SPACE DEBRIS, ANOTHER ENVIRONMENTAL ISSUE

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Abstract

Space debris is defunct artificial objects in space which no longer serve a useful function (nonfunctional spacecraft and abandoned launch vehicle stages, mission-related debris, and particularly numerous in Earth orbit, fragmentation debris from the breakup of derelict rocket bodies and spacecraft; solidified liquids expelled from spacecraft, and unburned particles from solid rocket motors) and represents a risk to spacecraft and also for the Earth. Collisions with debris have become a hazard to spacecraft; the smallest objects cause damage especially to solar panels and optics like telescopes or star trackers that cannot easily be protected by a ballistic shield. It is theorized that a sufficiently large collision of spacecraft could potentially lead to a cascade effect or even make some particular low Earth orbits effectively unusable for long term use by orbiting satellites, a phenomenon known as the „Kessler Syndrome". The accumulation of space debris has become an irreversible process since and it is a fact that the space debris began to accumulate in Earth orbit immediately with the first launch of an artificial satellite, Sputnik 1, into orbit, in October 1957. Even there is no international treaty minimizing space debris, limiting the amount of space debris, by all possible means, it is now a duty, with the basic provisions in the existing international space law, particularly in the Outer Space Treaty (1967) and the Liability Convention (1972).

Keywords: *space debris, space objects, international space law, Outer Space Treaty, Liability Convention, absolute liability, fault-based liability, Kessler Syndrome.*

1. Introduction

Pieces of satellites, rockets and other space vehicles orbit the planet and endanger future launches, equipment in working order or may cause damages to the Earth's surface. The provisions of art. 2 of the Convention on International Liability for Damage Caused by Space Objects (1971)[1] (*hereafter: the Liability Convention*) were actually applied in 1979, when the Soviet satellite „Cosmos 954" disintegrated in the Canadian atmospheric space, with radioactive debris spreading across Canada[2]. The largest are the size of a bus and represent the remains of rockets that carried capsules or satellites into space[3].

A study made by the company RS Components shows which countries are responsible for this problem[4]. According to the Space-Track.org, there are 30,000 rubbish in space, with a diameter of more than 10 cm, and, according to NASA, up to 500,000 smaller objects. As Space-Track.org has noted, in first place is Russia with 14,403 pieces of space garbage, followed by the USA (8,734 pieces), China (4,688 pieces), France (994 pieces), India (517 pieces) and other countries (538 pieces).

Unfortunately, this amount of junk space, even the smallest pieces, can cause serious damages. In 2016, a small object from space made a hole of 40 cm in the European Space Agency's satellite (*hereafter: the ESA*), Sentinel-1A.

Some space debris re-enters the atmosphere and burns or falls on the surface of the ground or in the oceans, but others remain and must be removed somehow in the future. Garbage was discovered even in the deepest place on Earth, the Marianas Trench. Due to the fact that it is such an isolated place, Nemo Point is a spaceship „cemetery". Between 1971 and 2016, at least 260 spacecraft were thrown there. Also there, at a depth of 3,2 kilometers, are the MIR Space Station (1986-2001), 140 Russian capsules and even a Space X rocket.[5]

Many technologies have been proposed in order to neutralize this garbage, from powerful lasers to claw-equipped satellites.

More than an environmental problem, some legal issues are important to be noted in the following, namely certain legal aspects related to space debris, by reference to the provisions of the Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other

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[1] Available at *https://www.unoosa.org/oosa/en/ourwork/spacelaw/treaties/introliability-convention.html*, *https://www.unoosa.org/pdf/gares/ARES_26_2777E.pdf*, last time consulted on 6.04.2022.

[2] See M. Diaconu, *On the international responsibility of states in the environmental law*, in Journal of Legal Sciences no. 12/2005, at *https://drept.ucv.ro/RSJ/images/articole/2005/RSJ12/0108Diaconu.pdf*, last time consulted on 11.03.2022.

[3] See A. Popa, *Space junk is becoming a big issue. Top polluting countries*, 2020, at *https://wwwgo4it.ro/content/stiinta/gunoiul-spatial-devine-o-mare-problema-tarile-tarilor-care-au-poluat-cel-mai-mult-191449481/*, last time consulted on 11.03.2022.

[4] See *https://uk.rs-online.com/web/generalDisplay.html?id=space-junk*, last time consulted on 11.03.2022.

[5] See *https:// wwwgo4it.ro/content/stiinta/punctul-nemo-cel-mai-izolat-loc-de-pe-planeta-este-si-el-poluat-cu-plastic-17225147/*, last time consulted on 11.03.2022.

Celestial Bodies from 1967[6] (*hereafter: the OST*) and the Liability Convention from 1971.

