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Weaponization of Outer Space: Double-Edged Blade of Dual-Use Technology

Master's thesis

Author: Bc. Jakub Pražák

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Supervisor: Mgr. Bohumil Doboš, Ph.D.

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Declaration

1. I hereby declare that I have compiled this thesis using the listed literature and resources only.
2. I hereby declare that my thesis has not been used to gain any other academic title.
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References

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Abstract

The thesis considered the feasibility of space warfare with an emphasis on the malicious potential of dual-use technology. I have described the orbital principles and set the presumptions of space warfare and the principles for space warfare strategy, introduced dual-use technology and its connections to space weapons, elaborated on existing counterspace capabilities and its impact, described the challenges for space warfare and evaluated the utilization of dual-use technology as space weapons. I have reached the conclusion that current space technology does not allow to lead extensive space warfare. However, counterspace technology is mature enough for the conduct of destructive space operations and states are encouraged to proliferate advanced offensive counterspace capabilities that are not sufficiently addressed and bounded to international law. Though, despite it seems space warfare is unlikely, the growing tensions of state space actors and rapid development of new technology that is currently mostly driven by the commercial actors may soon change the situation. Potentially destructive dual-use technology may then increase the risk and probability of space warfare. The thesis proposed several options of potentially destructive dual-technology technology that could be turned into space weapons.

Abstrakt

Diplomová práce zvážila proveditelnost vesmírné války s důrazem na zlomyslný potenciál technologií dvojího užití. Popsal jsem orbitální principy a stanovil základní podmínky pro vedení soubojů ve vesmíru, uvedl technologii dvojího užití a její spojitosti s vesmírnými zbraněmi, posoudil současné counterspace schopnosti, vymezil výzvy a komplikace pro vesmírný boj a zhodnotil možnosti využití technologií dvojího užití jako vesmírných zbraní. Došel jsem k závěru, že současná technologie neumožňuje vést rozsáhlou vesmírnou válku. Současná counterspace technologie je avšak dostatečně vyspělá pro vedení ničivých vesmírných operací a státy jsou odhodlané vyvíjet útočné counterspace prostředky, jejichž proliferace není dostatečně ukotvena a omezena mezinárodním právem. Ačkoliv vesmírná válka se v současné době jeví jako nepravděpodobná, narůstající napětí mezi vesmírnými aktéry a prudký rozvoj nových vesmírných technologií vyvíjených komerčním sektorem tuto situaci může brzy změnit. Ničivý potenciál technologií dvojího užití pak navyšuje rizika a pravděpodobnost vesmírné války. Diplomová práce navrhla několik možností, jak by technologie dvojího užití mohla být využita k ničivým účelům a mohla být proměněna ve vesmírné zbraně.

Keywords

Outer Space, Space Security, Dual-Use, Space Weapon, Counterspace, Space Warfare, Weaponization, ASAT

Klíčová slova

Vesmír, vesmírná bezpečnost, dual-use, vesmírná zbraň, counterspace, orbitální boj, weaponization, ASAT

Název práce

Uvedení zbraní do vesmírného prostoru: Dvojsečné ostří technologií s dvojím využitím

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1. Introduction

Outer space is after sea, land, and air (and followed by cyberspace) considered as a fourth independent strategic domain. Technological development and its exploitation during the previous century brought up many new issues with further strategic consequences. Thus, the actors had to adapt to the new environment (Lonsdale, 1999, pp. 137-139). However, the dynamics of outer space are in constant progress and regarding many challenges. Presumably, outer space has been militarized but not weaponized. Notwithstanding, it would be rather short-sighted to deem outer space as a sanctuary in the future (Bartels, 2018). Despite sources suggesting there are no weapons placed in outer space (Krepon and Kazt-Hyman, 2005, p. 325), Johnson-Freese estimated 95 % of space technology have both, military and civilian implications (Johnson-Freese, 2006, p. 131). The dual-use nature of space technology may raise serious concerns about their utilization. The central argument of my thesis claims that at least some space technology could be actually easily turned into offensive capabilities. Thus, seemingly non-weapon related technology may have destructive and warfighting potential and arguably, the concept and definition of space weapons should be reconsidered.

The contemporary outer space expansion may be characterized and is being stressed especially in the United States (U.S.) strategy by "triple C" - outer space is a congested, contested and competitive strategic domain. Increased congestion has been caused by the considerable amount of space debris that is still rising. Contested, since more actors are willing to penetrate into outer space and test their counterspace capabilities, and competitiveness because the U.S. are losing their share on the space market and more states and commercial actors are trying to exploit outer space for profits and prestige (Space Foundation, 2011; Harrison, 2013, pp. 123-131). Joan Johnson-Freese (2017, pp. 48-49) argues that contested outer space implied the aggressive, zero-sum approach to the space environment. Many militaries believe in the inevitability of space warfare and in such a case, it is utmost appropriate to be prepared to strike first and develop “offensive counterspace” programs (Johnson-Freese, 2017, p. 49). On the other hand, if we consider space warfare would be evadable, the focus and should be then given on “defend and defeat” programs that, however, *“may serve as little more than totems of protection”* (Johnson-Freese, 2017, p. 49). Thus, the debate about the implications of space warfare is a highly relevant research topic.

Mankind is increasingly dependent on various satellite services such as navigation, communication, weather, military support, or enhancement applications (Milowicki and Johnson-Freese, 2008, p. 17). The satellites are located in Earth's orbit in the altitude between approximately 200 km and 36 000 km. In 2018, almost 2 000 operational satellites were orbiting Earth, with the leading share of the U.S. systems. Most of the satellites (about 1 200) are located in low Earth orbit (LEO) in the altitude between 200 km and 2 000 km.[1] More than 500 satellites are then in the geosynchronous orbit (GEO) in the altitude of approximately 36 000 km. The rest orbit in medium Earth orbit (MEO) and elliptical orbits (Union of Concerned Scientists, 2019). LEO is useful mainly for remote-sensing, meteorological, electro-optical, infrared and radar-intelligence satellites. In MEO and GEO then orbits navigation and guidance satellites, military communications platforms and early-warning and nuclear-detonation detection systems (Tellis, 2007, pp. 53-54). However, the satellites are rather fragile systems and disruption of any of their components may easily lead to their dysfunction or loss of control. The repairs of disrupted satellites would be a complicated process, thus, eventually, it would be more convenient to replace destroyed satellite with a new one (Stein, 1988, pp. 49-51). Therefore, the interruption of a satellite network could have serious implications not only for space, but also for Earth's security.

