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Protection of the space environment against space debris pollution

Introduction

The term "space debris" is used for all artificial objects and their small fragments in outer space which will never function and cannot serve any useful purpose but pose a danger to functioning spacecraft and other space objects[1]. Space as a natural element is exposed to degradation changes[2].

Although the problem of near-Earth space pollution by "space debris" theoretically appeared immediately after the launch of the first artificial earth satellites in the 1950's, this problem received official status at the international level only after December 10, 1993 when the UN Secretary-General reported on "The Impact of Space Activities on the Environment". Therein, he identified the international and global littering of Earth's space with various wastes[3].

When modern carrier-rockets launch a payload of tens of tons in orbit they consume 20–30 times more fuel than the payload. For example, the starting mass of the American Saturn-5 rocket was 2,900 tons but its payload was only approximately 100 tons. This activity results in hundreds of tons of combustion products emitted into the atmosphere with each powerful rocket launch, thus causing acute environmental problems. The frequent launches and space flights pollute the atmosphere and ionosphere and they emit enormous amounts of carbon dioxide and other gaseous compounds into the atmosphere with irreversible consequences[4]. Moreover, the current level

[1] R. Klima, D. Bloembergen, R. Savani, K. Tuyls, A. Wittig, A. Sapera and D. Izzo. *Space Debris Removal: Learning to Cooperate and the Price of Anarchy. Front. Robot,* "Frontiers in Robotics and Al." 2018, vol. 5, p.54.

[2] D.Kuźniar, *Ochrona środowiska przestrzeni kosmicznej i ciał niebieskich. Studium prawnomiędzynarodowe*, Wydawnictwo Uniwersytetu Rzeszowskiego, Rzeszów, 2019, s.37.

[3] E.A. Манжула *Загрязнение космического пространства как международная проблема*, „Научно-технические ведомости Санкт-Петербургского государственного политехнического университета. Гуманитарные и общественные науки" 2013, No. 179, p. 175.

[4] A.A. Алексеев, *Проблема космического мусора в околоземном пространстве*, „Academy" 2019, No. 1(40), p. 31.

of contamination of the near-Earth orbit insists that further uncontrolled development should be curtailed and that outer space pollution must be addressed at economic, technical, environmental and legal levels[5]. Recent research into these combined problems, however, has now suggested possible solutions.

Economic and Technical Aspects of Space Pollution

From an economic viewpoint, limiting outer space pollution confronts major problems. These are associated with requisite measures which will prevent direct space debris impacts on spacecraft, and they will also eliminate the consequences of spacecraft development, production and testing by[6]:

– protecting spacecraft from the effects of space debris and preventing collisions with space debris[7] and also the partial loss of functionality or deterioration of spacecraft technical characteristics[8];

– eliminating present space debris and preventing future accumulation[9];

– enabling spacecraft to "evade" space debris. Here, for example, the ISS has repeatedly maneuvered to avoid possible collisions with space debris[10];

– reducing the cost of launching spacecraft into orbit[11];

– rapidly detecting dangerous debris. This is the most important condition for ensuring operational safety[12];

The problem of "space debris" economically and technically affects the interests of all States involved in space exploration, and its solution therefore requires an international legal basis and the close cooperation of states[13].

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[5] J. Muwenis, *Odpady w przestrzeni kosmicznej i próby ich minimalizacji*, Kosmos, 2018, 67(2), p. 449–454.

[6] С.С. Зотина, Ю.В. Назаренко, Г.М. Гринберг, В.В. Сафронов, *Правовые, экономические и технические аспекты загрязнения космического пространства*, „Актуальные проблемы авиации и космонавтики" 2015, No. 11, p. 937.

[7] P. Chrystal, D. McKnight, P. L., Meredith, *Space debris: On collision course for ensures*, Swiss Re, Zurich 2011, p. 29.

