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# Developing planetary sustainability: Legal challenges of Space 4.0

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**Review**

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**Non-technical abstract**

Sixty years of space activities have led to ongoing scientific and technological progress. Space 4.0 reflects the rapid changes of the space community. Growing interest in space activities leads to increasing participation of numerous new actors in this field. Governments, private actors and international organizations are eager to fill existing gaps in securing global society's needs. The European Space Agency's Space 4.0 concept is designed to host a new era of space activities, aiming to resolve global challenges and to serve society. Space 4.0 developments are highly important, but are taking place in an extremely complex net of legal, regulatory and political considerations. This paper focuses on the legal challenges raised by the new era of Space 4.0 in a sustainability context.

**Technical abstract**

This paper spotlights the legal challenges related to the current age of space activities. After a cursory overview of the evolution of space activities in the different preceding eras, it provides some insight into the manifold interactions between the current era of Industry 4.0 and space activities in general. The following section gives an overview of the general legal norms applicable to space activities, mainly the five UN Treaties governing the activities of States in the exploration and use of outer space as adopted by the United Nations General Assembly. A core section then deals with legal challenges in the era of Space 4.0 relating specifically to environmental considerations in that era, which merit particular attention, namely the space debris issues. While taking the classical UN Outer Space Treaty system as a starting point, the legal appreciation of the environmental impact of space activities will be discussed in the light of the developing international environmental law context, including the direct relevance of general environmental law and policy. A concluding section provides some considerations concerning possible future developments.

## Social media summary

Space 4.0 reflects the rapid changes in the space community. This paper spotlights the legal challenges related to the current space era.

## 1. Space 4.0

Space 4.0 is leaving its hallmark on what appears to be a new era of space activities. In 2016 at the European Space Agency (ESA) Council meeting at Ministerial Level in Lucerne,[i] the landmark resolution 'Towards Space 4.0 for a United Space in Europe' was adopted. This resolution outlines the two guiding visions of the ESA: 'United Space in Europe' and 'Space 4.0'. The latter will be elaborated hereafter in more detail, with both objectives aiming for common goals among ESA´s Member States and to ensure the ongoing success of European space activities for the benefit of society and industry in the new space era.

### 1.1. The space eras

'Space 4.0' builds upon the achievements and developments of three previous chapters of exploration and use of space:

- *Space 1.0* started before the first satellites were launched into outer space, at a time when *astronomers* discovered the first shapes of celestial bodies, their movement and mechanics.[ii] The first practical uses of space are reflected by navigation in this period, which was guided from the lights of celestial bodies shining from outer space in the sky.
- *Space 2.0* was driven by the *political rivalry* of the Cold War era, leading to high levels of investments aiming at technological superiority to ensure national security and prestige.[iii] The *space race* influenced by those Cold War motives led finally to the Apollo era and

provided the basis of negotiations for a legal framework for outer space activities due to the increasing importance of space activities.

- *Space 3.0* was characterised by international *cooperation* efforts. The flagship project of this space era is the International Space Station (ISS) – the greatest common international research project of all time, in which the major space-faring nations and regions – the USA, Russia, Japan, Canada and Europe – are jointly investing in one project.

*Space 4.0* now marks the next chapter in the revolution of space activities. The most important maxim in the current space era is participation, characterized by a growing number of space actors ranging from governments to private investors. The development of small satellites and the technical advancements resulting from Industry 4.0 have enabled more nations to become active in space activities. These technologies allow cheaper and faster access to space, even for smaller nations and developing countries. Further, the number of private investors, scientific institutions and universities focusing on this area is continuously growing. Governments may also cooperate with private investors (e.g., in public–private partnerships). In such cases, traditional government contracts are supplemented by new business models. Space 4.0 represents the evolution of the traditionally state-driven space activities into an era of privatization and commercialization of space activities, mirrored by collaboration between governments, the private sector, society and politics. Space 4.0 leads to increasing international cooperation in various fields. ESA Director General Jan-Dietrich Wörner stated, "Sustainable development is an issue that concerns us all, and towards which we can all contribute […] ESA has been fostering sustainable development on Earth for years, and we strongly intend to further support this via our programmes, data and services."[iv] These ongoing commitments are reflected, among others, in the 'Clean Space Initiative' and the launch of its catalogue of 'Activities Supporting the Sustainable Development Goals'.[v] The international State community acknowledged in the context of UNISPACE + 50 and the preparation of the Space 2030 agenda the need to join forces to ensure the long-term sustainable and peaceful use of outer space. During the recent UN/Germany High Level Forum 'The way forward after UNISPACE + 50 and on Space 2030' at the UNSPIDER campus in Bonn, Germany, more than 300 high-level participants gathered to exchange information and to build new partnerships in order to foster sustainable development on Earth and in outer space. The event served as an important platform for providing recommendations addressing sustainable development challenges. Non-space actors received detailed information on how space applications and data can tackle the challenges of climate change and how they contribute to ensuring sustainable life on Earth. This reflects another goal of Space 4.0: to bring space closer to society and to use space for Earth.

## 1.2. Space 4.0 and Industry 4.0

Space 4.0 reflects the concept of Industry 4.0 and has been defined in an analogy to the fourth chapter of the evolution of industrial progress, including services as well as manufacturing.[vi] Industry 4.0 makes use of contemporary automation, manufacturing technologies, big data and the exchanges thereof. A core element of the current era of industrial revolution is innovation. New business concepts and technological advancements such as smart integrated services and digital technologies revolutionized production, and design and management mechanisms are taking the place of traditional value chains. Innovation in the space sector does not exist in isolation from the innovative developments in other fields of society. The space sector, as one industrial sector, is rather closely linked to the pioneering dynamics of Industry 4.0. The space sector has become increasingly relevant for industry and society as it makes use of interconnections with other technology fields and innovative mechanisms for improved spacecraft manufacturing and advanced general-use technologies for space missions. Artificial intelligence and 3D printing are two examples that currently find their use on board the International Space Station (ISS). On 6 June 2018, the Crew Interactive Mobile Companion (CIMON)[vii] – the world's first flying, autonomous astronaut assistant featuring artificial intelligence – was launched together with ESA astronaut Alexander Gerst to the ISS. Not only is a 3D printer installed on the ISS, where it is used for scientific experiment, but ESA has also considered using 3D printing technology[viii] in the frame of the Moon Village.[ix] Space 4.0 as a new concept building on Industry 4.0 is designed to host a new era of space activities, setting out to tackle global challenges using the advantages deriving from space and technological progress. In a reciprocal use, Industry 4.0 benefits strongly from various features of space activities, ranging from system approaches, connectivity, extreme reliability and remote operations in harsh environments. The conceptual analogy and combination of Industry 4.0 and Space 4.0 have clear advantages for numerous industrial sectors, citizens, governments and society. It mutually allows for a trend towards advancements and growing integration of space technologies for the benefit of society.