From another point of view[7], the OST „has kept any military activity in space from developing into a full-blown face-off between the United States and the Soviet Union". As the author noted in the article, „in signing this treaty, both countries agreed not to place any nuclear weapons or weapons of mass destruction into Earth orbit, on the moon, on any other celestial body, or install them on any orbiting space station. In fact, no nation could make exploring other planets into a military endeavor – there could be no military bases established in orbit or on any celestial bodies, no fortifications of any kinds built in space, and neither country could build any weapons testing facilities or conduct military activities on any planets or in space".

2. Overview of what space debris means. Some aspects regarding space debris's history, characterization and sources. „Kessler Syndrome"

2.1. History and characterization. „Kessler Syndrome"

Also known as space junk, space trash, space pollution or space garbage, space debris is defunct artificial objects in space (principally in Earth orbit) which no longer serve a useful function.

Space debris represents a risk to spacecraft and is typically a negative externality, it creates an external cost on others from the initial action to launch or use a spacecraft in near-Earth orbit, a cost that is not taken into account nor fully accounted for in the cost by the launcher or payload owner. The measurement mitigation and potential removal of debris are conducted by some participants in the space industry[8].

Space debris began to accumulate in Earth orbit immediately with the first launch of an artificial satellite Sputnik 1 into orbit, in October 1957.

Debris history in particular years[9]:

a) as of 2009, 19,000 debris over 5 cm were tracked by United States Space Surveillance Network;

b) as of July 2013, estimates of more than 170 million debris smaller than 1 cm, about 670,000 debris 1-10 cm, and approximately 29,000 larger pieces of debris are in orbit;

c) as of July 2016, nearly 18,000 artificial objects are orbiting above Earth, including 1,419 operational satellites;

d) as of October 2019, nearly 20,000 artificial objects in orbit above the Earth, including 2,218 operational satellites.

Both space objects and space debris are carefully monitored by government agencies and space objects are placed in orbits that are intended to avoid potential collisions with other space objects. But avoidance is not always possible due to the sheer amount of space debris. More than 21,000 orbital debris larger than 10 cm are known to exists. The estimated population of particles between 1 and 10 cm in diameter is approximately 500,000. The number of particles smaller than 1 cm exceeds 100 million, according to NASA.[10] Even small pieces of debris can cause significant damage, as the average impact speed of space debris with a space object is 10 km/s, with maximums reaching above 14 km/s due to Orbital eccentricity.

As a result, space objects must constantly analyze potential collisions and, if necessary, conduct avoidance procedures. The International Space Station must conduct such avoidance procedure approximately once per year, as NASA stated[11].

This debris crosses many other orbits and increases debris collision risk. It is theorized that a sufficiently large collision of spacecraft could potentially lead to a cascade effect or even make some particular low Earth orbits effectively unusable for long

[6] Available at *https://www.unoosa.org/oosa/en/ourwork/spacelaw/treaties/outerspacetreaty.html#a7*, last time consulted on 6.04.2022.

[7] „Of course, at the time the treaty was signed, both the United States and the Soviet Union had military satellites in orbit. And the language of the OST didn't penalize this; it didn't call for the disarmament of space but rather focused on the non-aggressive use of space. The OST didn't prohibit non-aggressive military activity like reconnaissance satellites gathering intelligence, and it didn't expressly prohibit dual-purpose satellites like communications satellites that can transfer both civilian and military information. The treaty also didn't prohibit military personnel from participating in any space-based activities so long as their being in space develops for scientific research or for any other peaceful purposes. But, in this instance, research was a vague term; the treaty didn't directly prohibit either nation from testing individual systems or hardware that might be used as part of a space weapons system. This deficient, insufficient, imperfect expression of the OST's provisions were exploited to varying degrees by both countries with spy satellites, military spaceplanes like the Air Force's X-37B program, and even NASA's partnership with the Department of Defense in building the space shuttle, which in turn spurred the Soviet Union into building its own shuttle Buran. And throughout the Cold War, the agreed non-aggressive use of space didn't entirely quell fears of a possible nuclear war in orbit with bombs raining down from space." See A. Shira-Teitel, *The Outer Space Treaty Promised Peace in Space*, 2013, at *www.seeker.com/the-outer-space-treaty-promised-peace-in-space-1767936768.html*, last time consulted on 4.04.2022.

[8] Space debris by the numbers, archived 6 March 2109 at the Wayback Machine ESA, January 2019. Retrieved 5 March 2019, on *Space debris – Wikipedia*, at *https://en.wikipedia.org/wiki/Space_debris*, last time consulted on 11.03.2022.

[9] *Idem*, 1, 1.1. Debris growth.

[10] See S. Kerr, *Liability for space debris collisions and the Kessler Syndrome (part 1)*, endnote 15, in The Space Review, 2017, at *https://thespacereview.com/article/338711*, last time consulted on 11.03.2022.