[8] A. Wilkins, *How NASA Fights to Keep Dying Spacecraft Alive, Scientific American*, 2016, October 24, available at: https://www.scientificamerican.com/article/how-nasa-fights-to-keep-dying-spacecraft-alive/ (reference date: June 29, 2019).

[9] J.S. Greenberg, *Economic Principles Applied to Space Industry Decisions*, American Institute of Aeronautics and Astronautics, Virginia 2003, p. 326.

[10] S. Habimana, P. Ramakrishna, *Space debris: Reasons, types, impacts and management*, "Indian Journal of Radio and Space Physics" 2017, Vol. 46, p. 24.

[11] Therefore, the creation of a multinational network of the SST sensors is a clever solution to enable the capabilities of the participants to be leveraged. The Space Surveillance and Tracking (SST) is the detection of space objects to determine and predict their orbits.

[12] A. Console, *Command and Control of a Multinational Space Surveillance and Tracking Network*, "Joint Air Power Competence Centre" 2019, June, p. 1–2.

[13] M. Pietkiewicz, *European Union And Commonwealth of Independent States–Protection of Space Environment*, „International Multidisciplinary Scientific GeoConference: SGEM: Surveying

Moreover, it is most important that the relevance of the problem is recognized by the entire global community so that agreements in this area can be rapidly adopted[14].

Space Exploration and Modern Environmental Risks

Although well over more than $500 billion has already been spent on integrated space exploration[15], the project to clean up near-Earth space from space debris will cost at least several billion more and this is completely overshadowed in human terms by all environmental damage. As well as creating a "space dump", there is also the problem of launch vehicles and fragments falling on the Earth's surface and oceans with resultant irreparable damage to the planet[16]. This damage is compounded by rocket engine gaseous emissions into the atmosphere and a violated ozone layer[17]. Till nowadays a lot of new methods and means for removing space debris from orbits were invented[18].

While Russia complied with international law by ensuring that its Mir station was safely flooded in the Pacific Ocean without surface environmental flaws after completing its work in 2001, other countries have been remiss[19]. For example, China's non-observance of the relevant norms of international law led to their 2007 accurate hit of a military missile which "eliminated" its malfunctioning weather satellite[20] and India's satellite destruction in April 2019[21] created an increased 44% risk of debris colliding with the ISS and this fear mounted over a minimum 10-day period following their tests.

Geology & mining Ecology Management" 2017, No. 17, p. 299–306; E. Zębek, *Legal and organisational solutions of the municipal waste management in chosen countries of UE*, „Studia Prawnoustrojowe" 2016, No. 33, p.127–129.

[14] J. Kurt, *Triumph of the Space Commons: Addressing the Impending Space Debris Crisis without an International Treaty*, "Wm. & Mary Envtl. L. & Pol'y Rev" 2015, No. 40, p. 334.

[15] Е.А. Манжула, *Загрязнение космического пространства… op.cit.*, p. 176.

[16] J. Matson, *U.S. Taking Initial Steps to Grapple with Space Debris Problem*, "Scientific American" 2011, 31 August, available at: https://www.scientificamerican.com/article/orbital-debris-space-fence/ (reference date: June 29, 2019).

[17] M. Ross, J.A. Vedda, *The policy and science of rocket emissions*, The Aerospace Corporation, California 2018, p. 3–4.

[18] R. Borek, *Powstawanie i rozprzestrzenianie śmieci kosmicznych w świetle przepisów Unii Europejskiej*, Obronność–Zeszyty Naukowe Wydziału Zarządzania i Dowodzenia Akademii Sztuki Wojennej, 2016, 1 (17), p.24–25.

[19] M. Warren, *Mir returns to Earth with perfect splashdown*, "The Telegraph" 2001, 24 March, available at: https://www.telegraph.co.uk/news/worldnews/australiaandthepacific/fiji/1327811/Mir-returns-to-Earth-with-perfect-splashdown.html (reference date: June 25, 2019).