## 1.3. ESA and Space 4.0i

To elucidate its own role in this new era, the ESA has implemented its own motto of Space 4.0i, identifying its main lines of action based on the mandate given to it by its Member States in its founding instrument, the Convention for the Establishment of a European Space Agency.[x] This leitmotif of Space 4.0i embodies the vision of ESA as *the* space agency for Europe that constantly innovates, inspires, informs and interacts for the benefit of the European citizen, society and economy.

### 1.3.1. Information

The exchange of scientific and technical information in the fields of space research and technology is rooted in Article III of the ESA Convention. The ESA disseminates the value and knowledge generated by space activities, ensuring the availability of data for their use by potential stakeholders and shareholders, such as decision-makers in various sectorial areas and at all levels in States. As a reaction to the development of data regarding 'the gold from Space',[xi] ESA has taken the decision to implement an open access policy for its information and data. While it previously already shared large amounts of space imagery and data with multiple actors in the fields of science, industry, media and the public on digital platforms,[xii] as an outcome of its digital agenda, ESA's free and open data policies are mirrored in its public web pages, providing a wide range of information for the general public,[xiii] specific thematic pages and reports on programmes, information pages for industry, the organization of or participation in conferences or workshops[xiv] and blogs written by, for example, the Director General, Johann-Dietrich Wörner, or ESA astronauts, such as Alexander Gerst.[xv]

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### 1.3.2. Innovation

The Agency's activities are driven by its innovation strategy and by the desire for a seamless grid of innovation. Innovation relates to technology and processes, to spin-off activities (e.g., the Technology Transfer Programme and its network of brokers), spin-in to use on-the-ground innovations and spin-along co-development activities. In addition, new funding schemes are developed in order to extend the implementation of public–private partnerships to foster innovative missions, technologies and services in European industry. Moreover, the ESA uses its long-standing technical and business development expertise to support private activities by setting up an ever-expanding network of ESA Business Incubation Centres all over Europe, which have already supported more than 500 start-ups to turn space-related business concepts into commercial, sustainable and innovation-led start-ups.

### 1.3.3. Interaction

Article II of the ESA Convention already stipulates the provision for and promotion of cooperation among European Member States in space research and technology and their space applications as the central purpose of the ESA's activities.[xvi] The reliability of the ESA as a partner is extensively recognized internationally: the ESA interacts with international partners, third States and international organizations as a promoter or enabler of international projects. A special advantage of the ESA as an international partner is its special nature as an intergovernmental organization and its global position, allowing it to build bridges between partners with diverging political or economic systems. The ESA interacts and cooperates with industry, both the 'traditional' space industry as well as non-space industry. Based on close collaboration with its Member States, the ESA supports the interaction between industry and European academia to further encourage innovation and sustainability in the European space industry – intending to obtain maximum benefits from space activities for the benefit of European citizens. The interaction with academia also aims to foster a skilled and trained workforce, contributing to the European knowledge base and its global competitiveness. The ESA's Citizens' Debate on Space for Europe is a prime example of its interaction with the general public. The first Citizens' Debate was organized in the run-up to the last Ministerial Council in order to collect the ideas and opinions of European citizens from different backgrounds to help in the creation of the future European space strategy. The day-long event in September 2016 attracted 2000 persons from 22 States.[xvii] The results of this direct interaction with European citizens were immediately fed into the ESA's strategic debate.

### 1.3.4. Inspiration

Space has an extremely high potential for inspiration. The ESA's fourth 'i' refers to this phenomenon. The sky has fascinated humanity for generations. Artist, poets, navigators and explorers were inspired by what they saw far above them. Starting with the era of Space 1.0, astronomers started to use telescopes to explore the movement of celestial bodies. As a result, space activities have motivated generations of young people and adults to deepen their knowledge of this field and to pursue careers in the space or the STEM sector in general. However, beyond this direct and obvious effect, the ESA aspires to inspire more challenging endeavours that are conceived for the long term, such as the Rosetta mission, the development of which started in the early 1990s and the trajectory of which had to be modified to accommodate a different target comet than originally foreseen. The Rosetta performed an amazing number of manoeuvres during its ten-year journey to finally arrive in the orbit of comet 67P/Churyumov–Gerasimenko and put a lander on its surface. This is one of the most beautiful representations of the audacity, tenacity and resilience required, as well as the satisfaction of finally reaching a goal after intense effort. The inspiration these missions spark is not limited to space endeavours alone, but can spill over into any discipline.

## 2. Space 4.0 and the law

Space activities allow significant improvement to the standard of living of humankind. Earth observation satellites provide data that are relevant, for example, in the fields of environmental protection, disaster management, forestation and agriculture. Earth observation enables the international community to monitor the challenges of climate change. Outer space activities are significantly contributing to sustaining life on Earth, and the international community is eager to ensure a long-term sustainable use of outer space. In the Horizons mission, the first German commander of the ISS, Alexander Gerst, conducted numerous experiments the results of which are contributing to the following UN Sustainable Development Goals: SDG 3: Good Health and Well-Being; SDG 4: Quality Education; SDG 7: Affordable and Clean Energy; SDG 8: Decent Work and Economic Growth; SDG 9: Industry, Innovation and Infrastructure; and SDG 13: Climate Action.

The atmosphere surrounding our home planet plays a decisive role in human well-being, and outer space in that sense is not far away. Having said that, it is important, however, to highlight the difference in the legal status of airspace and outer space: as Hobe emphasised, "[…] the regulation of the airspace[xviii] cannot be compared to outer space legislation because airspace is subject to the sovereignty and jurisdiction of a subjacent State, the others, i.e. the Deep Seabed, High Seas and Antarctica, like outer space, are also common areas."[xix] At this point, it is worth noting that neither airspace nor outer space is defined in the relevant treaties.[xx] The delimitation of outer space from airspace has been debated since the 1950s and still figures as a permanent Agenda Item on the agenda of the Legal Subcommittee of the United Nations (UN) Committee on the Peaceful Uses of Outer Space (UNCOPUOS) in 2019.