[11] *Idem*, endnotes 16 and 17.

term use by orbiting satellites, a phenomenon known as the „Kessler Syndrome".[12]

The „Kessler Syndrome", proposed by NASA Scientist Donald J. Kessler in 1978, is a theoretical scenario in which the density of objects in *low Earth orbit (hereafter: LEO)* is high enough that collisions between objects could cause a cascade effect where each collision generates space debris that increases the likelihood of further collisions. He further theorized that one implication if this were to occur is that the distribution of debris in orbit could render space activities and the use of satellites in specific orbital ranges economically impractical for many generations.

Despite the efforts to reduce risk, spacecraft collisions have occurred. The ESA's telcom satellite Olympus-1 was struck by a meteoroid on August 11, 1993, and eventually moved to a graveyard orbit. On March 29, 2006, the Russian Express-AM11 communications satellite was struck by an unknown object and rendered inoperable; its engineers had enough contact time with the satellite to send it into a graveyard orbit.[13]

On February 10, 2009, a Russian military satellite and a private communications satellite owned by an United States-based company collided in orbit, at a closing speed of 11,7 km/s, creating over 2,000 large debris fragments. The Russian satellite had been defunct since 1995, while the United States' satellite was still operational. Following the unfortunate event of 2009, both satellites were destroyed.[14]

2.2. Sources of debris

Sources of space debris include, among others, dead spacecraft, lost equipment, boosters and weapons.

A. Dead spacecraft

In 1958, the United States launched Vanguard I into a medium Earth orbit. As of October 2009, it and the upper stage of its launch rocket were the oldest surviving artificial space objects still in orbit.[15] In a catalog of known launches until July 2009, the Union of Concerned Scientists listed 902 operational satellites[16] from a known population of 19,000 large objects and about 30,000 objects launched.

In February 2015, the USAF Defense Meteorological Satellite Program Flight 13 (DMSP-F13) exploded on orbit, creating at least 149 debris objects, which were expected to remain in orbit for decades.[17]

Another example of additional derelict satellite debris is the remains of the 1970's / 1980's Soviet naval surveillance satellite program. Orbiting satellites have been deliberately destroyed. The United States and the Soviet Union / Russia have conducted over 30 and 27 ASAT tests, respectively, followed by 10 from China and one from India.

B. Lost equipment

Space debris includes, among others: a glove lost by the astronaut Ed White on the first American space-walk (*extravehicular activity – EVA*), a camera lost by Michael Collins near Gemini 10, a thermal blanket lost during STS-88 (*Space Transportation System – STS*), garbage bags jettisoned by Soviet cosmonauts during MIR's 15 year life, a pair of pliers lost during an STS-120 EVA to reinforce a torn solar and a briefcase sized tool bag in an STS-126 EVA.[18]

C. Boosters

On March 11, 2000, a Chinese Long March 4 CBERS-1 upper stage exploded in orbit, creating a debris cloud.

Seven years away, a Russian Briz-M booster stage exploded in orbit over South Australia on February, 19, 2007. Launched on February 28, 2006, carrying an Arabast-4A communications satellite, it malfunctioned before it could use up its propellant. Although the explosion was captured on film by astronomers, due to the orbit path, the debris cloud has been difficult to measure with radar. By February 21, 2007, over 1,000 fragments were identified.[19]

A long March 7 rocket booster created a fireball visible from portions of Utah, Nevada, Colorado, Idaho and California on the evening of July 27, 2016; its disintegration was widely reported on social media.[20]

In December 2020, scientists confirmed that a previously detected near Earth object, 2020SO, was a

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[12] See also Donald J. Kessler, Burton G. Cour-Palais (1978), *Collision Frequency of Artificial Satellites: The Creation of a Debris Belt*, Journal of Geophysical Research, at *Space debris – Wikipedia, op. cit.*, last time consulted on 15.03.2022.

[13] See *Space debris – Wikipedia, op. cit.*, 2.3., last time consulted on 15.03.2022.

[14] See S. Kerr, *op. cit.*, endnote 18.

[15] See *Space debris – Wikipedia, op. cit.*, 2.3., last time consulted on 15.03.2022.

[16] UCS Satellite Database, Archived 3 June 2010 at the Wayback Machine Union of Concerned Scientists, 16 July 2009, cited on *Space debris – Wikipedia, op. cit.*, 3.1., last time consulted on 16.03.2022.

[17] M. Gruss, *DMSP-F13 Debris To Stay on Orbit for Decades*, at *https://www.space.com/dmsp-f13-debris-to-stay-on-orbit-for-decades*, 2015, last time consulted on 16.03.2022.

[18] For more examples, see *Space debris – Wikipedia, op. cit.*, 3.2., last time consulted on 16.03.2022.

[19] See K. Than, *Rocket Explodes over Australia, Showers Space with Debris*, 2007, at *https://www.space.com/3493-rocket-explodes-over-australia-showers-space-debris.html*, last time consulted on 16.03.2022.