[20] Bussert J.C., *Antisatellite Weapons Pose Major Cyberthreat,* "Signal. AFCEA" 2015, February 1, available at: https://www.afcea.org/content/antisatellite-weapons-pose-major-cyberthreat (reference date: June 25, 2019).

[21] Operation called: „Mission Shakti".

The damage caused to local habitats particularly cannot be ignored. This especially applies to those areas directly adjacent to the launch sites affected not only by spacecraft launching but also by "abnormal" situations resulting from accidents, destruction and space technology machinery collapse[22]. These situations are further overshadowed by the threats to human life and the animal and plant kingdom by toxic rocket fuel spills. In addition, the growth in global national spaceports has increased threats posed to populations and localities adjacent to cosmodromes; even in strategically planned and controlled landings. The environmental risks assumed by the space industry are further aggravated by the use of highly toxic heptyl as rocket liquid fuel[23]. Heptyl[24] is a flammable, volatile and toxic liquid with characteristic ammonia odor. It is also soluble in water and forms white-colored atmospheric vapors in the air which accumulate in low places. Heptyl poisoning can therefore initiate human liver damage, pulmonary edema and possible death[25].

Further danger emanates from rocket engine gaseous emissions into the atmosphere. The American Shuttles are particularly unfavorable in this aspect[26] because increased space rocket launches are directly related to health deterioration in people with compromised immunity, weather abnormalities and irreversible ozone layer depletion[27].

This threat to the Earth's ozone umbrella has now divided the academic world into opposing camps: orthodox skeptics forecast melting of the Arctic ice by 2050, but optimists continue to dismiss arguments that reasonably prove the reality of holes in the ozone layer and future cloudless earthlings[28]. Disturbing signals on the irreversibility of techno-genetic influence on the safety of our planets' ozone layer surfaced 30 years ago when anomalous violation of the integrity of the ozone shell over Antarctica[29] coincided with accelerated space research. This integrity was also later compromised over the Arctic and Siberia.

[22] M. Mora, A. Mahnert, K. Koskinen, M. R. Pausan, L. Oberauner-Wappis, R. Krause, A. K. Perras, G. Gorkiewicz, G. Berg, C. Moissl-Eichinger, *Microorganisms in confined habitats: microbial monitoring and control of intensive care units, operating rooms, clean rooms and the International Space Station*, "Frontiers in Microbiolog" 2016, Vol. 7, available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5061736/ (reference date: June 25, 2019).

[23] M. Byers, B. Cameron, *Toxic Splash: Russian Rocket Stages Dropped in Arctic Waters Raise Health, Environmental and Legal Concerns*, "Polar Record" 2017, Vol. 53, no. 6, p. 580–591.

[24] Unsymmetrical dimethylhydrazine, UDMH; 1,1-dimethylhydrazine $H_2NN(CH_3)_2$.

[25] D.S. Thakur et al. *Glyphosate poisoning with acute pulmonary edema*, "Toxicology International" 2014, No. 21 (3), p. 328.

[26] С.В. Жаров, *Анализ экологических рисков в освоении космоса*, „Вестник СибАДИ", 2009, No 12, p. 92.

[27] G. Horneck, D. M. Klaus, R.L. Mancinelli, *Space Microbiology*, "Microbiology and Molecula Biology Reviews" 2010, No. 74(1), p. 121.

[28] J. Masters, *The Skeptics vs. the Ozone Hole, Weather Underground*, available at: https://www.wunderground.com/resources/climate/ozone_skeptics.asp (reference date: June 29, 2019).

[29] W. Parry, *Earth's First Arctic Ozone Hole Recorded*, "Live Science" 2011, October 2, available at: https://www.livescience.com/16337-arctic-ozone-hole.html (reference date: June 25, 2019).