The existing legal framework governing outer space activities has nevertheless been successfully ensuring the peaceful use of space for current and future generations for decades. The corpus of law is the result of years and decades of negotiations of the international community, in which the world has seen the emergence of new rules and the codification of fundamental legal principles regulating the peaceful exploration and use of outer space for all humankind. On an international level, a range of multilateral treaties was concluded within the UN, UN General Assembly Resolutions were negotiated and numerous bilateral arrangements and guidelines by international organizations elaborated. The *corpus iuris spatialis* has developed as an increasingly relevant segregated corpus of law within general public international law.

### 2.1. General overview of the public international law governing the exploration and use of outer space

The main five multilateral treaties – drafted and concluded in the 'Cold War' era[xxi] – within the UNCOPUOS[xxii] are:

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- 1967 Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and other Celestial Bodies [*Outer Space Treaty*, or OST][xxiii];
- 1968 Agreement on the Rescue of Astronauts, the Return of Astronauts and the Return of Objects Launched into Outer Space [*Rescue and Return Agreement*][xxiv];
- 1972 Convention on International Liability for Damage Caused by Space Objects [*Liability Convention*][xxv];
- 1975 Convention on Registration of Objects Launched into Outer Space [Registration Convention][xxvi]; and
- 1979 Agreement Governing the Activities of States on the Moon and other Celestial Bodies [*Moon Agreement*].[xxvii]

The OST is the *magna carta* of outer space activities and sets out the general legal principle applicable to space activities, which are further deepened in the subsequent four multilateral treaties. These activities include: the non-appropriation of outer space by any one State; the freedom of the use and exploration of outer space; a liability regime applicable in the case of damage caused by space objects; the safety and rescue of space objects and astronauts; the notification and registration of space activities with the UN; the scientific investigation and exploitation of the natural resources of outer space; and the settlement of disputes arising from outer space activities.

In addition to the above-mentioned treaties, the UN General Assembly adopted five sets of principles applicable to the exploration and use of outer space:

- 1963 Declaration of Legal Principles Governing the Activities of States in the Exploration and Use of Outer Space[xxviii];
- 1982 Principles Governing the Use by States of Artificial Earth Satellites for International Direct Television Broadcasting[xxix];
- 1986 Principles Relating to Remote Sensing of the Earth from Outer Space[xxx];
- 1992 Principles Relevant to the Use of Nuclear Power Sources in Outer Space[xxxi]; and
- 1996 Declaration on International Cooperation in the Exploration and Use of Outer Space for the Benefit and in the Interest of All States, Taking into Particular Account the Needs of Developing Countries.[xxxii]

However, it is worth noting that Resolutions of the General Assembly are considered ‘soft law’ and as such have a non-legally binding character in the sense of Article 38(1) of the Statute of the International Court of Justice.[xxxiii] Nevertheless, some of the provisions may have reached customary law status.[xxxiv] This must be proven on a case-by-case basis.

## 2.2. Legal challenges in the era of Space 4.0: considerations on sustainability

The developments of Space 4.0 as described above reflect the changes in the space community. As the world continues to face a growing need for dedicated space applications, with challenges ranging from climate change to shortages of resources, health, demographic development, the digital divide and more, revolutionary space applications – such as small satellites and mega-constellations – bring space closer to society and inspire new generations. However, these new tools also comprise legal uncertainties and challenges. One reason for this is that these developments are taking place in a highly complex environment of legal, regulatory and political considerations, which are themselves raising challenges.

### 2.2.1. Starting from treaty law

Space activities enable humankind to reach further and to use the benefits of space applications and data for their lives on Earth. Nevertheless, it is a reality that the exploration and use of outer space by their nature involve elements that can be inherently threatening to the environment on Earth and in outer space.

Due to the increasing relevance of space activities for society and industry and the growing number of space actors and missions, the sustainability of these activities and also their environmental impacts have begun to be addressed. Since the *corpus iuris spatialis* depicted above was developed as a result of negotiations beginning in the Cold War era of Space 2.0, they do not provide a comprehensive legal framework for the sustainable and environmentally protective exploration and use of outer space and in particular not with a view to the currently exploding numbers of satellites and actors. The traditional legal framework for outer space activities does not contain specific environmental standards, as it was developed well ahead of the codification of environmental law. Rather, environmental protection was considered – if thought was given at all – as a hindrance to the emerging space activities at that time.[xxxv]

Nevertheless, the traditional space law instruments have laid down a starting point: *sedes materiae* in the OST concerning the protection of the environment is Article IX,[xxxvi] and more specifically its second sentence, which stipulates primarily back and forward contamination as it includes the obligation to conduct exploration of outer space, including the moon and other celestial bodies “so as to avoid their harmful contamination and also adverse changes in the environment of the Earth resulting from the introduction of extraterrestrial matter […].” It is interesting to note in this context that only in the case of a State Party having reason to believe that an activity or experiment planned by it or its nationals would cause potential harmful interference with activities of other States Parties should the State Party concerned shall undertake appropriate international consultation before proceeding with any such activity or experiment. This is not foreseen for the ‘mere’ harmful contamination of the outer space environment or the adverse changes in the environment of the Earth. The environmental integrity of outer space as such is not at the heart of this provision.

The same Earth-centric perspective can be found in the Liability Convention, which establishes a system of absolute liability (Article II) to be applied in case of damage caused by a space object on the surface of the Earth or to aircraft in flight, and of fault-based liability (Article III) if the damage is caused elsewhere than on the surface of the Earth to a space object or to persons or property on board such a space object of another launching State. Article I(a) defines damage as meaning “loss of life, personal injury or other impairment of health; or loss of or damage to property of States or of persons, natural or juridical, or property of international intergovernmental organisations.” This can also comprise environmental damage. However, the Liability Convention does not address any kind of environmental damage outside the surface of the Earth.

