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Space as a New Category of Threats to National Security

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Abstract

The scientific considerations presented in this paper concern threats to national security arising from the activity in outer space. The objective of this analysis is to identify these dangers and to propose solutions to minimize them.
The theoretical research methods employed in this study are: synthesis, analysis, abstracting and generalization.
In the course of the analysis, several modern threats were established, including anti-satellite and hypersonic weapons. Another important sphere discussed in the paper is the cyber security of satellite/communication devices and systems operating in space. With respect to satellite systems, the EA-18G Growler electronic warfare aircraft was presented as one of the concepts developed with the capability of disrupting their operation. The results from the conducted study emphasize the need to create a Space Domain Awareness (SDA) system, which is substantiated by the indication of natural threats that must be minimized, namely space debris, space weather and the possibility of collision with Near-Earth Objects.
The presented considerations are concluded by the analysis of the legislative state regarding space security, which in reality accentuate the incompatibility of the existing laws with the emerging threats, and other issues concerning space law.

Keywords: space, threats, state security, space law

1. Introduction

Space has always remained in the scope of military interest. Technical advancements and slowly accumulated experience have gradually allowed different actors to explore it so as to achieve various benefits or even military advantage. Similar trends are commonly observed at present. Space objects constructed nowadays surpass subsequent technological barriers: they fly higher and faster than ever before. As in the case with any technology subject to such dynamic progress, this also brings an equal share of new opportunities on the one hand, and threats on the other.

This study is devoted to the issue of space threats; therefore, it sets out to identify them and attempts to present a conceptual framework for their minimization. The specific question that drives the research is whether or not space is an environment the emergence of threats in which jeopardizes state security. In an attempt to verify this hypothesis, theoretical research methods were employed, *i.e.* synthesis, analysis, abstraction and generalization.

2. Anti-satellite weapon

Anti-satellite weapon (ASAT) is a system of missiles capable of destroying targets in space. Typically, this is a kinetic weapon, *i.e.* a solution that destroys targets by transferring large amounts of kinetic energy through the shock of impact; the amount of released energy is typically regulated by the mass of the particular object, its velocity in motion and at impact. Usually, warfare devices of this class are equipped with a special design of exploding fragmentary warheads, nuclear warheads or propellant actuated devices of a specific cone and density of fire. Since they operate in outer space to a certain length, they are equipped with gas-dynamic control systems (*Ilustrowany leksykon lotniczy. Uzbrojenie*, 1991, p. 170).

The air-launched anti-satellite multistage missile, ASM-135 ASAT, is an example of the air-to-space anti-satellite weapon. The system targeted satellites in space in a range exceeding 560 km from the carrier. It was projected to high altitude by an air platform and fired upon reaching the specified ceiling, at which point its rocket engine was initiated. At the end of the 1980s, despite positive test results, further research on this type of weapon was abandoned, the major reason for it being the implementation and development of international legal regulations related to space exploration (Dougherty, 2010, p. 17).

In the face of the growing capabilities of the United States' network of military satellites, Russian armed forces have been making substantial investments in the development of anti-satellite weapons, which in the event of war, could deprive the US and its Western partners of a critical asset. Russia's air defense forces are set to induct the S-500 Prometheus surface-to-air missile system (SAM) into service by 2020. The platform, alongside its formidable anti-aircraft and anti-missile capabilities, is also able to deploy advanced 40N6 self-homing guided missiles designed to destroy low-orbit satellites, at real altitudes of 100km. The military has also invested heavily in the development of laser-equipped satellite hunting aircraft, making use of its A-60 Airborne Laser Laboratory to develop advanced strike capabilities to target satellites from within the atmosphere. Alongside these new platforms, Russia has also carried out six flight tests of a second anti-satellite missile system, known as A-235 PL19 Nudol, with the latest tests taking place at the end of March 2018. This came shortly after the system's fifth test in December 2017, which was also successful. Nudol is designed to operate from a mobile launch platform, with test launches having been carried out from a transporter erector launcher. Mobility is key to ensuring the missile's survivability in times of war. The platform's test in March represented its fourth successful flight test, and the missile is likely to enter service in the Russian armed forces in the near future. Deployment of the system near Moscow is scheduled for late 2018.