The following sources of negative phenomena were then determined: atmospheric pollution with nitrogen oxides from volcanic eruptions, smoke plumes from forest and steppe fires and the emissions and exhausts from aircraft, automobiles, ships, boilers and thermal power plants[30]. Freon gas, however, has been established as the major ozone enemy. Freon is employed in the cryogenic systems of industrial and domestic refrigerators, air conditioners and aerosol cans and a single Freon molecule is capable of initiating a sequence of reactions resulting in the disappearance of many ozone molecules. Moreover, the lifetime of the most dangerous Freon emission persists from 40 to 150 years[31].

The "Legal Arguments" and Space Debris

The "Convention on the Liability of Damage Caused by Space Objects" (1972) has a unique place in the international legal regulation of space ecology. This Convention imposes 'absolute responsibility for damage caused by space objects on the Earth's surface and aircraft in flight on the launching State' (Article 2). If damage is caused to one State's space object by another State's space object, the latter is only liable if the damage was caused through its fault, or by persons for whom it is responsible. Therein, the definition of "space object" includes all component parts of a "space object", its delivery launching vehicles and its parts from all stages and individual components, even those not necessarily functioning; and this definition empowers the convention to impose responsibility for potential space pollution on the launching State[32].

The establishment of liability for damage caused by a space object to the space environment is very difficult – liability can be pursued only from damage. This term is defined in Article 1 of the Convention as "loss of life, personal injury or other impairment of health; or loss of or damage to property of States or of persons, natural or juridical, or property of international intergovernmental organizations". Despite this significant list of possible situations, it is obvious that they all relate to physical damage and they do not apply to the space environment[33].

However, specific documentation does exist – the 1977 "Convention on the Prohibition of Military or Any Other Hostile Use of Environmental Mo-

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[30] Sh. B. Sharma, *The effects of air pollution on the environment and human health*, "The Indian Journal of Research in Pharmacy and Biotechnology" 2013, Vol.1(3), p. 391–392.

[31] F. Sh. Rowland, *Chlorofluorocarbons and the Depletion of Stratospheric Ozone*, "American Scientist" 1989, Vol. 77, No. 1, p. 36–38.

[32] H. Ijaiya, *Space Debris: Legal and Policy Implications*, "Environmental Pollution and Protection" 2017, Vol. 2, No. 1, p. 25–26.

[33] Н.С. Хлебодаров, *Озонная дыра: измерить или заштопать,* „Техника молодежи" 1988, No. 5, p. 37.

dification Techniques" (ENMOD). This special document directly prohibits pollution of space and has direct bearing on the issues under consideration Under its auspices, the participating States commit "not to resort to military or any other hostile use of means of influence on the natural (including space) environment, the use of which causes wide, long-term or serious consequences, by deliberately changing its dynamics, composition or structure"[34]. However, this Convention is universal in nature and its contribution to solving space ecology problems is therefore quite generalized[35]. Further, the Convention contains no specific provisions affecting the problems of space contamination by man-made space bodies or adequate mechanisms for taking practical preventative measures[36].

Nevertheless, the limited legal protection offered by the constitution of outer space is very welcome. This specifically includes "The Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies". Article IX therein states that "Parties to the Treaty shall pursue studies of outer space, including the Moon and other celestial bodies, and conduct exploration of them so as to avoid their harmful contamination and also adverse changes in the environment of the Earth resulting from the introduction of extraterrestrial matter and, where necessary, shall adopt appropriate measures for this purpose".

At the same time, there is an obvious and publicly understandable solution to the problem of space ecology – reducing the scale of space activities and regulating improved rocket and space technology for environmental protection by reducing the number of uncontrollable objects left in space and returning spacecraft descending into the Earth's atmosphere and then enforced cleaning of the orbits. Unfortunately, no one has yet reliably estimated either the effectiveness of such measures or their suitability under the criterion of "costs efficiency"[37]. Moreover, from a political viewpoint, combined global desire to reduce the scale of space activities appears impossible.