Other norms of the UN space treaties – such as Article 7 of the Moon Agreement – refer to the environmental considerations related to the exploitation of natural resources in outer space, the so-called *in situ* resource utilization, which is a promising subject in Space 4.0 in relation to additive manufacturing (i.e., 3D

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printing). Since the Moon Agreement was negotiated at a time when environmental considerations had become a global concern, it elaborates more on the principles regarding the protection of the outer space environment. There is another novelty with regard to the principles of international environmental law and space law to be found in the Moon Agreement: the concept of intergenerational equity makes its first outer space-specific appearance only in Article 7.1 of the Moon Agreement, even though reflections on the concept can historically be found in a number of different cultural circles all around the globe.[xxxvii] It is, however, worth noting that the Moon Agreement so far has only gathered 18 State Parties – compared to 107 State Parties for the OST, among which all major space-faring nations can be found.[xxxviii]

#### 2.2.2. Taking on broader perspectives in international environmental law

Article III of the OST reaffirms that States Parties to the Treaty shall carry on activities in the exploration and use of outer space in accordance with international law – which, of course, includes international environmental law. The first significant legal statement of fundamental international principles for the protection of the environment[xxxix] is embodied by the 1972 Stockholm Declaration.[xl] According to Principle 21 of the Stockholm Declaration, States have, in accordance with the Charter of the UN and the principles of international law, "[…] the responsibility to ensure that activities within their jurisdiction or control do not cause damage to the environment of other States or of areas beyond the limits of national jurisdiction." Since outer space is one of the areas beyond the limits of national jurisdiction, it is directly protected by this principle. The UN General Assembly Resolution 2996 (XXVII) 1972 asserts that Principle 21 (and 22) of the Stockholm Declaration "lay down the basic rules governing the matter." The principle is further repeated by Principle 2 of the Declaration of the UN Conference on Environment and Development, adopted in Rio de Janeiro in 1992, and Article 3 of the 1992 Convention on Biological Diversity. This maxim was further affirmed by the International Court of Justice (ICJ) in its Advisory Opinion on the *Legality of the Threat or Use of Nuclear Weapons*[xli]:

> […] the existence of the general obligation of States to ensure that activities within their jurisdiction and control respect the environment of other states or of areas beyond national control is now part of the corpus of international law relating to the environment.

The precautionary principle is further developed by Principle 15 of the Rio Declaration:

> To protect the environment, the precautionary approach shall be widely applied by States according to their capabilities. 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 environmental degradation. Accordingly, if there is sufficient scientific evidence to establish the possibility of a risk of serious harm, States cannot justify their lack of action with the absence of a proof of harm.

Given the current lack of readiness of States to commit to internationally binding hard law, internationally agreed standards are increasingly important instruments for the international community to provide legal guidance in the further development and implementation of the applicable law, including the law applicable to space activities. Two examples are the COSPAR Planetary Protection Policy[xlii] and the UN Space Debris Mitigation Guidelines.[xliii] The latter will be elaborated upon in more detail in the following subsections.

#### 2.2.3. Soft law: guidelines, principles and policies

In addition to the Treaty provisions, the international State community developed sets of principles that are particularly directed towards specific environmental concerns – such as the use of nuclear power sources in outer space[xliv] and space debris.[xlv] These principles have soft law character and are as such not legally binding upon the international community. However, they might have politically binding character and provide guidance in the interpretation of the existing obligations of States: since Article IX of the OST obliges State Parties to conduct their activities in outer space with due regard to the interests of other States and the protection of the global environment, States are further obliged to take appropriate measures to prevent, minimize and control the potential environmental harm resulting from their activities in outer space. Due diligence as a central element requires States to conduct close monitoring and the transposition of new scientific and technological findings promptly into rules and policies to ensure the compliance with the international legal standards.

#### 2.2.4. The example of space debris

In more than 60 years of space activities and more than 8593 launches since 1957,[xlvi] the number of pieces of tracked space debris exceeding the size of 10 cm is estimated to be greater than 22,000. Each year, the amount of space debris capable of endangering life on Earth and beyond (e.g., the lives of astronauts on board the ISS[xlvii]) and with the ability to threaten operating space objects increases. New space actors, mainly private entities such as OneWeb and SpaceX, aim to launch hundreds and thousands of small satellites into outer space to install mega-constellations that can connect large parts of the globe to the internet. Consequently, these kinds of business models are further contributing to the growing number of space objects in the already crowded low Earth orbit (LEO), providing the issue of space debris with a whole new dimension both from a technical and from a legal perspective. This situation severely endangers the long-term sustainability of space activities. Around 42,000 objects are currently being tracked in orbit. Some 23,000 of these objects remain in space and are regularly tracked by the US Space Surveillance Network.[xlviii] Objects larger than about 5–10 cm within the LEO and 30 cm–1 m in geostationary orbit are maintained in a catalogue. Only around 1200 of these objects are operational satellites. In general, 24% of the tracked objects are satellites and 18% are upper stages. Since 1961, 290 in-orbit fragmentations have led to an increase in the amount of space debris. The majority was caused by explosions of spacecraft and upper stages.[xlix] The installation of large and mega-constellations of small satellites and the growing amount of space debris has led to the danger of cascade effects, known as *Kessler syndrome*[l] – which further underlines the immense risk resulting from debris, ultimately resulting in a debris belt in LEO. In February 2009, the Kosmos–Iridium accident took place. It was the first collision of two intact satellites – the Russian communications satellite Kosmos 2251 and the American commercial satellite Iridium 33 –resulting in approximately 700 additional pieces of ultra-hazardous debris being created, with the potential to cause additional decades-long pollution in space.[li] With the proliferation in actors and the exponential rise in small satellites and mega-

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constellations, there is a fear that the quantity of space debris will explode.