1.1. Methodology

My thesis will be written as a case study focused on the development of space technology. The thesis will explain the interconnections between the military and civilian uses of outer space. While most space systems are primarily deployed for "peaceful" or civilian exploitation, some of them may be turned into harmful devices. Therefore, the risks of dual-use technology, should be considered, and, how destructive they can be, as well as if they can be utilized as space weapons. The possibilities of space warfare have been proven by successful kinetic direct-ascent anti-satellite (DA-ASAT) tests that are deemed to be space weapons (Ensuring Space Security, 2006, p. 1), however, considering only kinetic DA-ASAT weapons, the impact in conflict would be only limited. Thereby, in my thesis, I intend to incorporate space assets that are not generally considered as weapons as well as to evaluate the practical utilization of existing counterspace capabilities for space warfare. Counterspace capabilities *"can be used to deceive, disrupt, deny, degrade, or destroy*

[1] The dispersion may vary according to the author

space systems” (Weeden and Samson, 2018, p. x). Center for Strategic & International Studies addresses the counterspace capabilities as weapons that *“vary significantly in the types of effects they create, the level of technological sophistication required to conceive them, and the level of resources needed to develop and deploy them. Counterspace weapons also differ in how they are employed and how difficult they are to detect and attribute. The effects of these weapons can also be temporary or permanent depending on the type of system and how it is used”* (Harrison et al., 2018, p. 2). However, both definitions are suggesting that counterspace capabilities involve broader scope of instruments such as cyber espionage that can focus on both space-based and Earth-based components but do not necessarily have destructive or irreversible potential. Space weapons can be thus perceived as a subset of counterspace capabilities. Therefore, I will elaborate on counterpace capabilities, space weapons definition and dual-use problematics later in the thesis as a part of the research.

My primary research question states:

- Is existing space technology plausible for the conduct of extensive space warfare?

For this research question, I will consider operational ASAT weapons as well as a counterspace and dual-use technology. I take into consideration the impact of the utilization of such technology and its feasibility.

My secondary research question states:

- Which of the space assets could be turned into effective space weapons?

In my thesis, I intend to apply a realistic approach to outer space rivalry. Specifically, I will utilize Dolman's outer space analysis of space to the possible exploitation of space systems as space weapons. For the theoretical background about basic orbital movement and different kinds of orbits for particular purposes, I will primarily derive from the books and articles by Everett Dolman and Howard Kleinberg. For the evaluation of counterspace capabilities, I will mostly consider the assessments written by the Secure World Foundation and Center for Strategic and International Studies. Johnson-Freese then in her books provided a substantial background about space dual-use technology. To evaluate its implications, I took into consideration various open sources. My intention will be to reveal whether the current space systems are able to gain an advantage in the space sector through military offensive actions.

I will consider outer space as a warfighting domain with the proven existence of possible space weapons. I reckon I will recognize the considerable limits and boundaries of space warfare, nevertheless, I aim to distinguish, or at least outline the opportunities for space military operations.

The primary research question will be answered positively if I conclude that an actor is able to successfully attack the enemy systems with considerably greater damage than caused to itself or, in case of identification of relevant spoiler actors, to be capable to avert access to outer space to its adversary. For the positive answer to the research question, some criteria have to be met. The outcome of the offensive action has to provide a visible advantage over the opponent. Moreover, the attack should result in damage to enemy systems, yet, own systems should be preserved or only be minorly affected. By *extensive* is understanding space warfare with global impact leading to space superiority by one actor.

The secondary research question will evaluate the utility of space assets as space weapons. Effective space weapons should be able to successfully destroy or irreversibly damage or overtake enemy system.

In my thesis, firstly, I will theoretically describe the proposed space warfare strategies and introduce the thinking about approaches to outer space and set the premises on space warfare. Secondly, I will elaborate on the problematics of dual-use technology regarding their utilization as space weapons. Following, I will introduce the existing counterspace technology of the major space actors that could be involved in space warfare. Subsequently, I will characterize the dual-use technology that could be exploited for the proliferation of space weapon technology. After that, I will include the challenges for space warfare that are represented by the doctrines and behaviour of space actor developing counterspace technology, space law and the proliferation of space debris. Finally, I will evaluate the space warfare feasibility, interpret the results and answer the research questions.

My methodology differs from the project in some minor points. I involved all the elements promised in the project, however, unlike the planned thesis methodology, I put greater emphasizes on offensive counterspace capabilities, space weapons and their development and put aside the specific space warfare scenario making based on the debris modelling for two reasons. Firstly, the understanding of the development of counterspace technology was eventually more relevant for answering the research questions. Secondly, the scenarios would require a further study that would outreach the scope of the thesis and would be more suitable for a more comprehensive study regarding the quantitative research. Notwithstanding, all the promised aspects from the project are incorporated in the thesis and the space debris and other challenges for space warfare with specific cases were not omitted. The outline of the thesis remained, and the result of these changes is that the thesis is formulated as a case study instead of comparative case study that I believe contributed to the more accurate results of the thesis.

2. Theoretical Approaches to Outer Space and Premises for Space Warfare

Many authors have discussed and attempted to outline the basic principles of space warfare. Outer space is an independent strategic domain with its specifics. However, similarly to other domains, it has its limitations and boundaries. In this chapter, I intend to introduce the fundamental principles to space warfare and its presumptions. Subsequently, I will present theoretical approaches to space warfare and considerations for the war in space.

2.1. On War in Space

Howard Kleinberg (2007) in his article "On War in Space" set the principles and assumptions for the conduct of space warfare. Moreover, he did not only focus on the space domain itself but put it in contrast to other traditional domains – land, sea, and air. Thus, he provided analysis that described the evolution of space warfare theory and enables to propose his own space warfare strategy based on the more recent trends in space technology advancement.

First of all, before the Kleinberg narrating space warfare itself, he mentions important highlights valid for all kinds of warfare. He stresses the works of Sun-Tzu and Liddell-Hart, who both emphasize the importance of deception and believe the ultimate goal is to reach strategic advantage and break the enemy forces without actual fighting. For that, it is vital to exploit enemy weaknesses and wisely incorporate and maximize all your own capacities (Kleinberg, 2007, pp. 2-5).