In 2002, the Interagency Debris Coordination Committee published the IADC Space Debris Mitigation Guidelines[38], and presented them to the UN COPUOS Scientific & Technical Subcommittee (STSC), where they now form

[34] C. R. Englert, J. T Bays, K. D. Marr., C. M. Brown., A. C. Nicholas, T. T. Finne, *Optical orbital debris spotter*, "Acta Astronautica" 2014, No. 104 (1), p. 102.

[35] T. Hanada, *Orbital debris modeling and applications at Kyushu University*, "Procedia Engineering" 2013, No. 67, p. 408.

[36] J. Tallis, *Remediating Space Debris Legal and Technical Barriers*, "Strategic Studies Quarterly" 2015, Spring, p. 90–92.

[37] E.A. Taylor, J.R. Davey, *Implementation of debris mitigation using International Organization for Standardization (ISO) standards*, "Proceedings of the Institution of Mechanical Engineers: G", 2007, Vol. 221, No. 8, p. 989.

[38] *IADC Space Debris Mitigation Guidelines*, available at: http://www.unoosa.org/documents/pdf/spacelaw/sd/IADC-2002-01-IADC-Space_Debris-Guidelines-Revision1.pdf (reference date: June 29, 2019).

the baseline for the UN Space Debris Mitigation Guidelines. In 2007 these guidelines were approved by the 63 STSC member nations as voluntary high-level mitigation measures. According to the document's "General Guidelines", the Mitigation Plan should include the following:

– A management plan addressing space debris mitigation activities;

– A plan for assessing and mitigating risks related to space debris, including applicable standards;

– adopting measures minimizing hazards from malfunctions which have the potential to generate space debris;

– A plan for disposal of the spacecraft and/or orbital stages at mission end;

– Justification of choice and selection where several possibilities exist;

– A compliance matrix addressing the recommendations of these Guidelines.

A complementary document was then initiated in 2010 when the UN adopted the "Space Debris Mitigation Guidelines of the Committee on the Peaceful Uses of Outer Space"[39]. This document has 7 guidelines:

– Limit debris released during normal operations;

– Minimize the potential for break-ups during operational phases;

– Limit the probability of accidental collision in orbit;

– Avoid intentional destruction and other harmful activities;

– Minimize the potential for post-mission break-ups resulting from stored energy;

– Limit the long-term presence of spacecraft and launch vehicle orbital stages in the low-Earth orbit (LEO) region after the end of their mission; and

– Limit the long-term interference of spacecraft and launch vehicle orbital stages with the geosynchronous Earth orbit (GEO) region after the end of the mission.

In addition, current international cooperation on space debris is now developing in the following priority areas:

– Environmental monitoring of near-Earth space, including the area of the geostationary orbit: monitoring "space debris" and maintaining a catalog of objects entitled "space debris"[40];

– The following measures have been developed in the latest fight again space debris from_"mathematical modeling of "space debris", the creation of international information systems for forecasting the contamination of the near-Earth space and its danger for space flights and informational support

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[39] *Space Debris Mitigation Guidelines of the Committee on the Peaceful Uses of Outer Space*, The United Nations Organization 2010, Vienna, available at: http://www.unoosa.org/pdf/publications/st_space_49E.pdf (reference date: June 29, 2019).

[40] C. Bombardelli, J. Peláez, *Ion Beam Shepherd for Contactless Space Debris Removal,* "Journal of Guidance, Control, and Dynamics" 2011, Vol. 34, No. 3, May–June, p. 918.

of events of dangerous convergence of space objects and their uncontrolled entry into the dense layers of the atmosphere”[41];

– Development of methods and means of protecting spacecraft from the effects of high-speed particles of “space debris”; and the

– Development and implementation of measures aimed at reducing the debris in near-Earth space[42].