[20] See M. Wall, *Amazing Fireball over Western US Caused by Chinese Space Junk*, 2016, at *https://www.space.com/33581-amazing-fireball-from-chinese-rocket-space-junk-viedo.html*, last time consulted on 16.03.2022.

rocket booster space junk launched in 1966 orbiting Earth and the Sun (Centaur Rocket Booster).[21]

D. Weapons

A past debris source was the testing of *anti-satellite weapons (ASATs)* by the United States and the Soviet Union during the 1960s and 1970s. By the time the debris problem was understood, widespread ASAT testing had ended; the United States Program 437 was shut down in 1975.[22] Despite that, in the 1980s, the United States restarted their ASAT programs with the Vought ASM-135-ASAT. A 1985 test destroyed a 1 tonne satellite orbiting at 525 km, creating thousands of debris larger than 1 cm. Due to the altitude, atmospheric drag decayed the orbit of most debris within a decade.

China's government was condemned for the military implications and the amount of debris from the 2007 anti-satellite missile test, the largest single space debris incident in history, creating over 2,300 pieces golf-ball size or larger, over 35,000 1 cm or larger and one million pieces 1 mm or larger.[23]

On March 27, 2019, Indian Prime Minister announced that India shot down one of its own LEO satellite with a ground-based missile, announcing that the operation, part of Mission Shakti, would defend the country's interests in space. Afterwards, US Air Force Command announced they were tracking 270 new pieces of debris but expected the number to grow as data collection continues, but the International Space Station was not at risk.[24]

Russia destroyed, on November 15, 2021, Kosmos 1408 orbiting at around 450 km above the Earth, creating over 1,500 pieces of trackable debris and hundreds of thousands of pieces of untrackable debris, according to the US State Department.[25]

2.3. Hazards and dealing with debris

Space debris can be a hazard to active satellites, to uncrewed[26] or crewed[27] spacecraft and to the Earth itself and the Earth orbit could even become impassable if the risk of collision grows. Although spacecraft are typically protected by Whipple shields, solar panels, which are exposed to the Sun, wear from low-mass impacts. Even small impacts can produce a cloud of plasma which is an electrical risk to the panels.

Some notable examples[28] of space junk falling to Earth and impacting human life are highlighted below:

- 1969 – five sailors on a Japanese ship were injured when space debris from what was believed to be a Soviet spacecraft struck the deck of their boat;
- 2001 – the upper-stage rocket for NAVSTAR 32, a GPS satellite launched in 1993, re-entered the atmosphere after a catastrophic orbital decay, crashing in the Saudi Arabian desert;
- 2002 – Wu Jie, a six-year-old boy, became the first person to be injured by direct impact from space debris, suffering a fractured toe and a swelling on his forehead after a block of aluminum, 80 cm by 50 cm and weighing 10 kg, from the outer shell of the Resource Second satellite struck him as he sat beneath a persimmon tree in the Shaanxi province of China;
- 2003 – on February, the space shuttle Columbia broke apart during its re-entry into Earth's atmosphere after sustaining damage during its launch; the resulting loss of control led to Columbia's disintegration over the state of Texas (more than 84,000 pieces, along with the remains of the seven STS-107 crew members);[29]

[21] For more details, see *https://nasa.gov/feature/new-data-confirm-2020-so-to-be-the-upper-centaur-rocket-booster-from-the-1960-s*, last time consulted on 16.03.2022.

[22] See Chun Clayton, *Shooting Down a Star: America's Thor Program 437, Nuclear ASAT and Copycat Killers*, Maxewell AFB Base, AL Air University Press, 1999, cited at *Space debris – Wikipedia, op. cit.*, last time consulted on 16.03.2022.

[23] The targed satellite orbited between 850 km and 882 km, the portion of near-Earth space most densely populated with satellites. Since atmospheric drag is low at that altitude, the debris is slow to return to Earth, and in June 2007 NASA's Terra environmental spacecraft maneuvered to avoid impact from the debris. An U.S. Air Force officer and Secure World Foundation staff member has noted that the 2007 Chinese satellite explosion created an orbital debris of more than 3,000 separate objects that then required tracking. For more information about this incident, see *Space debris – Wikipedia, op. cit.*, and also *Space week: Is Space junk Cluttering Up the Final Frontier?*, 2020, at *https://www.npr.org./2020/09/02/908772331/space-week-is-space-junk-cluttering-up-the-final-frontier*, last time consulted on 16.03.2022.

[24] See N. Chavez, S. Pokharel, CNN, *India conducts successful anti-satellite missile operation, Prime minister says*, 2019, at *https://edition.cnn.com/2019/03/27/india/india-modi-satellite-missile-mission/index.html*, last time consulted on 16.03.2022.