*2.2.4.1. The Inter-Agency Space Debris Coordination Committee Space Debris Mitigation Guidelines.* In 1993, as a consequence of environmental concerns, the international community decided to establish among interested space agencies the Inter-Agency Space Debris Coordination Committee (IADC) – an international governmental forum for the worldwide coordination of activities related to the issues of human-made and natural space debris. "The primary purpose of the IADC is to exchange information on space debris research activities between member space agencies, to facilitate opportunities for cooperation in space debris research, to review the progress of ongoing cooperative activities and to identify debris mitigation options."[lii] The IADC formulated the IADC Space Debris Mitigation Guidelines[liii] and formally adopted them by consensus in October 2002 during the Second World Space Congress in Houston, Texas. Section 2 of the IADC Guidelines[liv] describes existing practices that have been identified and evaluated for limiting the generation of space debris in the environment. The Guidelines cover the overall environmental impact of the missions with a focus on the limitation of debris released during normal operations, the minimization of the potential for in-orbit breakups, post-mission disposal and the prevention of in-orbit collisions. The IADC presented its guidelines to the UNCOPUOS Scientific and Technical Subcommittee (STSC).

*2.2.4.2. The evolution of the Space Debris Mitigation Guidelines through the UN system.* The IADC Guidelines served as basis for the development of the UN Space Debris Mitigation Guidelines. In 2007, the UN General Assembly endorsed the Space Debris Mitigation Guidelines as adopted by the UNCOPUOS STSC. The UN General Assembly agreed in its Resolution 62/217 that the voluntary guidelines for space debris mitigation reflected existing practices developed by numerous national and international organizations. Space debris and their cascading effects are some of the greatest challenges for the long-term sustainability of space activities. Nonetheless, the existing international texts serve as 'soft law' at best. Member States are invited to implement those guidelines through their relevant national mechanisms. By doing so, policy-makers might ultimately contribute to the formation of a due diligence standard, if international practice is representative.

The Resolution recognizes two broad categories of space debris mitigation measures: short-term measures (the limitation of the production of mission-related space debris and the avoidance of breakups) and long-term measures (end-of-life procedures that remove decommissioned spacecraft and launch vehicle orbital stages from regions populated by operational spacecraft).

The seven guidelines[lv] remain at a general level and encourage actions that would:

1. Limit debris released during normal operations;
2. Minimize the potential for breakups during operational phases;
3. Limit the probability of accidental collision in orbit;
4. Avoid intentional destruction and other harmful activities;
5. Minimize potential for post-mission breakups resulting from stored energy;
6. Limit the long-term presence of spacecraft and launch vehicle orbital stages in the LEO region after the end of their mission;
7. Limit the long-term interference of spacecraft and launch vehicle orbital stages with the geosynchronous region after the end of their mission.

The IADC is an open association of technical entities of rather homogenous space-faring nations contrary to the UN, which incorporates the representatives of both space-faring and non-space-faring States and so involving various opinions and partially diverging interests.[lvi] The UN Guidelines make clear reference to the IADC Guidelines[lvii] and invite the Member States and international organizations in chapter 6 of its Guidelines to refer to the latest IADC guideline version "[…] for more in-depth descriptions and recommendations pertaining to space debris mitigation measures."[lviii]

The Report of the UNCOPUOS Legal Subcommittee from its 57th session[lix] presents its proposal for the agenda items for the upcoming 58th session in 2019, indicating the "General exchange of information and views on legal mechanisms relating to space debris mitigation and remediation measures, taking into account the work of the Scientific and Technical Subcommittee" as a dedicated item for discussion within the Subcommittee. This clearly reflects the relevance of the space debris subject and the need to urgently clarify some uncertainties – such as the framework conditions for active debris removal (ADR). Even though these efforts had only limited success and Member States remained cautious regarding adopting new and even binding legal norms, the latest session report addressed very important questions as regards the matter of space debris mitigation.[lx] Recently, the Legal Subcommittee delegates expressed *inter alia* the need to adapt the existing guidelines to the latest scientific and technical findings, to create legal certainty by defining the terms – such as 'space object' and 'space debris'[lxi] – and the need to establish an international fund for the removal of space debris in order to support coordinated efforts on space debris removal by providing means to address the technological and financial aspects of such operations. The financial participation of States in the fund should depend on the role of those States in the creation of space debris.[lxii]

*2.2.4.3. The implementation of the Space Debris Mitigation Guidelines.* States and space agencies implement the guidelines into their national laws and regulations, aware of the fact that such implementation serves their own interests in keeping the relevant orbits accessible and useable. Some States are using the space debris mitigation guidelines, the European Code of Conduct for Space Debris Mitigation, International Organization for Standardization standard 24113:2011 (Space systems: space debris mitigation requirements) and International Telecommunication Union (ITU) recommendation ITU-R S.1003 ('Environmental protection of the geostationary-satellite orbit') as references in their regulatory frameworks for national space activities.[lxiii]

The USA as a traditional major space-faring nation has an extensive set of rules regulating space debris mitigation – the basis of which are the US Government Orbital Debris Mitigation Standard Practices – as adopted in 2001.[lxiv] Those Guidelines served as one of the primary sources for the development of the IADC Space Debris Mitigation Guidelines and the later Space Debris Mitigation Guidelines of the Committee. As a founding member of the IADC, NASA has played a leading role in discussions of space debris mitigation in the IADC and in the UNCOPUOS STSC. The NASA STD 8719.14 'Process for Limiting Orbital Debris' and NASA-NPR-8715.6A 'Procedural Requirements

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for Limiting Orbital Debris' also represent informative references for other States.

Two European examples are Germany and France.[lxv] In 2012, Germany issued the 'Product Assurance and Safety Requirements for DLR Space Projects', which include mandatory space debris mitigation requirements for all phases of space missions of the DLR Space Administration. The DLR requirements are consistent with numerous international standards, to which development Germany has also contributed. The French national mechanism for space debris mitigation is the mandatory Decree on Technical Regulation issued pursuant to Act no. 2008-518 of 3 June 2008, adopted on 31 March 2011. It contains all of the technical requirements for any operator and is composed of dedicated sections for launch systems and orbital systems. France has also contributed to the development of international space debris mitigation standards. The French Technical Regulation is consistent with these guidelines, as well as with the ISO 24113 standard. In the context of space debris, active removal technologies are being considered as one key technology for the future. ADR aims to reduce the number of large and massive (mostly physically intact) objects. Reducing the overall number of intact objects in space is not at all feasible considering the growing dependence of society on space activities and new trends, such as the installation of large and mega-constellations, providing *inter alia* telecommunication services in remote areas. Therefore, it is more important than ever before to strongly comply with post-mission mitigation measures[lxvi] in order to maintain the number of intact objects and at the same time to deal with more objects in addition to those already in space. Studies show that with a removal sequence planned according to a target selection based on mass, area or cumulative collision risk, the environment can be stabilized when approximately five to ten objects are removed from LEO per year.