Approximately 6,000 devices have been launched in the history of space exploration and significant parts of these satellites and rocket-stage fragments have contributed to littering the near-earth orbit[43]. Here, spectacular problems were caused by rocket stages: the Russian “Protons”, American “Deltas” and French “Arians” were heated by sun-rays and exploded in orbit. Fuel-tank remnants ignited and burst the rockets into thousands of fragments scattered randomly at great speed in all directions – a complete cloud of debris ensued and this rose along the Earth’s orbit[44].

One of the most important modern ISS tasks is to dodge flying debris[45]. The particular problem here is that although all debris in low orbits can enter the atmosphere and burn[46]. Debris in the geostationary orbit region remains almost forever.

Conclusions

In conclusion, the basic generally accepted norms of international space law were established over the short period from 1963 to 1976. These standards included:

(1) a treaty banning nuclear testing in the atmosphere, outer space and under water;

(2) a treaty on the principles of state activity in the exploration and use of outer space, including the moon and other celestial bodies;

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[41] H. Klinkrad, P. Wegener, C. Wiedemann, J. Bendisch, H. Krag, *Modeling of the Current Space Debris Environment* [in:] *Space Debris. Models and Risk Analysis,* H. Klinkrad, Springer, Berlin 2006, p. 59.

[42] A. Milne, *Sky Static: The Space Debris Crisis*, Praeger, Westport 2002, p. 86.

[43] B. Weeden, *Overview of the legal and policy challenges of orbital debris removal*, “Space Policy” 2011, No. 27, p. 41.

[44] C. Trentlage, E. Stoll, *The Usability of Gecko Adhesives in a Docking Mechanism for Active Debris Removal Missions*, Symposium on Advanced Space Technologies in Robotics and Automation, Noordwijk 2015, p. 7, available at: http://robotics.estec.esa.int/ASTRA/Astra2015/Papers/Session%207A/98904_Stoll_Trentlage.pdf (reference date: June 29, 2019).

[45] B. Virgili, J. Dolado, H. Lewis, J. Radtke, H. Krag, B. Revelina, C. Cazaux, C. Colombo, R. Crowther, M. Metz, *Risk to space sustainability from large constellations of satellites*, “Acta Astronautica” 2016, Vol. 126, p. 158.

[46] M. Emanuelli, G. Federico, J. Loughman, D. Prasad, T. Chow, M. Rathnasabapathy, *Conceptualizing an economically, legally, and politically viable active debris removal option*, “Acta Astronautica” 2014, Vol. 104, p. 84.

(3) consensus on the rescue and return of astronauts.

(4) the Convention on International Liability for Damage Caused by Space Objects; and

(5) the Convention on Registration of Objects Launched into Outer Space[47].

However, the interpretation of these major international space law documents requires caution[48] because they were adopted before the problem of technogenic pollution of near-Earth space. The dynamic growth in "space debris" and the danger it poses to near-Earth space and activities on Earth and other celestial bodies require the adoption of new international rules that oblige states to respect the principle of prohibiting space pollution.

Most importantly, the future of the ecology of near-Earth space is directly dependent on the long-term planning of rational exploration of space; and further development of space exploration science and technology can no longer be considered without the integration of new, environmentally flawless technology. The first steps in this direction involve construction of new generation spaceports and mass production of safe fuel that meets all international standards. This will significantly improve the economic and technical characteristics of spacecraft and will help resolve the problem of space pollution when it is combined with improved international legal regulations for safe space exploration.

Therefore to ensure the safety of the movement of space objects and reduce environmental harm, it is essential to draw up an international treaty which includes the following international rules and provisions for space traffic:

– Safety requirements for space navigation;

– Requirements to reduce the number of unmanaged objects left in space[49];

– Requirements of enforced orbital cleaning[50];

– Creation of a legal regime for outer space which polices mission control center responsibility for space debris control;

– The creation of an international central space flight control defining its rights and obligations[51] and this will have the status of an international intergovernmental organization.