Russia's development of anti-satellite weapons systems has been met with much apprehension in the West, with Western militaries heavily reliant on satellite capabilities to engage in power projection operations abroad. In his 2018 Worldwide Threat Assessment, US Director of National Intelligence, Dan Coats, commented on these developments: "Both Russia and China continue to pursue anti-satellite (ASAT) weapons as a means to reduce US and allied military effectiveness. Russia and China aim to have non-destructive and destructive counterspace weapons available for use during a potential future conflict… We assess that, if a future conflict were to occur involving Russia or China, either country would justify attacks against US and allied satellites as necessary to offset any perceived US military advantage derived from military, civil, or commercial space systems." Echoing director Coats' words, US Defense Intelligence Agency Director, Lt. Gen. Robert Ashley, noted that Russia was set to "continue to pursue the development of a full range of ground, air, or space-based anti-satellite weapons as a means to reduce US military effectiveness and control the escalation of conflict if deterrence fails" (*Russia Tests New Nudol Anti Satellite Missile System; Implications for the Future of Western Power Projection*, 2018).

3. Hypersonic weapon

At present, what is understood under the term **hypersonic weapon** is any combat aerial vehicle capable of developing hypersonic or high-hypersonic velocities, which is an advantage, increasing their chance of avoiding detection and tracking by the attacked party.

Currently, five countries are developing the technology in question. The USA has already launched several programs: Lockheed Martin SR-72, Boeing X-51 Waverider, Advanced Hypersonic Weapon (AHW), Hypersonic Technology Vehicle 2, HTV-3X and Boeing X-37B. France is developing the ASN4G cruise missile. The Russian Federation has three hypersonic objects in the pipeline: Avangard, AS-19 Koala air-to-surface missile and 3M22 Zircon anti-submarine hypersonic cruise missile, whereas India two – BrahMos-II and Shaurya. The People's Republic of China is developing a hypersonic glide vehicle (HGV) DF-ZF (Bielawski, 2019, p. 53). It ought to be remembered that these projects are at various stages of development – from initial concepts to actual tested designs; the latter category is represented by *e.g.* a Russian HGV Avangard, which is reported to have developed hypersonic and even high-hypersonic velocities in tests.

Modern hypersonic weapons are typically included in the Prompt Global Strike (PGS) system (Advanced Hypersonic Weapon (AHW) n.d.), whose primary objective is to demonstrate the capability to target and destroy any object on the globe in under an hour, compromising the attacked party's defensive capacity. Apart from AHWs, the PGS system includes: ICBM missiles launched from the surface or submarines; hypersonic cruise missiles launched from carriers (aircraft) or submarines (*e.g.* Boeing X-51 Waverider or AHW); kinetic weapon launched from in-orbit platforms.

With respect to the development of the defense capabilities of the Russian Federation, its new strategic system consists of six elements, hypersonic weapons being one (Trevithick, 2018). Other weapon systems essential to Russia's new military potential are: missiles equipped with nuclear warheads; an intercontinental ballistic missile, SS-28 Sarmat; an intercontinental unmanned autonomous nuclear submarine – Kanyon/Status-6; hypersonic anti-submarine missile 3M22 Zircon – engaging targets on the water surface and submerged. Finally, the last element of the system is Avangard, mentioned in the preceding paragraph, and high-energy laser (HEL), used to target: unmanned aerial systems (including swarm formations), high-altitude aircrafts, elements of satellites and electronic warfare systems.

Technology-wise, hypersonic weapons are highly advanced objects. In order to develop high velocity, they are equipped with hypersonic ramjet engines, such as the Turbine Based Combined Cycle (TBCC) propulsion system

(Walker, 2008, p. 1). In brief, this technology ensures a horizontal takeoff and landing utilizing a jet engine, which operates up to a speed of 4 Ma. Upon reaching the specified velocity, the turbine-based engine's flow channel is mechanically shut off and the ramjet/scramjet engine takes over (Greatrix, 2012, p. 1068). When the speed falls below 4 Ma, the inlet opens and the turbine propulsion engine works until the object lands on the landing site.

Hypersonic speeds entail highly elevated temperatures. The issue is resolved by the use of high-strength, low-mass, thermally durable structural materials, such as Q-fibers (Walker, 2008, pp. 2–3). These come as cuboid plates of ultrapure amorphous silica fibers, filled with air (94% by volume). They increase the thermal strength of the objects for temperatures amounting to 1357°C (Lee, 1992, p. 114). The solution is applied on surfaces under the heaviest thermal loading, the bottom surfaces of wings and fuselage, vertical fins, the leading edges of wings and vertical fins, the nose cone and the section in the region of the main propulsion system.