## 3. Conclusion

The developments and innovations related to the new space era – Space 4.0 – have led to an ever-increasing number of space actors, shifting from a traditionally governmental to an increasingly commercialized industry. The range of potential space applications is expanding, and the international community has become more and more dependent on space activities. Space helps to improve the lives of people around the globe and helps us to face the challenges of our time. Space imagery and data enable experts to develop strategies to fight climate change and to reduce the damage resulting from environmental catastrophes.

The space debris problematic clearly shows that space activities, if conducted without the relevant legal and environmental considerations, can lead to huge danger for humankind and the environment and shows us that the international community needs to work on a more agile and extensive legal regime ensuring and contributing to sustainability on Earth and in space.

The existing body of international space law touches upon environmental protection, but does not provide a comprehensive legal framework for the protection of outer space, nor does it contain any strict environmental guidelines and principles regarding the way space activities are conducted. General obligations relating to the environmental aspects of the exploration and use of outer space that are found in the UN Treaties or Principles need to adapt to recent scientific, technological and industrial developments. Article III of the OST emphasizes that "international law" applies to "activities in the exploration and use of outer space." Nonetheless, some issues remain unresolved. One of them is the increasing privatization of outer space activities. State Parties to the OST are bound by its obligations and have to continuously supervise and control their activities, irrespective of whether they are conducted by the government or private actors. However, private actors are not per se bound by the UN Space Treaties.[lxvii] They are subject to case-by-case variable local laws and the provisions negotiated in commercial launch service contracts.

In addition, it is not clear whether international law can be applied to the unique characteristics of activities conducted in the extraterrestrial environment. Principle 21 of the 1972 Stockholm Declaration and Principle 2 of the 1992 Rio Declaration on Environment and Development[lxviii] refer to "areas beyond the limits of national jurisdiction," which can be considered to include outer space.

The regulation of future outer space activities necessitates cooperation among international partners and common approaches and commitments. Non-legally binding soft law instruments will play a central role in creating legal certainty and filling in the 'gaps' in the *corpus iuris spatialis*. The UNCOPOUS Legal Subcommittee recently underlined the effectiveness of soft law instruments regulating the issue of space debris and ADR activities.[lxix] Since the first mentioning of sustainable development in the 1987 Brundtland Report, environmental considerations have become more and more important, and not only for the space industry. The codification of new emerging principles dealing with environmental considerations is to be expected to expand upon the fundamental regulations already existing in the UN Space Treaties. The recent consent within the UNCOPUOS Legal Subcommittee over 21 long-term sustainability guidelines[lxx] paved the way for their implementation into national law. This represents a decisive step towards ensuring the sustainability of current and future space missions and a major contribution to UNISPACE + 50 Thematic Priority 3, 'Enhanced information exchange on space objects and events'. Moreover, the success of the UN/Germany High Level Forum in Bonn, Germany, in November 2018 reflects the increasing awareness and interest of the international community in the matter of sustainable development.

The exploration and use of outer space for all humankind have to reflect the notions of cooperation and benefit – which are already laid down in the OST, the *Magna Carta* of space activities.

## Notes

[i] https://www.esa.int/About_Us/Ministerial_Council_2016/What_is_space_4.0 (accessed 10 June 2018).

[ii] Isabelle Duvaux-Béchon and Ulrike M. Bohlmann, *Space 4.0 – A Guiding Vision for ESA*, p. 1.

[iii] See: Ulrike M. Bohlmann and Moritz Bürger, 'NewSpace – Putting an end to national prestige and accountability?' *Proceedings of the 61st Colloquium on the Law of Outer Space*, September 2018, publication upcoming.

[iv] ESA. A toolbox for sustainability. https://www.esa.int/Our_Activities/Preparing_for_the_Future/Space_for_Earth/Space_for_Sustainable_Development/A_toolbox_for_sustainability (last accessed 2 December 2018).

[v] ESA. ESA and the sustainable development goals. http://m.esa.int/Our_Activities/Preparing_for_the_Future/Space_for_Earth/ESA_and_the_Sustainable_Development_Goals (last accessed 2 December 2018).

[vi] See: Klaus Schwab, *The Fourth Industrial Revolution*, Penguin, 2017.

[vii] https://www.dlr.de/dlr/en/desktopdefault.aspx/tabid-10306/469_read-26307/year-all//usetemplate-print/ (last accessed 10 June 2018).