[25] See E. Berger, *Russia acknowledges anti-satellite test, but says it's no big deal*, 2021, at *https://arstechnica.com/science/2021/11/russia-acknowledges-anti-satellite-test-but-says-its-no-big-deal* and Eric Berger, *Russia may have just shot down its own satellite, creating a huge debris cloud*, updated November 15, 2021, at *https://arstechnica.com/science/2021/11/debris-from-a-satellite-shot-down-by-the-russians-appears-to-threaten-the-iss/*, last time consulted on 6.04.2022.

[26] The first major satellite collision occurred on February 10, 2009. The 950 kg Russian derelict satellite Kosmos 2251 and the operational 560 kg Iridium 33 collided, 800 km over northern Siberia. Both satellites were destroyed and thousands of pieces of new smaller debris were created, with legal and political liability issues unresolved even years later. On January 22, 2013, a Russian laser-ranging satellite was struck by debris suspected to be from the 2007 Chinese anti-satellite missile test, changing both its orbit and rotation rate. In January 2017, the *European Space Agency (ESA)* decided to alter orbit of one of its three Swarm mission spacecraft, based on data from the US Joint Space Operations Center, to lower the risk of collision from Cosmos-375, a derelict Russian satellite. See *Space debris – Wikipedia, op. cit.*, 4.1., last time consulted on 30.03.2022.

[27] It was the case of the Soviet Space Station MIR since it remained in space for long time with its original solar module panels. Debris impacts on MIR's solar panels degraded their performance. See *Space debris – Wikipedia, op. cit.*, 4.1., last time consulted on 30.03.2022.

[28] For more details, see *Space debris – Wikipedia, op. cit.*, 4.2., last time consulted on 30.03.2022.

[29] See also R.Z. Pearlman, *Debris from Fallen Space Shuttle Columbia Has New Mission 15 Years after Tragedy*, 2018, at *https://www.space.com/39565-columbia-debris-teaches-after-15-years.html*, last time consulted on 6.04.2022.

- 2020 – the empty core stage of a Long March-5B rocket made an uncontrolled re-entry (the largest object to do so since the Soviet Union's 39-ton Salyut 7 space station in 1991) over Africa and the Atlantic Ocean and a 12-meter-long pipe originating from the rocket crashed into the village of Mahounou in Côte d'Ivoire;
- 2021 – the Falcon 9 rocket made an uncontrolled re-entry over Washington State on March 25, producing a widely seen „light show" and a composite-overwrapped pressure vessel survived the re-entry and landed on a farm field in eastern Washington State[30].

Dealing with debris requires several methods for their removal, such as growth mitigation, self-removal and external removal, the use of remotely controlled vehicles, laser methods, nets or harpoon.[31]

3. Legal issues regarding space debris

3.1. Definition of space debris

What is the legal definition of the space debris? Are we facing a misinterpretation of the very large meaning of the notion of „object", perhaps mistaken with spacecraft or vehicle? If every space object is not a space debris, every space debris is a space object? There are some interesting and important questions that we intend to clarify in the following lines, compared to the opinions that have been retained in the matter that interests us, taking into consideration also that there is no legal definition on space debris, generally accepted or regulated as such in a treaty, convention or other instrument.[32] So, even the OST is considered[33] to be the „Magna Carta" of the space law, its provisions are too generic to deal with the complex problems of space debris.

First of all, a classical definition[34] of debris is „the remains of anything broken down or destroyed".

Secondly, some of the authors retained that the term „space debris" refers to the debris from the mass of defunct, artificially created objects in space, especially Earth orbit, including old satellites and spent rocket stages, as well as the fragments from their disintegration and collisions[35], or even naturally occurring objects such as asteroids or meteors[36].

As it was retained[37], a misinterpretation may come from a disputable wording of the „component part" of a space object within the Liability Convention from 1971[38]: « (d) The term „space object" includes component parts of a space object as well as its launch vehicle and parts thereof. ». The author mentioned propose also a legal definition of space debris as „a useless man-launched object in outer space".[39]

While there is yet to be an acceptable legal definition of what space debris means, there have been proposals for defining space debris but mostly in the context of legally binding treaties and liability for space debris. Perhaps the closest definition[40] we have, *which I personally agree with*, is that space debris constitutes any man-made object that is all man-made objects including fragments and elements thereof, in Earth orbit or re-entering the atmosphere, that are non-functional. This concept covers fragments and component parts of space objects, as well as decommissioned or failed spacecraft and spent upper stages of launchers.

A similar definition, a little bit more detailed, was proposed by Joseph S. Imburgia[41], a definition that could be used in a legally binding treaty: „(…) space debris (*must*) include all man-made objects, including fragments and elements thereof, in Earth orbit or reentering the atmosphere, that are non-functional, regardless of whether the debris is created accidently or intentionally; the term includes but is not limited to, fragments of older satellites and rocket boosters resulting from explosions or collisions, as well as any non-functional space object, such as dead satellites, spent rocket stages or other launch vehicles, or components thereof".