The framework for a comprehensive space warfare strategy lacks sufficient empirical evidence. Therefore, authors mostly derived from other well-described domains – land, sea, and air. Considering naval strategies, for instance, Martin France proposed to draw upon Mahan's knowledge and John Klein recommends Corbett's thoughts. From Corbett, we may easily distinguish several aspects plausible for the space environment. Outer space has its own Lines of Communication (LOCs), Common Routes, Choke Points, or Harbor Access. LOCs are the connections between the home territory and forces in the field. Cutting those lines will disrupt the enemy's supply, reinforcement and communication, eventually, disrupt his ability to carry on fighting. Space common routes include orbits that regularly overfly any given point to achieve their mission, this could be, for example, geostationary or geosynchronous orbit. Choke points can find equivalents in ground stations, launch facilities and transit routes through low Earth orbit. As harbours can be similarly considered space launch facilities. Satellites as space platforms are then the critical element of the overall space system. The situation in space is, however, more complex since everything is happening in constant motion with high velocities. Three-dimensional movement and difficult manoeuvring without significant geographical limits such as coastlines or sea-beds complicating space-sea analogy. Similar restraints are valid for space-land comparison. It is practically impossible to hold a specific point or location in space and the movement is always performed around the globe in the fixed path, the change in orbit requires a considerable amount of limited onboard propellant. Satellites could have more similarities with naval vessels since both can cross their domains for months in comparison to the aircraft, however, even the aircraft can be refuelled in the air and new technology such as nuclear propulsion could lessen their dependence on airfields (Kleinberg, 2007, pp. 5-17).

On the other hand, air analogy can provide additional insights and similarities. For instance, naval harbours are fixed, however, Command, Control, and Communication (C3) can be fixed or mobile for both air and space systems. Aircraft carriers are then mobile equivalent of an airfield. Inter-continental ballistic missiles (ICBMs) are an example of technology that can be mobile and penetrate into air and space domain. Mobile C3 components can be applied for space systems as well. Airspace enables 3-dimensional movement and the projection of airpower is in comparison to land, and sea, which mostly operate in their own theatre of war, on a global level. Worth noting, air was originally exploited primarily for reconnaissance, likewise outer space, nevertheless, air warfare soon took place and this could be a later case of outer space. However, the space movement remains more complex and global in nature. There is no local theatre of war for outer space and outer space always stands above the other domains (Kleinberg, 2007, pp. 5-17).

While the naval warfare theory provides a basic outline for the understanding of the space environment, the air can describe conditions in outer space more precisely. An important feature of air warfare strategies valid for outer space is the ability to strike all over enemy territory through battlefield dominance and the combination of efficient offensive capabilities to strike and defensive to protect own air space. Center of Gravities (COGs) refers to the critical elements with vital warfighting or governing capability that disruption would cripple the enemy. Optimal air strike should, therefore, focus and on enemy's COGs and LOCs. The key is to find what is most valuable and promptly target it. Though such precision and promptness have universal meaning, air can multiply the effect. The same could be stated for the space warfare strategy (Kleinberg, 2007, pp. 5-17). In the end, I would like to point out that such comparisons should not be taken ultimately since space is an independent domain with its own features and the technological development can shape its dynamics (Mendenhall, 2018, pp. 97-118).

Based on previous knowledge, Kleinberg himself proposed basic principles for space warfare I would like to consider later in my thesis:

- "Space overarches all other media, and is always global in nature.
- Objects in space are in regular, unceasing motion around the entire globe on a regular basis.
- Space is a national COG; those who have it have a strategic advantage over those who do not.
- Space is the ultimate high ground and its exploitation must thus serve to support and integrate operations in all terrestrial media.
- Control of space is essential. Missions in this category include protecting friendly space assets, and denying the use of space to enemies.
- Space COGs are comprised of two types of items, satellites and terrestrial facilities. Of these, satellites represent the most important items, as they provide the most critical capabilities.
- Space LOCs are made of two types of items, information and trajectories. Information links satellites and weapons to their operators, and brings globe-spanning Situational Awareness to the warfighter. Trajectories link launching missiles to their intended orbits, and orbiting satellites to their missions.
- Interactions between objects in space involve either aligning or intersecting orbital paths; maneuvering is limited to varying orbital paths.
- Combat in space can be accomplished by attacking the enemy's space LOCs, COGs, or both.
- Technology drives and enables all space operations and warfare" (Kleinberg, 2007, pp. 17-18).

All of these aspects should be borne in mind when discussing the space warfare strategy and proposing the possibilities and feasibility of any kind of space weapon.

2.2. Towards the Space Warfare Strategy

Everett C. Dolman in this article Geostrategy in the space age: An astropolitical analysis (1999) described the critical orbits and regions and proposed the geopolitical reflections for the space dominance. He later broadened his thoughts in the book Astropolitik: Classical

Geopolitics in the Space Age (2002). Similarly to Kleinberg, Dolman was aware of the analogies with other domains and also referred to the features such lines of communication, space chokepoint, common space routes etc. However, he went further with his analysis and came up with so-called neo-classical astropolitics that corresponds with realist IR theories applied a for an outer space environment.

Apart from points mentioned by Kleinberg, for the theory of space warfare, it is important to know the basics of orbital mechanics, since the satellites are moving in orbital paths. The space assets located in the stable orbit do not exhaust any fuel. Orbits are characterized by their altitude and eccentricity. The lowest point of orbit is called perigee and the highest apogee. Thus, orbits may be described as circular, with constant altitude and, therefore, the same apogee and perigee or elliptical, with varying altitude and eccentricity. Generally, the higher the altitude, the slower and more stable the orbit is. Lower orbits provide a more detailed view, a higher wider scope. The elliptical orbit is usually utilized for the observation of critical points on Earth, usually in apogee or perigee. Worth noting, inclination defines the north and south latitude limits of the orbit. Satellite in the equatorial plane has an inclination of 0°, the most vertical ascension of 90° is a polar orbit. Posigrade are called inclinations below 90° that are drifting eastward and retrograde are inclinations above 90° drifting westward (Dolman, 1999, pp. 84-89).