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[47] С.В. Жаров, *К вопросу интеграции современных экологических проблем планетарного характера*, [in:] Материалы II Международной научно-практической конференции „Актуальные проблемы экологии". Караганда: КарГУ им. Букетова, 2003, p. 168.

[48] M. Pietkiewicz, *The Main Directions of EU Environmental Strategy*, "International Multidisciplinary Scientific GeoConference: SGEM: Surveying Geology & mining Ecology Management"2017, No. 17, p. 395–400.

[49] С.М. Малюкова, Ю.В. Русина, С.П. Дуреев, *О загрязнении космоса*, "Актуальные проблемы авиации и космонавтики" 2011, No 7, p. 381–382.

[50] E. Magli, D. Valsesia, R. Vitulli, *Onboard payload data compression and processing for space borne imaging*. "International Journal of Remote Sensing" 2018, No. 39:7, p. 1951–1952.

[51] C. Bonnal, J.-M. Ruault, M.-C. Desjean, *Active debris removal: Recent progress and currenttrends*, "Acta Astronautica" 2013, Vol. 85, p. 53.

Finally, this analyzed problem is highly relevant in international legal terms; and it can be solved only by developing an international treaty that regulates and controls all spacecraft flight and orbital cleaning. This is legally essential to protect spacecrafts from collisions with each other and with other objects and it will also ensure future space environmental protection against space debris.

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Summary

Key words: environmental protection, space debris, space law, Outer Space Treaty.

The right to a clean environment in the twenty-first century is recognized as a human right. Therefore, states bear international responsibility for its protection, because they have legal possibilities to set legal norms, the aim of which is to pursue policies ensuring the ecological security of current and future generations – as the Constitution of the Republic of Poland provides. From the beginning of the establishment of Ius Spatiale, the problem of the delimitation of outer space and the establishment of the boundary between air and space is still actual. Based, for example, on the content of art. IX of the Outer Space Treaty, the study and research of outer space, including the Moon and other celestial bodies, should be conducted to avoid harmful contamination and also adverse changes in the environment of the

Earth. The problem of "space debris" is not only about ecology, but it is also a major economic threat to entities operating in space. The work was based on foreign literature, concerning not only the legal aspects of the above mentioned problem, but also technical issues such as the indication of specific factors affecting the environment.

Streszczenie

Ochrona środowiska w zakresie kosmicznych odpadów

Słowa kluczowe: ochrona środowiska, kosmiczne odpady, prawo kosmiczne, Traktat o przestrzeni kosmicznej.

Prawo do czystego środowiska w dobie XXI wieku stanowi jedno z praw człowieka. Na państwach ciąży zatem odpowiedzialność za jego ochronę, albowiem to one mają prawne możliwości ustanawiania norm prawnych, których celem jest zagwarantowanie obywatelom bezpieczeństwa ekologicznego, zarówno współczesnemu, jak i przyszłym pokoleniom – o czym stanowi chociażby Konstytucja RP. Od początku stanowienia *Ius Spatiale* kwestią problematyczną była (i nadal pozostaje) delimitacja przestrzeni kosmicznej i ustalenie granicy pomiędzy przestrzenią powietrzną a kosmiczną. W oparciu chociażby o treść art. IX Traktatu o przestrzeni kosmicznej, studia i badania przestrzeni kosmicznej, łącznie z Księżycem i innymi ciałami niebieskimi, winny być prowadzone w taki sposób, aby uniknąć ich szkodliwego zanieczyszczenia, jak również niekorzystnych zmian w środowisku ziemskim. Problem „kosmicznych śmieci" nie dotyczy tylko ekologii, ale w znacznym stopniu również jest zagrożeniem ekonomicznym dla podmiotów prowadzących działalność w przestrzeni kosmicznej. W pracy oparto się na literaturze zagranicznej, poruszając nie tylko aspekty prawne ww. problematyki, ale również kwestie techniczne, takie jak wskazanie konkretnych czynników oddziałujących negatywnie na środowisko.