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[30] See also *https://phys.org/news/2021-04-piece-spacex-rocket-debris-washington.html*, last time consulted on 30.03.2022.

[31] See *Space debris – Wikipedia, op. cit.*, 6., last time consulted on 30.03.2022.

[32] See: A. Kerrest, *Space debris, remarks on current legal issues*, in Proceedings of the Third European Conference on Space Debris, 19-21 March 2001, Darmstadt, Germany, at *https://conference.sdo.esoc.esa.int/proceedings/sdc3/paper/3/SDC3-paper3.pdf*, last time consulted on 6.03.2022; S. Kerr, *op. cit., loc. cit.*; T. Robinson, *Space debris: The legal issues*, 2014, at *https://www.aerosociety.com/news/space-debris-the-legal-issues/*, last time consulted on 16.03.2022; E. Morozova, A. Laurenava, *International Liability for Commercial Space Activities and Related Issues of Debris*, 2021, at *https://oxfordre.com/planetaryscience/view/10.1093/acrefore/9780190647926.001.0001/acrefore-9780190647926-e-63*, last time consulted on 16.03.2022; L. de Gouvon Matignon, *The legal status of space debris*, 2019, on Space Legal Issues, at *https://www.spacelegalissues.com/the-legal-status-of-space-debris/*, last time consulted on 15.03.2022; M. Mejia-Kaiser, *Space Law and Hazardous Space Debris*, 2020, at https://doi.org/10.1093/acrefore/9780190647926.013.70, last time consulted on 5.04.2022; M. Listner, *Legal issues surrounding space debris remediation*, 2012, at *https://www.thespacereview.com/article/2130/1*, last time consulted on 6.03.2022.

[33] See T. Robinson, *op. cit., loc. cit.* and the OST, *op. cit., loc. cit*.

[34] See *https://www.dictionary.com/browse/debris*, last time consulted on 30.03.2022.

[35] See L. de Gouvon Matignon, *op. cit., loc. cit*.

[36] See M. Listner, *op. cit., loc. cit.*

[37] See A. Kerrest, *op. cit., loc. cit.*, p. 869 and p. 873 note 1.

[38] The Liability Convention, cited *supra*, *op. cit., loc. cit.*, art. I, letter (d).

[39] See A. Kerrest, *op. cit., loc. cit.*, p. 870.

[40] See: T. Robinson, *op. cit., loc. cit*.; S. Kerr, *op. cit., loc. cit*.

[41] See M. Listner, *op. cit., loc. cit.*

3.2. Applicable law. Liability. The determination of the liable launching State

The applicable law related to the space activities was developed and enshrined in two legally binding instruments: the OST (1967) and the Liability Convention (1971).

The most proeminent issue surrounding cleanup of orbital space debris rests with art. VIII of the OST[42], in which space objects, including non-functioning satellites and other space debris, continue to belong to the country or countries that launched them.

The Liability Convention was seen[43] as the other legal pillar and *lex specialis* to the OST, elaborating on the liability regime, providing two types of liability, absolute and fault-based, as follows.

Art. II of the Liability Convention specifies that a launching state is absolutely liable to pay compensation for damages caused by its space object on the surface of the Earth or to aircraft in flight (*absolute liability*).

Under art. III of the Liability Convention, 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 (*fault-based liability*).

Several scenarios have been made[44] regarding the implementation of art. II and III of the Liability Convention.

First, if a State were to launch a normal operation (such as placing a satellite in orbit) but intentionally and unnecessarily released space debris in the process, that State would be in violation of *Guideline 1. Limit debris released during normal operations*[45]. If that space debris were to cause damage to Earth or aircraft, the question of liability is simple, meaning that the launching State would be liable for damage under art. II of the Liability Convention, which imposes *absolute liability*. However, if the space debris were to remain in space and collide with another state's orbiting satellite, launching State would be liable under art. III of the Liability Convention, which requires fault-based liability. The answer must be affirmative because the launching State caused damage (collision with another satellite) through an intentional act (releasing space debris) and the *fault-based liability* is established. The fact that the act was not in compliance with Guideline 1 is immaterial to establishing fault-based liability.

Secondly, the author proposed an example in relation to *Guideline 3. Limit the probability of accidental collision in orbit*[46]. If a State launched a space object (such as a satellite) and later abandoned it due to completion of its mission or failure of its systems, Guideline 3 suggests that the launching State should analyze available orbital data to predict potential collisions and limit the probability of a collision. But what if the launching State analyzes the available orbital data, is aware of a potential collision, but chooses not to utilize avoidance procedures? In that case, the launching State would be liable under Article III of the Liability Convention, which requires *fault-based liability* because he caused damage (collision with another satellite) through an intentional omission (failing to limit the potential collision) and so the fault-based liability is established and the fact that the state was not in compliance with Guideline 3 is immaterial to establishing fault-based liability.