Low Earth orbits are generally between 150 to 800 km. They are most suitable for Earth reconnaissance, especially for military observation and resource management and for manned flights. Medium Earth orbits (MEO) are from approximately 800 km up to 35 000 km. Navigational satellites are located here. Above 35 000 km are high Earth orbits (HEO). They provide maximum continuous coverage over the Earth and are utilized for global communication and weather satellites. Geosynchronous orbit (GEO) is an orbit with an orbital period of one day. If this orbit has 0° inclination it is called geostationary orbit, meaning it looks fixed from any given point on Earth. Only 3 satellites in geostationary orbit can observe whole Earth up to the latitude of 70° north or south. Above inclination of 70°, the Earth cannot be covered from the geostationary orbit. The solution is to place the satellite on some kind of highly elliptical orbit that can have perigee low as 250 km and can reach to an altitude of 700 000 km at apogee. Another specific of this orbit is that the orbital speed is much slower in apogee in comparison to perigee. Therefore, at the highest point, they may observe Earth for a relatively long period of time. With apogee at 36 000 – 40 000 km the satellites are moving with a velocity of 3 000 miles per hour in the lowest point and 20 000 miles per hour in the highest altitude. As a consequence, only three satellites are required for continuous connection with the ground station at the same latitude. For instance, The Russians widely exploited the semi-synchronous so-called Molnyia orbit with an orbital period of 12 hours for communication and weather satellites. Highly elliptical orbit with apogee over 700 000 km are suitable for scientific missions (Dolman, 1999, pp. 84-89).

Considering the strategic significance of outer space, Dolman derived from Mackinder's Heartland theory. According to Mackinder, world rule could be achieved by dominating the heartland, strategic land region with vast resources desirable to conquer other nations. Mackinder divided the world into three regions. Heartland or pivot area, inner crescent, and outer crescent. Mackinder summed up his thought into a simple formula: *"Who rules East Europe Controls the Heartland. Who rules the Heartland commands the World Island. Who rules the World Island commands the World"* (Dolman, 1999, p. 91). If the state is unable to control the heartland, it must ensure the denial of access to potential adversaries. Important to mention, Mackinder recognized the importance of technology at the turn of the 19th and 20th century, in his era specifically the development of railroads, enabling the shift of power from the sea back to the land, where the train dramatically increased the mobility and surpassed the advantage of ships, eventually permitting the dominance above both, land and sea domain (Dolman, 1999, pp. 89-93).

Dolman was very well aware of the prospects of exploitation of outer space to gain control over the Earth and the resources outer space provides. In accordance with that, he set four astropolitical regions – *Terra or Earth; Terran* or *Earth Space; Lunar* or *Moon Space;* and *Solar Space*.

Terra or *Earth* is the region below the threshold of viable orbit. It is a critical area through which all objects entering to/ or re-entering from outer space must cross. It is the only region that includes traditional topography. Terra includes space launches, command and control, tracking, data downlink, research and development, production, anti-satellite, and most servicing, repair, and storage operations. *Earth Space* is spreading from the lowest stable orbits beyond the geostationary orbit to approximately 36 000 km. This is the region where satellites are stationed and it is the area space military operations as well a place of current or planned space-based weaponry. At the lowest altitudes are passing through ballistic missiles and at the peak are geostationary satellites. Up the geostationary orbit just beyond the Earth's Moon is *Moon Space.* Then, *Solar Space* is the rest of the solar system and the decisive area of interest for the future in terms of space colonization but also the source of raw materials and resources. According to Dolman, Solar Space represents Mackinder’s heartland and the Earth Space is the critical location for access to it. From Earth Space, the actor has access to Solar Space but also possesses the dominance over Earth and, thus, holds the “high ground” (Dolman, 1999, pp. 92-93).

However, to achieve so is no easy task, since the outer has also its own geographical limits. The distance is not so determining as the propulsion requirements. The crucial factor is the gravity, specifically gravity wells. The more massive the object, the deeper the well is. In practical terms, Dolman states the example that the gravity well of Earth is 22 times deeper as in the case of Moon, therefore, it demands 22 times less effort to travel 35 000 km from the surface of the Moon than from the surface of the Earth. Thus, to propel the spacecraft from Moon to Mars would be much cheaper than the costs of propulsion for a vehicle travelling from the Earth´s surface to the Moon, albeit the distance of the latter is much shorter. Similarly, the further the spacecraft from Earth is, the less propulsion is required for movement. For the transition to higher orbit a two phase manoeuvre via Hohmann transfer orbit is then usually conducted, sparing propulsion (Dolman, 1999, pp. 93-99).

As mentioned authors argued, outer space encompasses lines of communications, common routes, chokepoint etc. Mahan's claimed for the sea dominance, a state does not have to occupy every given point, moreover, it is infeasible. The best strategy is to take over chokepoints and critical locations that can be done with a limited amount of forces. The similar strategy of control can be applied for outer space. Critical regions involve for instance LEO or geostationary orbit. Geostrategic thinkers of naval and air warfare, namely Alfred Thayer Mahan and Giulio Douhet, in addition, recognized the advantage of forward bases that should support naval and air operations. In space, we may find five location known as *“Lagrange Libration Points”* with significant strategic value because the asset in this position remains permanently stably due to gravitational effects of Earth and Moon, without the exhaustion of propulsion. Although there are overall five of those points, only the two of them (L4 and L5) are constantly stable without space environment perturbation. Besides, close to Earth are two[2] *“Van Allen radiation belts”* with high radiation endangering spacecraft and manned crews. Fortunately, those belts are well-mapped and can be avoided (Dolman, 1999, pp. 93-99).

[2] Recently, the third belt was discovered; see https://physicsworld.com/a/new-radiation-ring-spotted-in-van-allen-belt/

Finally, it is suitable to mention some strategic consequences for Earth. The equator is the most appropriate place for launches especially towards geostationary orbit because it can exploit the Earth's rotational force. A rocket launched from the French Space Center at Kourou, French Guiana, that is only 5° north of the equator has 17 % percent less fuel consumption than a rocket launched from the American Cape Canaveral located 28,5° north of the equator. The launch latitude defines the minimum inclination due east and maximum inclination due west. Accordingly, a launch from Cape Canaveral enters LEO with inclination due east at an inclination of 28,3° (greater azimuth would increase that) and maximum inclination due west at an inclination of 151,7° (180° minus 28,3°). A launch due north and south would set the inclination of 90° in polar orbit. The polar orbit is convenient for Earth's reconnaissance. If the satellite is placed in a somewhat retrograde motion, the satellite will fly over every point on the Earth and will be in the sunlight at all times that is convenient for the observation and power. Space centres that can launch rockets both east and north or south direction are at an advantage. Considering lower stages usually fall down back to the ground, the area of 1 000 km in the direction of launch should be unpopulated. Thus, eligible strategic locations are Brazil, the east coast of Kenya, and any of several Pacific islands east of New Guinea. Moreover, orbits at an inclination of 63,4° and 116,6° are more stable than others, again saving fuel due to fewer correction manoeuvres. Convenient areas for launch are Alaska and northwest Siberia. Russian spaceport Plesetsk is located at exact 63,4° latitude (Dolman, 1999, pp. 99-103).