Along with high speeds, the issue of immediate and precise positioning emerges. Modern satellite navigation systems, including Differential Global Positioning System (DGPS), enable locating objects with increased accuracy (Grantz, 2011, p. 4). DGPS owes its high precision of exact object position indication to the differential technique. The technique involves the use of corrections transmitted by reference stations, whose position is precisely determined and known. The said reference station of DGPS system consists of: a GPS receiver, a data processing system that determines corrections and supplies navigation data, and a correction data transmitter (El-Naggar, 2015, pp. 1127–1128).

Hypersonic missile warheads may carry a conventional, thermonuclear or nuclear payload of relatively high TNT equivalence factor. In this respect, the ASMP-A hypersonic missile carries a TN81 thermonuclear warhead with a TNT equivalence factor of 300 kt, while the payload transported by Russian Avangard is known to have an equivalent blast yield of 2 Mt.

Although hypersonic missiles are to an extent protected from attacks by the sheer velocity of flight, in order to increase their safety, anti-interference systems are employed, such as the anti-jamming protector technology. The protected object is coated with partially radio-wave absorbent paint that distracts the signal from the radiolocation station (Lardier and Barensky, 2018, p. 25). Alternatively, hypersonic missiles protection can be provided by means of plasma stealth technology. The surface of the missile is covered with a plasma cloud, *i.e.* ionized gas emitted from the apparatus located at the front part of the missile. The special properties of the plasma layer allow it to deflect or absorb the electromagnetic signal discharged from radiolocation stations (Singh, Antony and Jha, 2016, pp. 10–11). This solution is believed to significantly reduce the danger of radar recognition, thus concealing the object it camouflages (Kumar and Vadera, 2017, p. 532).

The list of protective measures must not omit an essential aspect – the cyber security of hypersonic missiles. Currently, two major types of threats are recognized, jamming and spoofing. In response to these threats, the US Armed Forces have designed a special Selective Availability Anti-spoofing Module (SAASM). Since 2006, the GPS encryption module has been installed in all military GPS receivers. This device provides greater signal accuracy in the event of GPS interference. Furthermore, in an emergency both the American and European modules are capable of disabling civilian satellite navigation signal so that the only remaining signal is reserved for authorized users. In effect, should an armed conflict or other threat emerge, only state services and the army will have permission to access GPS based on these systems.

With respect to economic viability, hypersonic weapon designs must be developed under the cost-effectiveness constraint, *i.e.* their high operational effectiveness must ensure the best use of the resources. With a view to guaranteeing that the future hypersonic measures conform to the cost-effectiveness criterion, they ought to be developed with the following factors in mind (Chansoria, 2008, p. 202): implementation of new technologies; application of the assumptions of R&D (research and development) concept; dividends in terms of such factors as: speed, reliability, capability and operability – including downtime; ease of operation; reducing collateral damage; reducing the fear of escalation beyond the acceptable threshold level, as well as compatibility with various platforms (carriers). Additional requirements include: extended shelf life, the capability for incorporation as part of a network-centric battle, as well as the capability to engage multiple targets with salvo feature.

4. Cyber threats in space

The space environment is categorized as an electronic environment (Bielawski and Grenda, 2019, p. 15), and as such, it is susceptible to cyber threats. In particular, these are navigational and telecommunications satellite systems that are believed to be the most vulnerable objects of cyber-attacks in space. The attacks could be performed by means of jamming or spoofing, described in the preceding section of this paper.

The EA-18G Growler air platform is an interesting technical concept employing jamming and spoofing techniques against space objects. Jamming targets in space is analogous to the engagement of airborne objects with the use of an ASAT missile launched from an aircraft.