Continuing this second scenario, the author raises another question and makes the third scenario. What if the State B has also analyzed orbital data and realizes there is a potential collision in the future (maybe in one year from the present date) and no damage has yet occurred. However, the launching State is unable to utilize avoidance procedures, either because of a systems malfunction or a lack of fuel. As a result of this potential collision, State B utilizes a significant amount

[42] See the OST, *supra, op. cit., loc. cit.*, art. VIII („A State Party to the Treaty on whose registry an object launched into outer space is carried shall retain jurisdiction and control over such object, and over any personnel thereof, while in outer space or on a celestial body. Ownership of objects launched into outer space, including objects landed or constructed on a celestial body, and of their component parts, is not affected by their presence in outer space or on a celestial body or by their return to the Earth. Such objects or component parts found beyond the limits of the State Party to the Treaty on whose registry they are carried shall be returned to that State Party, which shall, upon request, furnish identifying data prior to their return.").

[43] See E. Morozova, A. Laurenava, *op. cit., loc. cit.*

[44] See S. Kerr, *op. cit., loc. cit.*, referring to the Resolution no. 62/217, adopted by the United Nations General Assembly, which endorsed the Space Debris Mitigation Guidelines of the Committee on the Peaceful Uses of Outer Space (the „Space Debris Resolution"). These scenarios will be rendered in their entirety, as their author imagined them, because their cutting or reinterpretation could make difficult to pass on their basic ideas.

[45] *Ibidem*. „Guideline 1: Space systems should be designed not to release debris during normal operations. If this is not feasible, the effect of any release of debris on the outer space environment should be minimized.

During the early decades of the space age, launch vehicle and spacecraft designers permitted the intentional release of numerous mission-related objects into Earth orbit, including, among other things, sensor covers, separation mechanisms and deployment articles. Dedicated design efforts, prompted by the recognition of the threat posed by such objects, have proved effective in reducing this source of space debris."

[46] *Ibidem*. „Guideline 3: In developing the design and mission profile of spacecraft and launch vehicle stages, the probability of accidental collision with known objects during the system's launch phase and orbital lifetime should be estimated and limited. If available orbital data indicate a potential collision, adjustment of the launch time or an on-orbit avoidance manoeuvre should be considered.

Some accidental collisions have already been identified. Numerous studies indicate that, as the number and mass of space debris increase, the primary source of new space debris is likely to be from collisions. Collision avoidance procedures have already been adopted by some member States and international organizations."

of fuel to modify its own satellite's orbital altitude. Can State B claim damages (for fuel costs and lost satellite productivity) against the launching State for non-compliance? Is the launching state at fault? No, because the launching State indeed caused damage to State B (fuel costs and lost satellite productivity) due to non-compliance (failing to limit the potential collision), but that non-compliance was not intentional. If it were, then it would be considered an intentional act or omission, and non-compliance would be immaterial. The author takes the discussion further to the point of establishing that, in fact, the heart of the issue rests with the analysis of whether an intentional act or omission occurred that caused the damage, not whether the intentional act or omission was in compliance with United Nations General Assembly Resolutions and even an intentional act or omission that is in compliance with such Resolutions could lead to fault-based liability.[47]

Since art. II of the Liability Convention, which does not require proof of the fault of the conduct that causes damage in order to claim compensation and refers to this type of liability as absolute, reads similarly to art. VII of the OST[48], the latter is also generally considered an example of *absolute liability*. We consider, together with other authors[49], that this means that damage caused as a result of fault-free conduct is subject to compensation in accordance with both art. VII of the OST and art. II of the Liability Convention.

Art. IV (1)(b) and (2) together address situations where two or more states' property causes damage to a third-party state's property. In such a situation, the Liability Convention imposes also *fault-based liability*, stating that all states whose property caused damage to a third-party state's property, and are found to be at fault for such damage, are jointly and severally liable for that damage. Notably, the legal scheme referred to above only apply to damage that occurs within space, which is commonly considered to begin at 100 km above the Earth's surface.

In contrast, art. IV (1)(a) imposes *absolute liability* for such damage that occurs on the surface of the Earth or in the air.[50]

Where *fault-based liability* is required, the Liability Convention clearly delineates „causation" and „fault" as separate tests. Fault-based liability requires an intentional act or omission. Therefore, while a state may cause damage, the state is only liable if it was their intentional act or omission caused the damage.

So, one question was raised[51]: why are different standards of liability required (*absolute liability* for land-and-air-based damages and *fault-based liability* for space-based damages)? It seems likely that *absolute liability* is imposed where the loss of life or private property (on the Earth and in the air), in order to ensure protection of private citizens. However, space is changing and is increasingly becoming the realm of private citizens and corporations (such as SpaceX) and perhaps the presumed justification for imposing absolute liability (the protection of private citizens and corporations) should be extended to space as well.