The geostationary orbit is in a constant position relative to the surface of Earth. If we want to have global coverage over the regions between 70° north and south latitude, at least three satellites are required. However, areas above 70° are not visible from this position, making impossible to have surveillance over Scandinavia, Russia, and Canada. For the truly global coverage, at least four satellites placed at specific 63,4° inclination super-synchronous (greater than 24-hour) orbits, nevertheless, they require strong transmitters for communication and due to the distance are not suitable, for example, for high-resolution imagery. The lower the altitude, the more satellites are required for the coverage. Navigational satellites that demand access to four satellites at any point to provide accurate geolocations consist of a constellation of at least 21 satellites placed at semi-synchronous orbit (12-hour) at the altitude of 24 000 km. To maintain communication with the space systems, at least 3 ground control stations are necessary for the contact with HEO and 16 for LEO. Thus, the United States has their stations in Australia and Spain and Russia has deployed control ships (Dolman, 1999, pp. 99-103).

2.3. Space Warfare Strategy?

Dolman (2002, pp. 147-151) claims there is a scarcity of coherent space strategies, despite the interest in space domination since 1946. Already in 1961, the astronomical community generally agreed on outer space consists of strategic locations that could be compared to the strategic importance of the Panama Canal. The debates resulted in the creation of first two space schools of thoughts – sanctuary and high ground. Although the idea of space as sanctuary sounds appealing, the experts were from the beginning well aware of the space militarization that could outcome in weaponization. Therefore, David Zeigler argued space will remain sanctuary "so long as nations truly intended never to use space weapons" (Dolman, 2002, p. 148). Yet, despite the claims of space sanctuary policy by space leading actors, the thought of space weapons development and its utilization stayed in state's secrecy. However, Zeigler reached the conclusion the space weapons would be inconvenient and cost-inefficient. Nevertheless, in 1997, former Commander-in-Chief of US Space Command General Joseph Ashly proclaimed the U.S. is reliant on space systems, making them likely to be a target of attack and the U.S. "must be prepared to defend these systems" (Dolman, 2002, p. 149), presuming space warfare will take place. Moreover, that time the U.S. depended on multi-mission satellites that could be possibly disrupted and Russia still operated co-orbital ASAT facilities. Arthur C. Clark described the 1991 Gulf War as "the world's first satellite war" (Dolman, 2002, p. 149). Since then, the space systems efficiency is still increasing and previously underestimated functions such as navigation, communications, commercial imaging or weather prediction satellites are indispensable. Military operations are dependent on space technology and provide important Command, Control, Communications and Intelligence (C3I) and other mission support. Dolman argues "… space warfare has emerged from its embryonic stage and is now fully in its infancy" (Dolman, 2002, p. 150). At the same time, the calls for space as a sanctuary are still heard (Dolman, 2002, pp. 148-151). Thus, the question of the status of outer space remains open.

2.4. Existing Schools of Thoughts

As stated above, it is difficult to formulate a feasible space warfare strategy. Albeit, up to date, no war in outer space has taken place, the power shifts and technological development may turn the tables towards the enhanced space weapons development and further demand for the coherent space warfare strategy that could be practically applied. As mentioned, outer space could be potentially occupied and held by force. However, apart from that, various schools of thoughts by different authors describing how outer space should be approached have been proposed. To provide an overview, I will briefly refer to some of them.

2.4.1. Schools of Thoughts by James C. Moltz

To give a broader picture on the strategic perception of outer space, I will firstly conclude the existing schools of thoughts according to James Clay Moltz (2011), who distinguished four schools, sorted from the most conflictual to most cooperative – *space nationalism, technological determinism, social interactionism* and *global institutionalism.*

2.4.1.1. Space Nationalism

Space nationalism perspective derives from the state's rivalry and military programs that were already conducted during the Second World War and later enabled the beginning of the space age in 1957. Assumptions of space nationalism were adopted by many authors, among others by Dolman (2002) or Klein (2006). This school of thought considers space domain will be contested as were other domains before, rejecting the possibility of enhanced cooperation. Its essence is the realist approach and roots in authors such as Thucydides, Machiavelli, or Hobbs. Space nationalism argues the U.S. and USSR did not weaponize the outer space not because of the cooperation efforts but due to the situational and technological inconvenience, presuming space will be eventually weaponized when advanced technology will be available. Space nationalism is strongly military driven, aimed to gain a geostrategic advantage, refusing the transformative role of international organizations, non-governmental organizations or transnational corporations. For later consideration, arms control and other weapon-limiting regimes are generally inefficient, except those which are conducted with detailed verification or inspection (Moltz, 2011, pp. 24-27).

2.4.1.2. Global institutionalism

Based on the Kantian thought of "perpetual peace" and Grotius' idea in human desire for peaceful society, supporters of global institutionalism believe in cooperation and peace in outer space. Outer space may remain a sanctuary achieved by shared human and scientific thinking, fostered by international organizations and treaties. Via the methods of transnational governance mankind can overcome the pattern of terrestrial conflicts and achieve peace beyond Earth. Realism is already outdated and cooperation is more probably than a competition. The treaties regarding the exploitation and access to outer space in the 1960s encouraged the thoughts, however, the 1970s development with enhanced space military testing shifted from idealistic notions to the neoliberal assumption of possible cooperation due to the cooperative treaties and international organizations. Nowadays, there are calls for legal instruments and space arms treaties that could support the thoughts of global institutionalism. For instance, German legal scholar Detlev Wolter proposed the negotiations over a Cooperative Security in Outer Space Treaty and establishment of International Organization that should implement new agreement, however, the results of such proposals and calls remain unclear (Moltz, 2011, pp. 27-31).

2.4.1.3. Technological Determinism

For the technological determinism, the technology and its structural content are more important than political processes. Space technological development may either result in the improvement of everyday life or in the creation of new means of destruction. In the Cold War, the U.S. technological optimists claimed the cooperation will be inevitable since the technological complexity, cost and destructive potential of space assets will eventually lead to the convergence of the society and broadened collaboration to face space challenges. The Soviet counterparts have suggested the space technology will lead society beyond conflicts via scientific-technological revolution and result in the establishment of the single world class. The pessimists argued it is problematic to stop development of weapon technology. The desire for the arms development within the military-industrial and research complexes have an overwhelming effect on policy-decision processes that are driven by the fear of state's protection. Another opinion pointed out the state's economic and strategic calculations have an impact on the level of cooperation. The final issue regarding technological determinism is the likely weaponization of space. The current dynamics in development suggests gradual weaponization of space that can be, according to technological determinists, managed by appropriate negotiations and communication (Moltz, 2011, pp. 31-37).