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[viii] http://www.esa.int/Our_Activities/Space_Engineering_Technology/TTP2/3D_Printing_our_future_in_space_and_on_Earth (last accessed 10 June 2018).
[ix] http://blogs.esa.int/janwoerner/2016/11/23/moon-village/ (last accessed 10 June 2018).
[x] See Article II of the ESA Convention, opened for signature on 30 May 1975 and entered into force on 30 October 1980, https://www.esa.int/About_Us/Law_at_ESA/ESA_Convention (last accessed 10 June 2018).
[xi] Margarita Chrysaki, Space: Still an important Matter of National Prestige? http://www.europeanbusinessreview.eu/page.asp?pid=1820 (last accessed 10 June 2018).
[xii] For an overview of the historical evolution of ESA's Earth Observation policies, see: Ulrike M. Bohlmann and Alexander Soucek, 'From "Shutter Control" to "Big Data": Trends in the legal treatment of Earth observation data'. In: Christian Brünner *et al.* (eds.), *Satellite-Based Earth Observation*. Cham: Springer, 2018, pp. 185–196.
[xiii] www.esa.int (last accessed 10 June 2018).
[xiv] https://earth.esa.int/web/guest/events/all-events (last accessed 10 June 2018).
[xv] http://blogs.esa.int/. See also: http://blogs.esa.int/janwoerner/ (last accessed 10 June 2018).
[xvi] See Article II of the ESA Convention.
[xvii] For results, see: https://esamultimedia.esa.int/docs/corporate/ESA-2_EN_BAG_30-11-3.pdf (last accessed 10 June 2018).
[xviii] Stephan Hobe, 'Luftraum und Lufthoheit'. In: Stephan Hobe and Nicolai von Ruckteschell (eds.), *Kompendium des Luftrechts Volume I*. Cologne: Carl Heymanns, 2008, pp. 255–277.
[xiv] For a detailed discussion of this provision, see, for example: Stephan Hobe, 'Article I', and Michael Gerhard, 'Article VI', in Stephan Hobe, Bernhard Schmidt-Tedd and Kai-Uwe Schrogl (eds.), *Cologne Commentary on Space Law, Volume I – Outer Space Treaty*. Cologne: Heymanns Verlag GmbH, 2009, pp. 27–28; 107.
[xx] A theoretical proposal by Theodore von Kármán defines the border between airspace and outer space at an altitude of 100 km. The Kármán line, however, is widely debated.
[xxi] In that period, only a small number of countries had space-faring capability.
[xxii] UNCOPUOS was established by the United Nations General Assembly in 1959, shortly after the launch of Sputnik 1: see United Nations General Assembly Resolution 1472 (XIV) on International co-operation in the peaceful uses of outer space (1959). It currently has 70 Members, which, according to UNCOPUOS, means that it is "one of the largest Committees in the United Nations." http://www.unoosa.org/oosa/en/members/index.html (last accessed 10 June 2018).
[xxiii] 610 U.N.T.S. 205 (Outer Space Treaty).
[xxiv] 672 U.N.T.S. 119 (Rescue Agreement).
[xxv] 961 U.N.T.S. 187 (Liability Convention).
[xxvi] 1023 U.N.T.S. 15 (Registration Agreement)
[xxvii] 1363 U.N.T.S 3 (Moon Agreement).
[xxviii] United Nations General Assembly Resolution 1962 (XVIII) on the Declaration of Legal Principles Governing the Activities of States in the Exploration and Uses of Outer Space.
[xxix] United Nations General Assembly Resolution 37/92 on the Principles Governing the Use by States of Artificial Earth Satellites for International Direct Television Broadcasting.
[xxx] United Nations General Assembly Resolution 41/65 on the Principles relating to Remote Sensing of the Earth from Outer Space.
[xxxi] United Nations General Assembly Resolution 47/68 on the Principles relevant to the Use of Nuclear Power Sources in Outer Space (Nuclear Power Source Principles).
[xxxii] United Nations General Assembly Resolution 51/122 on the Declaration on International Cooperation in the Exploration and Use of Outer Space for the Benefit and in the Interest of All States, Taking into Particular Account the Needs of Developing Countries.
[xxxiii] See, for example, D.J. Harris, *Cases and Materials on International Law* (6th edn,, 2004), 57–61 and the references referred to therein. See also: 1 U.N.T.S. 16 (ICJ Statute) http://www.icj-cij.org/en/statute (last accessed 10 June 2018). Following the opinion of international law scholars, Article 38 (1) of the ICJ Statute lists the sources of international law, see: Antonio Cassese, *International Law* (2nd edn,, 2005), 156.
[xxxiv] See, for example, Ricky J. Lee and Steven Freeland, 'The crystallisation of general assembly space declarations into customary international law', (2004) 46 *Proceedings of the Colloquium on the Law of Outer Space* 122.
[xxxv] L.I. Tennen, 'Evolution of the planetary protection policy: conflict of science and jurisprudence?' (2004) 24 *Advances in Space Research* 2354.
[xxxvi] For a detailed discussion of this provision, see Sergio Marchisio, 'Article IX', in Stephan Hobe, Bernhard Schmidt-Tedd and Kai-Uwe Schrogl (eds.), *Cologne Commentary on Space Law, Volume I – Outer Space Treaty*. Cologne: Carl Heymanns, 2009, 169–182.
[xxxvii] See Edith Brown Weiss, 'Intergenerational equity: a legal framework for global environmental change'. In: Edith Brown Weiss (ed.), *Environmental Change and International Law: New Challenges and Dimensions*. Tokyo, United Nations University, 1992, who identifies mainly three different approaches to defining intergenerational equity:

- The preservationist one, where the present generation does not destroy or deplete resources or significantly alter anything, preserving the same level of quality in all aspects of the environment;
- The Calvinist or Stalinist one, where today is sacrificed for the future;
- The approach of opulence, where the present generation consumes all that it wants today and generates as much wealth as it can, either because there is no certainty that future generations will indeed exist or because maximal consumption is understood to lead economically to maximal wealth for future generations.

[xxxviii] Status of international agreements relating to activities in outer space as at 1 January 2018, UN- A/AC.105/C.2/2018/CRP.3, available at: http://www.unoosa.org/documents/pdf/spacelaw/treatystatus/AC105_C2_2018_CRP03E.pdf (last accessed 11 June 2018).
[xxxix] Rymn James Parsons, 'The fight to save the planet: U.S. armed forces, "greenkeeping," and enforcement of the law pertaining to environmental protection during armed conflict' (1998) 10 *Georgetown International Environmental Law Review* 441, 455.
[xl] Declaration of the United Nations Conference on the Human Environment (16 June 1972) UN Doc A/CONF.48/14/Rev.1 (1972 Stockholm Declaration).
[xli] [1996] ICJ Rep. 226, para. 29.
[xlii] The current version of the COSPAR Planetary Protection Policy, 20 October 2002, amended up December 2017, available at https://cosparhq.cnes.fr/sites/default/files/pppolicydecember_2017.pdf (last accessed 10 June 2018).
[xliii] Adopted by the Scientific and Technical Subcommittee of UNCOPUOS at its 44th session in 2007, A/AC.105/890, para. 99, and endorsed by the United Nations General Assembly in Resolution 62/217 on international cooperation in the peaceful uses of outer space; http://www.unoosa.org/documents/pdf/spacelaw/sd/COPUOS-GuidelinesE.pdf (last accessed 10 June 2018).
[xliv] See 1992 Nuclear Power Source Principles and United Nations Committee on the Peaceful Uses of Outer Space (UNCOPUOS) Scientific and Technical Sub-Committee and International Atomic Energy Agency (AIEA), Safety Framework for Nuclear Power Source Applications in Outer Space (2009), http://www.fas.org/nuke/space/iaea-space.pdf (last accessed 10 June 2018).
[xlv] See, for example, the 2007 United Nations General Assembly Resolution 62/217 on international cooperation in the peaceful uses of outer space, which (at para. 26) endorsed The Space Debris Mitigation Guidelines of the United Nations Committee on the Peaceful Uses of Outer Space (A/62/20) (at para. 27) and agreed that "the voluntary guidelines for the mitigation of space debris reflect the existing practices as developed by a number of national and international organizations," and (at para. 28) considered it "essential that Member States pay more attention to the problem of collisions of space objects, including those with nuclear power sources, with space debris, and other aspects of space debris." See also United Nations General Assembly Resolution 65/97 (10 December 2010), para. 8.
[xlvi] Spacecraft-Index. http://claudelafleur.qc.ca/Spacecrafts-index.html#q (last accessed 24 February 2018).