Only damage caused by a space object is subject to compensation under the liability regime of international space law and the Liability Convention makes a fundamental distinction according to the location of the damage: damage caused on Earth and damage caused in Outer Space. Then according to the OST and to the Liability Convention, the launching State of a space object is liable for damage it may cause and, of course, it should be proven to be the launching State of that object[52]. So, we are facing with another issue (or maybe the same issue that we discussed previously when we tried to establish a legal definition of space debris): space debris are not always known „by their father's or mother's name"[53].

For this real problem for damage caused in outer space, when it is not possible to know the origin of the debris, it was stated[54] that maybe it should be possible to create an international fund to pay for damage caused by unknown debris. And, once accepted, if the contribution to this fund is made according to the creation of debris it may be a good incentive to mitigate their creation.

4. Conclusions

When the Soviet Union launched Sputnik in 1957 (the first successful space craft), the United States began to fear and the question was simple enough: if the Soviet Union could launch such a craft, then it would be easy also to send off a nuclear weapon in

[47] *Ibidem*.

[48] See the OST, *supra, op. cit., loc. cit.*, art. VII („Each State Party to the Treaty that launches or procures the launching of an object into outer space, including the moon and other celestial bodies, and each State Party from whose territory or facility an object is launched, is internationally liable for damage to another State Party to the Treaty or to its natural or juridical persons by such object or its component parts on the Earth, in air or in outer space, including the moon and other celestial bodies.").

[49] See E. Morozova, A. Laurenova, *op. cit., loc. cit.*

[50] See S. Kerr, *op. cit., loc. cit.*

[51] *Ibidem*.

[52] An important distinction was made between *where* the space object launched from and *who* is launching the space object. For more details, see S. Kerr, *Liability for space debris collisions and the Kessler Syndrome (part 2)*, 2017, at *https://thespacereview.com/article/3392/1*, last time consulted on 6.04.2022.

[53] See A. Kerrest, *op. cit., loc. cit.*, p. 870, point 2.2. Liability / The determination of the liable launching State.

[54] *Ibidem*.

space that could destroy the United States? Because no one knew how space would be exploited and protected, or what rights and responsibilities would arise related to the exploration of the space.

So, in 1962, the United States and the Soviet Union realized that there was a need for a new treaty, and that was, a few years later, the OST, designed to ensure that ongoing exploration of the space will be a peaceful attempt for all nations.

The OST was not about seeking to prove technological or political dominance but establishing political and legal guidelines to ensure that the man's expansion into space would be done for the benefit of all nations irrespective of economic wealth or scientific development.

There is no doubt that fundamental principles of general international law are fully applicable to all spheres of international relations, including outer space activities. At the same time, some principles of outer space law are applicable only to international relations in the process of the exploration and uses of outer space. For example, the exploration and use of outer space for the benefit and in the interests of all countries (art. I of the OST) and State responsibility for all national activities in outer space (art. VI of the OST).

For years, many legal experts have been drawing attention to the fact that an important gap exists in the OST and in the other UN space treaties (for example, in the Liability Convention), due to *the lack of definition of „outer space"*, notwithstanding that the UN space documents use the term of „outer space", „space activities", „space objects" and so on, and attach to these terms important legal consequences.

Another issue of great importance is one of the space debris. It should be noted *the lack of enough regulation in reference to the liability for the damages caused by space debris*. The OST and the Liability Convention established the international liability of launching States for the damages caused by space objects or its component parts on Earth, air space or outer space. So, space debris are part of space objects and it can be applied the liability regime of the OST and the Liability Convention. But the most difficult task is to identify the origin of a component part of a space object. It is necessary then to count on a more precise regulation that should define the concept of space debris, to set certain guidelines in order to avoid the production of debris and to establish measures to reduce its growth.

The problem is how to define and identify space debris. We believe that it should be supported the proposal of creating a world-wide monitoring entity or an international guarantee fund with the main and proportional contribution of those who use and take benefits/ profits from space activities, and according to the danger they create and their frequency.

The accumulation of space debris has become an irreversible process and limiting the amount of space debris, by all possible means, it is not only a must, but is a duty. And now there is no justification for delaying and wasting time, obviously with a strong impulse of political will… We do believe that we already have the necessary basic provisions in the existing international space law, particularly in the OST and in the Liability Convention, with all the gaps these documents have. Indeed, the OST at present is way too general (for instance in providing definitions), but, nevertheless these space treaties do provide us a framework and some important basic starting points. Obviously, we need clearer answers and we also need to admit that a specific situation calls for a specific legal regime and some special rules appear more than necessary, for example with regard to liability.

We must stop that the space around us becomes, sooner or later, a junk yard or a cemetery, with dramatic consequences on Earth itself.

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