2.4.1.4. Social Interactionism

Briefly, social interactionists assert the reasonable interactions between states may reduce the risk of conflict and promote cooperation. However, such collaboration can be difficult and have to oblige concurrent conditions. Thus, for instance, the arms control treaties are not necessarily the best solution if the negotiations would be doomed to fail. Instead, the manners should be pushed towards responsible behaviour that would lead to the construction of the code of conduct among the space actors rather than perceive and present others as a constant threat. Nevertheless, the U.S. withdrawal from the ABM Treaty in 2002 or the Chinese ASAT test 2007 may suggest the space norms are not mature enough. A better understanding of the hazards of the space environment could improve the attitudes of the actors (Moltz, 2011, pp. 37-40).

2.4.2. Schools of Thoughts by John J. Klein

Apart from using various naval/ air frameworks, John J. Klein (2014) recognized four schools of thoughts – *sanctuary, survivability, high-ground,* and *control.* Very briefly, *sanctuary* advocates outer space as war and weapon-free zone. *Survivability* school argues space systems cannot protect themselves. They are vulnerable to long-range weapons, cannot efficiently manoeuvre, or hide behind barriers. Moreover, they do not have political importance and their destruction would not result in a retaliatory strike. Hence, space must not provide essential military functions because they would not survive a hostile attack. *High ground* claims the opposite. Space forces should be the dominant force with offensive and missile defence capabilities to get supremacy over lower areas. *Control* accepts the naval and air strategic analogies such as lines communication. Space operations are the same as sea, air, and land, however, space control is fundamental to successful surface military operations (Klein, 2014, pp. 16-19).

Notwithstanding, Klein argues *sanctuary, survivability,* and *high-ground* are useful for the space weaponization debate but cannot contribute to formulating convincing space warfare strategy. *Control* school seems to be more suitable since it applies naval and air strategies. On the other hand, Klein claims these thoughts were not sufficiently developed and do not provide any further explanations. The author himself proposed the maritime framework for the constitution of space warfare strategy, though, advocating nor naval, air or maritime framework could encompass space environment and are helpful only for fundamental concepts (Klein, 2014, pp. 16-20).

2.4.3. Schools of Thoughts by Joan Johnson-Freese

Johnson-Freese (2007) acknowledges four schools of thought concerning space weaponization. The first perceive space as an ultimate high ground; second claims space weaponization is inevitable, therefore, the U.S. should prepare themselves; third, space should be only militarized by passive systems, or occupied by defence systems through arms controls and agreements; and last, space should be maintained as a sanctuary.

However, Johnson-Freese disagrees outer space would provide ultimate high ground over Earth due to the hostile space environment. Despite outer space grants certain advantages, drawbacks such as openness of space or determined tracks of space asset would make it difficult. Worth noting, missile defence systems could be much easily exploited as ASAT due to the predictability of satellite targets. Similarly, it is questionable to claim the space war will inevitably take place on one hand, and naïve to believe in space sanctuary on the other. What should be of concern for the thesis is the viability of arms control option. The argument states the proliferation of space weapons would be eventually disadvantageous for the U.S. since the U.S. possess most of the space systems that are extremely vulnerable, moreover, the application of space weapons would result in the creation of space debris endangering all the space systems. Efforts of arms control treaties are pursued due to the concerns of states about having weapons constantly above them. However, Dolman proposed the U.S. space weaponization and control of outer space could contribute to the commercial and civilian uses of outer space. Simultaneously, this would question open competition and security concerns of other states. Finally, any arms control endeavours are limited by the dual-use potential of space technology. It is practically impossible to tell, whether the missile defence is not an ASAT technology or if the navigational constellation will not guide other weapons (Johnson-Freese, 2007, pp. 131-136).

In my thesis, I intend to give special attention to the opportunity to exploit outer space as an ultimate high ground. In compliance with the orbital principles for space warfare, I will consider the options for the current space technology to get control over the *Terra* and *Terran Space*.

3. Dual-Use Technology

In this chapter, I will focus on the utilization of dual-use technology. Space or space-related technology is part of everyday life more than most people think through space services via, for instance, weather or communication satellites or through technology developed originally for space systems. Many technologies are beneficial for both – commercial-civilian and military purposes (Johnson-Freese, 2007, p. 27). Johnson-Freese addressed to the U.S. Department of Defence (DoD) dual-use technology definition as *"(...) a technology, that has both military utility and sufficient commercial potential to support a viable industrial base"* (Johnson-Freese, 2007, p. 28). Until the end of the Cold War, the U.S. space industry was divided into four sectors – military, intelligence, civilian, and commercial. However, after the Cold War Department of Defence became visibly interested in dual-use capabilities. Moreover, the role of the commercial sector changed rapidly during recent years and got significant importance. Specifically in the case of the U.S., the government does not need to invest in technologies that were already researched and development by commercial actors. For that, the U.S. government established the Dual Use Science and Technology program to ensure its access to dual-use technology and both government and military are dependant to commercial technology. On the other hand, commercial technology is available to many other customers and actors. For example, during Operation Iraqi Freedom, Saddam Hussein obtained Russian-made jamming equipment on the Internet and utilized it against the U.S. (Johnson-Freese, 2007, pp. 26-30).

Johnson-Freese argues that 95 % of space technology is dual-use. She states the examples of civil and military space-related technology, concluding only the planet and solar physics research has clear civil utilization. Nevertheless, even this technology may have military implications in the future. Some dual-use capabilities are clear – military rockets, launchers and missiles are based on the same basis as a technology for space flights. However, some distinctions are less obvious. For example, the Soviet Union perceived American space shuttles as potential weapons that could conduct rendezvous and proximity operation to destroy the Soviet satellites with a robotic arm or similar device (Johnson-Freese, 2007, pp. 33-34).

