd Ed. 2012).

III. Articles in periodicals

Sarfraz Alam & Mohammad M. R. Chowdhury & Josef Noll, *Interoperability of Security-Enabled Internet of Things*, 61 Wireless Personal Communications 567 (2011).

Marco Benetar, *The Use of Cyber Force: Need for Legal Justification?*, 3 Goettingen Journal of International Law 375 (2009).

P.J. Blount, *Renovating Space: The future of international space law*, 40 Denver Journal of International Law and Policy 515 (2012).

P.J. Blount, *The Preoperational Legal Review of Cyber Capabilities: Ensuring The Legality Of Cyber Weapons*, 39 Northern Kentucky Law Review 211 (2012).

Giugi Carminati, *French National Space Legislation: A Brief "Parcours" of a long History*, 36 Houston Journal of International Law 11 (2014).

Kirsten Eichensehr, *The Cyber-law of Nations*, 103 The Georgetown Law Journal 117 (2015).

Lajos Hanzo et al., *Wireless Myths, Realities, and Futures: From 3G/4G to Optical and Quantum Wireless*, 100 Proceedings of the IEEE 1853 (2012).

Oona Hathaway, *The Law of Cyber-Attack*, 100 California Law Review 817, 826 (2012).

André Horstmann et al., *Survey of the Current Activities in the Field of Modeling the Space Debris Environment at TU Braunschweig*, 37 Aerospace 1 (2018).

Mohammed Hussein et al., *Network pruning for extending satellite service life in LEO satellite constellations*, 23 Wireless Networks 117 (2017).

Donald J. Kessler and Burton G. Cour-Palais, *Collision Frequency of Artificial Satellites: The Creation of a Debris Belt*, 83 Journal of Geophysical Research 2637 (1978).

Thomas Hoppner & Anastasia Gubanova, *Regulatory challenges of the Internet of Things*, 21 Computer and Telecommunications Law Review 227 (2015).

Paul B. Larsen, *Application of the Precautionary Principle to the Moon*, 71 Journal of Air Law and Commerce 294 (2006).

Paul B. Larsen, *Small Satellites Legal Issues*, 82 Journal of Air Law and Commerce 275 (2017).

David Le Blanc, *Towards Integration at Last? The Sustainable Development Goals as a Network of Targets*, 23 Sustainable Development 176 (2015).

Stephen Mason, *The internet and privacy: some considerations*, 21 Computer and Telecommunications Law Review 68 (2010).

NASA, *Satellite Box Score*, 22 Orbital Debris Quarterly News 1 (May 2018).

Titiriga Remus, *Cyber-attacks and International law of armed conflicts - a "jus ad bellum" perspective,* 8 Journal of International Commercial Law and Technology 179 (2013).

Michael N. Schmitt, *Cyber operations and the jus ad bellum revisited*, 56 Villanova Law Review 569 (2011).

Aditya Sharma, *Protection of The Outer Space Environmental: Need to Revisit the Law*, 54 PROC. ON L. OUTER SPACE 69 (2011).

Julia J.A. Shaw, *From homo economicus to homo roboticus: an exploration of the transformative impact of the technological imaginary*, 11 International Journal of Law in Context 245 (2015).

Bruno Simma & Philip Alston, *The Sources of Human Rights Law: Custom, Jus Cogens, and General Principles*, 12 Australian YIL, 82 (Sept. 1988).

Farhad Talaie, *The Importance of Custom and the Process of its Formation in Modern International Law*, 5 James Cook University Law Review 27 (1998).

Mark Taylor & Jennifer Richardson*, 5G wireless technology,* 23 Computer and Telecommunications Law Review 152 (2017).

Stephen Townley, *The Rise of Risk in International Law*, 18 Chicago Journal of International Law 622 (2018).

Mark Weiser, *The Computer for the 21st century,* 265 Scientific American, September 94 (1991).

Mark H. Wittow & Daniel J. Buller, *Cloud Computing – emerging legal issues for access to data, anywhere, anytime*, 14 Journal of Internet Law 1 (2010).

Unpublished works:

Christopher Gordon Timpson, Quantum Information Theory and The Foundations of Quantum Mechanics (Trinity Term 2004) (unpublished Doctoral Thesis Trinity College).

7. MISCELLANEOUS

Chart of Signatures and Ratifications of Treaty 185, Mar. 1, 2018: https://www.coe.int/en/web/conventions/full-list/-conventions/treaty/185/signatures?desktop=false (05.07.2018).

David Bollier, *The promise and peril of Big Data*, The Aspen Institute, Communications and Society Program, 20-25 (2010).

European Code of Conduct For Space Debris Mitigation, Issue 1.0, Jun 28, 2004.

ESA Space Sitautional Awareness, Space Surveillance and Tracking: SST Segment, available: http://www.esa.int/Our_Activities/Operations/Space_Situational_Awareness/Space_Surveillance_and_Tracking_-_SST_Segment (last accessed: 02.07.2018).

FCC 17-77, WorldVu Satellites Limited, d/b/a OneWeb (OneWeb), *FCC Grants Oneweb Access To U.S. Market For Its Proposed New Broadband Satellite Constellation* (June 21, 2017).

ITU Member States: https://www.itu.int/online/mm/scripts/gensel11 (last accessed: 05.07.2018)

ITU Members and Associates: https://www.itu.int/en/ITU-R/terrestrial/fmd/Pages/administrations_members.aspx (last accessed: 05.07.2018).

Report ITU-R SM. 2093-2, *Guidance on the regulatory framework for national spectrum management* (2015), available: https://www.itu.int/dms_pub/itu-r/opb/rep/R-REP-SM.2093-2-2015-PDF-E.pdf (last accessed: 05.07.2018).

United States Joint Chiefs of Staff, *Joint Pub 3-13: Joint Doctrine for Information Operations*, I-9 (1998), available: https://www.hsdl.org/?view&did=3759 (last visited: 02.07.2018).

Statement

I hereby affirm that I wrote the present thesis without any inadmissible help by a third party and without using any other means than indicated. Thoughts that were taken directly or indirectly from other sources are indicated as such. This thesis has not been presented to any other examination board in this or a similar form, neither in Germany nor in any other country.

Lüneburg, 09.07.2018