The EA-18G Growler aircraft is an important platform in electronic warfare. It is equipped with special payload – jamming pods, which, as in the case of conventional weapons, are attached to the under-wing pylons. One of the systems that may be carried by EA-18G is AN/ALQ-218, supplied by Northrop Grumman. It is a Tactical Jamming System (TJS) applicable at the beginning of the radio-electronic reconnaissance. It is, namely, responsible for detecting the enemy infrastructure and weapons – the technical devices (*e.g.* radar stations), anti-aircraft defense (*e.g.* SAM guided missiles) or command and communication stations. It guarantees preliminary verification of the correlation between the pre-anticipated Electronic Order of Battle (EOB) and the factual current state of events. What is understood under EOB is a set of generated assumptions that require verification *e.g.* identification of signals intelligence (SIGINT) transmitters, which constitute potential destruction targets, pinpointing their geographical location or determining their range of mobility, identification of their signal source (whether emitted by telecommunication or radiolocation devices) and, if possible, determining their broader role in the organizations of enemy forces. This *modus operandi* of AN/ALQ-218 facilitates the decision-making process, inasmuch as it enables decisions that are more accurate and reduces the commanders or personnel reaction time, thus contributing to the successful completion of the mission – jamming technical devices of hostile forces. The intelligent operation system of this jamming pod provides constant updates on SIGNIT transmitter data should the opponent decide to modify their tactic with respect to Electronic Order of Battle parameters.

The jammer consists of two independent groups of receivers, primary and auxiliary. The primary receiver group consists of four channelized and four cued receivers, which operate in tandem to provide immediate signal acquisition, accurate parameter measurement, immediate updates and precision geolocation, employing geolocation techniques by means of GPS tracking, or the IP address of a given device. In turn, the auxiliary receiver group provides an extended range of frequencies, substitutes the primary receiver in long-term measurements, helps in the recognition of intrapulse modulation and updating estimates for geolocation. The AN/ALQ-218 engages a unique combination of short, medium and long baseline interferometer techniques, *i.e.* a device responsible for measuring the interference (overlap) of electromagnetic waves, with a patented passive algorithm to provide geolocation of emitters for cueing jammers and other built-in equipment such as electro-optical sensors, IR technology and on-board radar stations (Keller, 2018).

5. Space Domain Awareness

Space Domain Awareness (SDA) is a fundamental concept, essential for virtually any involvement in space-related activities (including reaction, adaptation or prevention), which is based on the knowledge of the Space Environment (SE), its current state, anticipation of its development and knowledge about the operational environment on which these activities depend, including terrestrial and space facilities (*Joint Publication 3–14. Space Operations*, 2018).

The purpose of the SDA system is to provide in-depth characteristics as required of the space situation in both the terrestrial and the space domain. The capabilities of the SDA system are subordinate to the interdisciplinary integration of data derived from multiple sources, *e.g.* space observation, data storage, handling, analysis and processing, monitoring changes in the space environment, collecting data on the capabilities of one's own and allied space systems and their assessment, evaluation of the readiness of one's own systems, foreign and international systems, analysis of space in a broad sense.

The development of Space Awareness System responds to the emergence of phenomena that can be grouped into three categories: the presence of space debris of man-made objects, *e.g.* remains of exploded or destroyed satellites, spent rocket stages or rocket nose cones orbiting the earth, which constitute a source of potential danger for future space operations and earth-bound objects (*i.e.* Space Surveillance and Tracking – SST), natural phenomena caused by solar activity or other space objects (*i.e.* Space Weather – SWE) and the possibility of earth colliding with natural space objects, such as asteroids or near-earth comets.

The rising number of in-orbit satellites along with technological advancements leading to their astounding miniaturization significantly increase the danger of collisions within the earth's orbit. Therefore, there is a clear and growing need for more extensive and detailed information on the location of all objects orbiting the earth. In addition, analysts agree that the appearance of large constellations (from several hundred to several thousand satellites) is bound to rapidly increase the risk of such events. Being fully aware of the consequences of the described developments, the United Nations also recognizes this risk and has already taken action, which resulted in the introduction of guidelines devised with the objective of maintaining sustainable long-term access to space (COPUOS). These guidelines are addressed to states and international organizations, also to promote methods and techniques for the improvement of accuracy of space objects orbiting the Earth.

Many countries have begun to recognize that space weather and related phenomena exert a great impact on societies, human life and the economy of states, and thus they should be regarded as of considerable importance to space use. To further substantiate the assumption, we may refer to an example from the UK, where in the 2011 British National Risk Register, which outlines key civil emergencies from various spheres, severe space weather phenomena were included among newly assessed risks. Furthermore, in 2015, both the UK and the USA introduced governmental space weather programs, namely, the former – Space Weather Preparedness Strategy, while the latter National Space Weather Strategy. The documents introduce action plans, which aim to promote space weather awareness with the end purpose of ensuring national readiness in the face of future space weather events. Other European countries have begun to develop their own national regulations on space weather.