3.1. Defining the Space Weapon

Karl Hebert defines a space weapon as *"any asset, Earth-based or space-based, designed to attack targets in space (Earth-to-space and space-to-space). Space weapons also include space-based assets designed to attack targets on Earth. For the purposes of this definition, space-based weapons include weapons placed on celestial bodies"* (Hebert, 2014, p. 3). Hitchens, Katz-Hyman and Lewis also mentioned the possible development space-to-Earth weapons and technology, specifically space-based missile defences and space-based strike capabilities (Hitchens et al., 2006, pp. 44-48). Krepon and Katz-Hyman argue while outer space has been militarized, no space weapons are currently deployed in outer space, thus, it is not weaponized. However, they also mentioned some authors claim otherwise when referring to "residual" or "latent" space warfare capabilities (e.g. inter-continental ballistic missiles that briefly penetrate into outer space) that did not turn into space warfare actuality. Therefore, they *"...define space weapons and offensive space warfare initiatives as terrestrially based devices specifically designed and flight-tested to physically attack, impair, or destroy objects in space, or space-based devices designed and flight-tested to attack, impair, or destroy objects in space or on earth. This definition respects the distinction between capability and actuality. It excludes residual or latent space warfare capabilities, such as ballistic missiles. Also excluded in this working definition are satellites that provide essential military functions but do not serve as weapon platforms"* (Krepon and Katz-Hyman, 2005, pp. 325-326). Moreover, in their definition, they expelled uplinks and downlinks interference (Krepon and Katz-Hyman, 2005, p. 326).

Since the thesis is focused on the problematics of dual-use capabilities of space assets, I will stick to Karl Hebert's definition with the emphasis on Earth-to-space and space-to-space capabilities. The thesis is focused on the feasibility of space warfare and space-to-Earth weapons would get further relevance after the reach of space dominance. I believe the definition proposed by Krepon and Katz-Hyman is outdated and do not reflect the reality of space technology development and basically excludes the destructive potential of dual-use technology. I argue this could be a mistake when evaluating counterspace threats and capabilities. As Harrison and his colleagues pointed out, *"[d]ue to the dual-use nature of many space technologies, even benign space capabilities can be viewed by others as counterspace weapons*" (Harrison et al., 2018, p. 23).

Finally, it should be noted the definition of space weapon can be very flexible in the meaning. The draft of the "Treaty on the Prevention of the Placement of Weapons in Outer

Space, the Threat or Use of Force against Outer Space Objects" proposed by Russia and China aims to forbid the placement of weapons in outer space, however, the treaty consider as space weapon only "weapon in outer space" that is defined as "*any outer space object or its component produced or converted to eliminate, damage or disrupt normal functioning of objects in outer space, on the Earth's surface or in the air, as well as to eliminate population, components of biosphere important to human existence, or to inflict damage to them by using any principles of physics*" (Ministry of the Foreign Affairs of People's Republic of China, 2014). Nevertheless, such definition excludes all the ground-based systems including DA-ASAT weapons and thus justify its further development.

3.2. From Dual-Use to Offensive Capability

Dual-use technology serves for both military and civilian-commercial purposes, however, some of the technologies could be even exploited as an offensive capability or space weapons. The U.S. Joint Chiefs of Staff defines space control as following: *"Space control employs OSC*[3] *and defensive space control (DSC) operations to ensure freedom of action in space and, when directed, defeat efforts to interfere with or attack US or allied space systems. Space control plans and capabilities use a broad range of response options to provide continued, sustainable use of space. Space control contributes to space deterrence by employing a variety of measures to assure the use of space, attribute enemy attacks, and consistent with the right to self-defense, target threat space capabilities"* (Space Operations, 2018, p. II-2). Hitchens and her colleagues (2006) found out the Pentagon budget involved space weapon-related technology to enable space warfare strategy. Despite the conclusion of the authors that "*…support for ''space superiority'' and ''space control'' systems remains largely rhetorical - with little actual budgetary support"* (Hitchens et al., 2006, p. 48), and actual consideration the information about the finances and results of the projects may be outdated, the developed technology well illustrates the weapon conundrum. First of all, the U.S. paid attention to the development of microsatellites capable of performing autonomous proximity operations. Such a system could be used, for instance, for refuelling but also as a weapon. Secondly, the Pentagon showed the willingness to develop directed energy ASAT weapons and albeit in contrast to the ground-based system there was no clear evidence of broad support to space-based directed energy weapons, the possibility of exploitation of satellites as weapon platforms

[3] Offensive space control

should be noted. Last but not least, an important observation, kinetic energy offensive ASAT weapon consisting of kill vehicle and a booster are similar to missile-defence interceptors (Hitchens et al., 2006, pp. 35-56).

In 2018, the Prague Security Studies Institute (PSSI) issued a report on Europe's Preparedness to Respond to Space Hybrid Operations. PSSI defined space hybrid operations as *"intentional, temporary, mostly reversible, and often harmful space actions/activities specifically designed to exploit the links to other domains and conducted just below the threshold of requiring meaningful military or political retaliatory responses"* (Robinson et al., 2018, p. 3). These operations are conducted in the "grey zone" spectrum and constitute a potential threat. I argue these threats are often based on dual-use capabilities and their elaboration can contribute to the recognition of the most severe dual-use offensive capabilities. PSSI divided space hybrid operations into five categories:

- directed energy operations that may result in space debris,
- orbital operations that generally do not result in space debris,
- electronic operations,
- cyber operations,
- and economic and financial operations (E&F).

By directed energy operations that may result in space debris is understood low-power laser dazzling or blinding, high-power microwave (HPM) or ultrawideband (UWB) emitters (Robinson et al., 2018, p. 3). Altogether with electronic and cyber operations, they can be considered as counterspace capabilities that serve as potential weapons (Harrison et. al., 2018; Weeden and Samson, 2018) and I will refer to them later. Orbital operations that generally do not result in space debris are space object tracking and identification and rendezvous and proximity operations (RPO). In this context, PSSI warns about the dual-use capabilities involving RPO and active debris removal system (ADR). *"ADR systems are a good example of how space assets can be utilized for both, benign and aggressive actions. These systems are purposed to remove a dysfunctional space object by using another spacecraft. That, however, means that they can also be used for removal of, or interference with, a functional system"* (Robinson et al., 2018, p. 2). Authors argue ADR systems have many things in common with RPO and can be exploited for offensive purposes. To add, space systems are not sufficiently protected and can be easily compromised (Robinson et al., 2018, p. 2-3). E&F operations are malicious economic and financial activities that aim to “space sector capture” that PSSI terms as *“a state actor’s provision of space-related equipment, technology, services and financing ultimately designed to limit the freedom of action and independence of the recipient state’s space sector, generally implemented on an incremental basis”* (Robinson et al, 2018, p. 4). Albeit such operations cannot be classified as space weapons, I argue financial and economic transactions can possess a challenge for a proliferation of dual-use technology and I will elaborate on them later in the thesis.