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[xlvii] On 12 March 2009, the three astronauts aboard the ISS – Americans Mike Fincke and Sandra Magnus and Russian Yuri Lonchakov – were forced to evacuate the main station and remain in the ISS escape vehicle for nine minutes while a piece of debris about 1 cm in length passed by. An impact would have possibly resulted in a fatal loss of air pressure. See, for example, Maggie McKee, 'Debris threat prompts space station crew to evacuate'. *New Scientist*, http://www.newscientist.com/article/dn16755-debris-threat-prompts-space-station-crew-to-evacuate.html (last accessed 10 June 2018).
[xlviii] https://www.nasa.gov/mission_pages/station/news/orbital_debris.html (last accessed 10 June 2018).
[xlix] http://www.esa.int/Our_Activities/Operations/Space_Debris (last accessed 10 June 2018).
[l] Donald J. Kessler, 'Collisional cascading: the limits of population growth in low Earth orbit' (1991) 11 *Advanced Space Research*, 63–66.
[li] NASA Orbital Debris Quarterly News, Vol. 13, issue 2, April 2009, pp. 1–2, https://orbitaldebris.jsc.nasa.gov/quarterly-news/pdfs/odqnv13i2.pdf (last accessed 1 November 2011); http://news.bbc.co.uk/2/hi/science/nature/7885051.stm (last accessed 1 November 2011).
[lii] http://www.iadc-online.org/index.cgi?item=torp (last accessed 10 June 2018).
[liii] Available in their current version, revision 1 of September 2007, http://www.iadc-online.org/index.cgi?item=docs_pub (last accessed 10 June 2018).
[liv] Section 1 of the guidelines; see also Nicholas L. Johnson, 'Developments in space debris mitigation policy and practices' (2007) 221:6 *Journal of Aerospace Engineering* 907–909.
[lv] The document is accessible at: http://www.unoosa.org/pdf/publications/st_space_49E.pdf (last accessed 10 June 2018).
[lvi] http://www.unoosa.org/pdf/publications/st_space_49E.pdf.
[lvii] As contained in the annex to UN document A/AC.105/ C.1/L.260.
[lviii] Chapter 6 of the Space Debris Mitigation Guidelines of the Committee on the Peaceful Uses of Outer Space.
[lix] Report of the Legal Subcommittee on its fifty-sixth session, held in Vienna from 09 to 20 April 2018, A/AC.105/1177. Agenda items for the 58th session can be found on p. 34 of the report.
[lx] The attempt in the April 2018 session to give the debate a clear legal impetus was also in the 'General exchange of information and views on legal mechanisms relating to space debris mitigation and remediation measures, taking into account the work of the Scientific and Technical Subcommittee' in the UN GA Draft Report A/AC.105/C.2/L.304/Add.4, available at: http://www.unoosa.org/oosa/oosadoc/data/documents/2018/aac.105c.2l/aac.105c.2l.304add.4_0.html (last accessed 11 June 2018).
[lxi] 'General exchange of information and views on legal mechanisms relating to space debris mitigation and remediation measures, taking into account the work of the Scientific and Technical Subcommittee' in the UN GA Draft Report A/AC.105/C.2/L.304/Add.4, para. 49.
[lxii] 'General exchange of information and views on legal mechanisms relating to space debris mitigation and remediation measures, taking into account the work of the Scientific and Technical Subcommittee' in the UN GA Draft Report A/AC.105/C.2/L.304/Add.4, para. 60.
[lxiii] 'General exchange of information and views on legal mechanisms relating to space debris mitigation and remediation measures, taking into account the work of the Scientific and Technical Subcommittee' in the UN GA Draft Report A/AC.105/C.2/L.304/Add.4, para. 32.
[lxiv] The US Government Orbital Debris Mitigation Standard Practices encompass all programme phases and serve as overall technical guidance and as the foundation for specific orbital debris requirements by individual government departments and agencies. For detailed information, see: COPUOS Compendium – Space Debris Mitigation Standards adopted by States and international organisations (26 January 2018), pp. 48–55, available at: http://www.unoosa.org/documents/pdf/spacelaw/sd/Space_Debris_Compendium_COPUOS_26-Jan-2018.pdf (last accessed 10 June 2018).
[lxv] For detailed information, see: COPUOS Compendium – Space Debris Mitigation Standards adopted by States and international organisations (26 January 2018), pp. 23–25 and 26–28, available at: http://www.unoosa.org/documents/pdf/spacelaw/sd/Space_Debris_Compendium_COPUOS_26-Jan-2018.pdf (last accessed 10 June 2018).
[lxvi] Particularly orbital decay in less than 25 years.
[lxvii] Article VI of the OST does, however, provide that: "States Parties to the Treaty shall bear international responsibility for national activities in outer space, including the Moon and other celestial bodies, whether such activities are carried on by governmental agencies or by non-governmental entities, and for assuring that national activities are carried out in conformity with the provisions set forth in the present Treaty. The activities of non-governmental entities in outer space, including the Moon and other celestial bodies, shall require authorization and continuing supervision by the appropriate State Party to the Treaty."
[lxviii] Declaration of the United Nations Conference on Environment and Development (14 June 1992) UN Doc A/CONF.151/26 (Volume 1), 31 I.L.M. 874 (1992 Rio Declaration).
[lxix] 'General exchange of information and views on legal mechanisms relating to space debris mitigation and remediation measures, taking into account the work of the Scientific and Technical Subcommittee' in the UN GA Draft Report A/AC.105/C.2/L.304/Add.4, para. 44.
[lxx] Guidelines for the Long-term Sustainability of Outer Space Activities of 28 June 2018 (A/AC.105/2018/CRP.20).

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