Another type of threat involves Near-Earth Objects (NEO) and possible collisions of these objects with earth. The most recent spectacular and well-documented example of the NEO's entry into the earth's atmosphere took place on 15 February 2015, near Chelyabinsk, Russia. The shockwave on the impact of the meteor caused damage to the Earth's surface and wounds in approximately 1,200 people (Zuluaga and Ferrin, 2013). That event was a harsh reminder of this type of threat, which may occur with higher frequency and could bring about catastrophic effects.

The awareness of the space domain and the ability to predict events originating from and associated with it has become increasingly urgent in recent years. Various studies show that the risks in question may generate substantial costs to ESA or EU member states, estimated at ca. EUR 2.6 billion should they not begin to counteract threats resulting from the space-weather-related phenomena alone. Secondly, the risks associated with the impacts of NEOs into the Earth's surface may involve the costs of EUR 2.23 billion (in the case of a 50-meter space object), EUR 42.8 billion in the case of a 140-meter object or even EUR 3.25 trillion in the case of an object as large as 1 km. The analyses furthermore indicate that present European observation and tracking systems (derived from individual national systems) are certainly inferior to American programs, which is why partner cooperation with the USA in this respect is yet impossible. Considering space weather, a recent study conducted in the US has indicated that power outages that may occur as a result of the Solar Storm could affect up to 66% of the US population. In monetary terms, the economic losses involved are likely to match USD 41.5 billion per day. However, considering the losses caused by disruptions in international supply chains, they could increase to an additional USD 7 billion (Chimicz, 2018, pp. 133–146).

6. Legal aspects of space security and space safety

An American lawyer, Andrew G. Haley, was the first to have postulated the need to codify space law as a set of rules transcending the existing international legal relations. He considered a "metalaw" as an alternative to the former approaches rooted in the geocentric space (cosmic) law. From the legal standpoint, the premier flight of an Earth satellite over the territories of several countries was to be carried out according to the principle of airspace sovereignty of states. The concepts of international law regulating spaceflight at that point had yet to be exhaustively defined. Although the international community was exhibiting the readiness to systematize the legal status of flights at high altitudes, these attempts were impeded by several unresolved issues, namely, the lack of a defined upper limit of airspace, the principle of innocent passage or the consent to flights of rocket propulsion devices in foreign airspace. The next step towards space law was the acceptance of the innocent passage of space objects, which, however, did not deprive states of the right to respond to an emerging threat to their own territory. What is more, the affirmation of this law was not to be understood as a case against the accepted and implemented international aviation law. The reaction of the international environment has begun to set the direction for the development of space regulations. According to the UN, the idea of differentiating space regulations and not integrating them with the law of airspace played a significant role in space legislation (Polkowska, 2011, p. 64). Since 1957, the expansion of space has begun to gain momentum, which resulted in the establishment of organizations whose activity was confined to space aspects, as in the case of the International Astronautical Federation. Regular work on the creation of space regulations began in 1958, which was when the United Nations Committee on the Peaceful Uses of Outer Space (COPUOS) was established by the UN General Assembly. That event was the milestone in the integration and consolidation of legislative work in the context of the international space law (Polkowska, 2011, p. 67).

Another notable date for the evolution of space law was 1963 – the year when the General Assembly adopted the Declaration of Legal Principles Governing the Activities of States in the Exploration and Uses of Outer Space. That resolution laid the foundation for the 1967 Outer Space Treaty. Since then, a series of legal regulations concerning the use of space have been introduced. Prior to focusing on the treaties, described below, let us consider the basic terminology associated with this area. The term is derived from English, and its semantic range encompasses numerous aspects of space flight, *i.e.* according to geographical, technical and pragmatic/functional indicators. The primary issue with respect to the geographical area is the delimitation of the border between airspace and outer space. The lack of international agreement on the issue has resulted in the emergence of three premises for the determination of the course of this border (Berezowski, 1964, p. 5). The first perspective on delimitation was closely associated with scientific and technical assumptions. The second concept assumed the demarcation of a categorical or conventional border of outer space. According to the third idea, the border was to follow from the functionality criterion. Eventually, after it had caused considerable confusion on the international arena, it was agreed that the airspace/outer space border would be set at the altitudes from approximately under one hundred to one hundred fifty kilometers above Earth. Over the course of the evolution in space technology, which has resulted in expanding our capabilities and enabled the projection of space devices at much lower altitudes, the boundary of outer space has come under modification. The terminological gap has become even more evident given the fact that the most essential documents regarding airspace and outer space, *i.e.* the 1944 Chicago Convention and the 1967 Outer Space Treaty, fail to clarify the concepts explaining the spatial spheres or the regulations that would enable their separation. The technical face of space law considered the aspects of both spacecraft, which operate as space objects and aircraft. In its current understanding, space law regulates the activity and uses of space, which are subject to international regulations, contained in five treaties prepared under the supervision of the United Nations (Polkowska, 2011, p. 71).

The intensification of space activities has brought the issue of space security to public attention. This conclusion is in a way a direct repetition of J.L. Pelton's views, for whom "space safety" is the protection of human existence and the entire space equipment and systems during a space expedition, regardless of whether the mission is manned or unmanned. This term encompasses all aspects of spaceflight, from the launch of a space object, through its on-orbit operation to the re-entry and return to Earth (Allahdadi, Rongier and Wilde, 2013, p. 5).

The wide spectrum of aspects that come into space safety required establishing specialized organs and space agencies. One such organization is the International Association for the Advancement of Space Safety, whose goals are: to develop space safety model, to refine regulations and laws relevant for space policy and to ensure that aid provisions for space mission safety emergencies are respected and implemented. On the other hand, another important term "space security" considers the use of space systems or defense facilities and methods for protecting space infrastructure against natural or human threat. This concept additionally incorporates the aspect concerned with the defense of human existence and the terrestrial ecosystem against the dangers arising from space. Therefore, from this perspective, it was of utmost importance to prepare international regulations so as to grant permission for modern military formations to penetrate space on missions that could also include space military operations.

To this day, 72 space agencies have been established worldwide, 14 states have obtained autonomous spacecraft launch systems and 60 states have placed their satellites in the Earth's orbit (OSCAR, 2019). It should be noted that the involvement of the private sector is on constant rise; as a result, it is slowly becoming the leader in space activities (telecommunications, internet and tourist weather services).

7. Conclusions

The purpose of the scientific considerations presented here was to approach space from the viewpoint of threats that may occur or originate therein. This investigation has identified space threats and presented the conceptual framework for minimizing these types of hazards. As a result, the working hypothesis, assuming that space is an environment, the emergence of threats in which jeopardizes state security, has been confirmed.

Primary modern threats determined in the study were anti-satellite (ASAT) and hypersonic weapons. These means of combat are certain to be developed further, particularly given that they have been incorporated as important elements of modern military systems: Prompt Global Strike (PGS) and the new strategic system of the Russian Federation. These modern weapons have been shown to use ramjet/scramjet engines, light construction materials of superb mechanical and thermal strength, highly accurate positioning systems as well as anti-jamming and anti-spoofing systems against radar recognition.

Cyber threat is another danger of concern to objects located in space. The solution that could ensure safety in face of cyber-attacks is theEA-18G Growler aircraft, equipped with an AN/ALQ-218 jamming pod. Since it is capable of reaching high ceiling altitudes, it could serve as a defense measure against enemy interference or engage enemy satellites by means of jamming and spoofing systems.

In order to counter the mounting natural hazards in space such as: space debris, space weather and collisions with Near-Earth Objects (asteroids, comets), there is a substantiated need to develop and implement a space domain awareness program. While various examples were given to support this claim, it is the economic aspect – the outlays to be incurred in the event of natural hazards – that emphasizes the urgent need for these problems to be addressed.

Despite several attempts having been taken to codify space law since 1957, the process is riddled with problems. To this day, for instance, the border between airspace and outer space has not been pinpointed. Furthermore, the dynamic development of space technologies implies the demand for an adaptation of international laws to modern reality – the militarization of space and the rise of the private sector in space environment. Therefore, the legal aspects relating to threats will be developed in further studies.

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References

[1] Allahdadi, F. A., Rongier, I. and Wilde, P. D. (2013) *Safety Design for Space Operations*. Elsevier. doi: 10.1016/C2010-0-65559-3.
[2] Berezowski, C. (1964) *Międzynarodowe prawo lotnicze*. Warszawa: Polskie Wydawnictwo Naukowe.
[3] Bielawski, R. (2019) 'Środki hipersoniczne jako współczesne zagrożenie bezpieczeństwa narodowego. Analiza stanu badań', *Kwartalnik Bellona*, 1(696), pp. 53–67.
[4] Bielawski, R. and Grenda, B. (2019) *Wybrane zagadnienia cyberbezpieczeństwa narodowego*. Wrocław: Exante.
[5] Chansoria, M. (2008) 'India's Integrated Guided Missile Development Programme: The BrahMos Way', pp. 199–203.
[6] Chimicz, A. (2018) 'Koncepcja rozwoju systemu świadomości sytuacyjnej w obszarze kosmosu (ang. Space Domain Awareness – SDA) w Polsce', in *Bezpieczeństwo w środowisku lotniczym i kosmicznym*. Warszawa: Semper, p. 185.
[7] Dougherty, M. J. (2010) *Nowoczesne uzbrojenie lotnicze. Podwieszenia-taktyka-technika*. Bremen: MAK.
[8] El-Naggar, A. M. (2015) 'Wavelets and triple difference as a mathematical method for filtering and mitigation of DGPS errors', *Alexandria Engineering Journal*, 54(4), pp. 1127–1134. doi: 10.1016/j.aej.2015.08.001.
[9] Grantz, A. C. (2011) 'X-37B Orbital Test Vehicle and Derivatives', in. Long Beach, California: American Institute of Aeronautics and Astronautics, p. 14.
[10] Greatrix, D. R. (2012) 'Air-Breathing Rocket Engines', in *Powered Flight: The Engineering of Aerospace Propulsion*. London: Springer London, pp. 435–456. doi: 10.1007/978-1-4471-2485-6_13.
[11] *Ilustrowany leksykon lotniczy. Uzbrojenie* (1991). Warszawa: Wydawnictwa Komunikacji i Łączności.
[12] *Joint Publication 3-14. Space Operations*. (2018). North Charleston: CreateSpace Independent Publishing Platform.
[13] Keller, J. (2018) *Electronic warfare (EW) upgrades to boost EA-18G electronic attack*. Available at: https://www.militaryaerospace.com/home/article/16707111/electronic-warfare-ew-upgrades-to-boost-ea18g-electronic-attack.
[14] Kumar, N. and Vadera, S. R. (2017) 'Stealth Materials and Technology for Airborne Systems', in Prasad, N. E. and Wanhill, R. J. H. (eds) *Aerospace Materials and Material Technologies : Volume 1: Aerospace Materials*. Singapore: Springer Singapore, pp. 519–537. doi: 10.1007/978-981-10-2134-3_24.
[15] Lardier, C. and Barensky, S. (2018) *The Proton Launcher: History and Developments*. John Wiley & Sons.
[16] Lee, S. M. (1992) *Handbook of Composite Reinforcements*. Hoboken: John Wiley & Sons. Available at: https://books.google.pl/books?id=pPirpE73tDYC.

[17] OSCAR [Observing Systems Capability Analysis and Review Tool]. (2019). 'List of all space agencies.' Available at: https://www.wmo-sat.info/oscar/spaceagencies

[18] Polkowska, M. (2011) *Prawo kosmiczne w obliczu nowych problemów współczesności*. Warszawa: Liber.

[19] *Russia Tests New Nudol Anti Satellite Missile System; Implications for the Future of Western Power Projection* (2018). Available at: https://militarywatchmagazine.com/article/russia-tests-new-nudol-anti-satellite-missile-system-implications-for-the-future-of-western-power-projection.

[20] Singh, H., Antony, S. and Jha, R. M. (2016) *Plasma-based Radar Cross Section Reduction*. Singapore: Springer Singapore (SpringerBriefs in Electrical and Computer Engineering). doi: 10.1007/978-981-287-760-4.

[21] Trevithick, J. (2018) 'Here's The Six Super Weapons Putin Unveiled During Fiery Address'. Available at: http://www.thedrive.com/the-war-zone/18906/heres-the-six-super-weapons-putin-unveiled-during-fiery-address.

[22] Walker, J. (2008) *Falcon Technology Demonstration Program HTV-3X Blackswift Test Bed*.

[23] Zuluaga, J. I. and Ferrin, I. (2013) 'A preliminary reconstruction of the orbit of the Chelyabinsk Meteoroid'. Available at: http://arxiv.org/abs/1302.5377.