Last but not least, Global Navigation Satellite Systems (GNSS) is an important strategic dual-use asset. Both American GPS and Russian GLONASS are exploited for both military and civilian purposes (Larsen, 2001, pp. 111-119). Navigation satellites can guide civilian airliners as well as munition with precision accuracy (Johnson-Freese, 2007, pp. 33-34). This was also nicely highlighted in the description of the encrypted European Galileo Public Regulated Service (PRS) that aims to provide assistance for humanitarian aid, civil protection or health services as well as support for fire brigades (Gsa.europa.eu., 2019). Despite its clear connections to weaponry, however, according to our definition GNSS cannot be considered as a space weapon since its capability alone does not aim to attack the target, moreover, it is space-to-Earth focused without the potential to regularly endanger other space assets. Navigation satellites are placed in MEO in altitude of about 22 000 km where orbits only the fraction of satellites and despite their clear dual-use capability and military force multiplier for ground military operations (Johnson-Freese, 2007, pp. 39-42) they cannot be easily turned into space weapon.

4. Counterspace Capabilities

The Secure World Foundation states counterspace capabilities *“can be used to deceive, disrupt, deny, degrade, or destroy space systems”* (Weeden and Samson, 2018, p. x) and can be thus exploited for malicious purposes with the potential to destroy the enemy space system. To evaluate the most recent and relevant counterspace capabilities the space actors have in possession, I will consider the assessments by Secure World Foundation (SWF) and Center for Strategic & International Studies (CSIS), both issued in 2018. CSIS divides counterspace capabilities into four groups – *kinetic physical, non-kinetic physical, electronic, and cyber*. In my thesis, I will adopt the same diversification and describe their threat. In addition, for every type of weapon, I will then introduce the main actors and their specific capabilities. It is important to mention that the details regarding the discussed technology are mostly classified by states, thus, the accurate specifications of capabilities may remain unknown.

For clarification, the U.S. Air Force states that offensive counterspace operations *“may occur in multiple domains and may result in a variety of desired effects including deception, disruption, denial, degradation, or destruction”* (Counterspace Operations, 2018, p. 9). Defensive counterspace operations then aim to *“protect friendly space capabilities from attack, interference, and unintentional hazards, in order to preserve US and friendly ability to exploit space for military advantage. Space capabilities include the space segment (e.g., on-orbit satellites), ground segment (e.g., space operations centers and telemetry, tracking, and commanding stations), and the link segment (the electromagnetic spectrum)”* (Counterspace Operations, 2018, p. 9). From the definition is clear that defensive counterspace operations may involve various space-based and ground-based components and their elaboration would be out of the scope of the thesis. Thus, when discussing “counterspace capabilities” or “offensive counterspace capabilities” I will follow the Secure World definition of counterspace capabilities.

4.1. Kinetic Physical Counterspace Capabilities

Kinetic physical weapons strike with kinetic vehicle or detonate nearby the target satellite. Direct-ascent ASAT weapons aim directly to destroy the satellite without the need of placement of any system in orbit. Moreover, ballistic missiles and defence interceptor can be potentially modified into DA-ASAT counterspace capabilities. Co-orbital ASAT weapons rest in the orbit until sending against the target. They could wait for hours or days but also for years. Kinetic Physical ASAT technology requires advanced guidance into target and testing. Inaccurate simple interception of target orbit could avoid the strike by safety maneuvers. Worth mentioning, ground stations can become easy targets for not only missiles but also for other means of conventional military operation. However, direct-ascent launch can be easily attributed and ground station should be able to track the previous satellite trajectory. In addition, the successful attack is clearly visible since it will most likely result in creation of space debris (Harrison et al., 2018, pp. 2-3).

China did many advanced rendezvous and proximity operations in LEO and GEO that could be exploited for malicious activity and as ASAT weapons. China has mature direct-ascent technology that can efficiently operate in LEO that could even become mobile within a few years. Moreover, the Chinese pursue to develop operational DA-ASAT technology in MEO and GEO, however, some successful tests were most likely already conducted (Weeden and Samson, 2018, pp. 1-2-1-23).

Albeit there were no proven recent malicious intentions, Russia conducted extensive co-orbital ASAT research during the Cold War and since 2010 tested various rendezvous and proximity operations in LEO and GEO. Despite the advanced development of DA-ASAT technology during the Cold War, Russian DA-ASAT capabilities are nowadays very limited. However, despite the bureaucratic pressures Russia seems to be encouraged to revive their DA-ASAT technology and should be capable of efficient operability in LEO within the following years (Weeden and Samson, 2018, pp. 2-1-2-20).

The United States conducted many rendezvous and proximity tests in both LEO and GEO even with hit-to-kill intercept technology for non-offensive missions, however, that could be as well easy-handed utilized as co-orbital ASAT weapons within a short period of time. The U.S. proved their DA-ASAT capability in LEO already in 1985 during the Cold War and again in 2008. The American ground-based interceptors (GBIs) and ship-based Standard Missile 3 (SM-3) interceptors should be able to serve as efficient DA-ASAT in LEO (Weeden and Samson, 2018, pp. 3-1-3-19).

Moreover, India and Israel have technology mature enough for construction of DA-ASAT weapons and some European states or Japan have advanced technology that could be transformed into co-orbital ASAT (Harrison et al., 2018, pp. 22-23). In March 2019, India conducted its first successful kinetic ASAT test and destroyed Microsat-R satellite in an altitude of about 300 km. The test created the limited amount of space debris that could threaten the International Space Station (ISS) and LEO satellites (Foust, 2019).

4.2. Non-kinetic Physical Counterspace Capabilities

Non-kinetic counterspace weapons include lasers, high-powered microwaves (HPM), and electromagnetic pulse. They have a physical effect on the satellite or ground station without physical contact. Moreover, they have a wide scope of the desired impact. High-powered lasers aim to damage the enemy satellite or its systems and component, however, low-powered can only blind or dazzle the space system sensors. They can exceed the speed of light and are more difficult to attribute than kinetic physical counterspace capabilities. Laser blocking system sensors may be attributed to approximate geographical region. Moreover, the attacker cannot be sure whether the attack was a success since there is not significant sign or space debris. Efficient Earth lasers must be sophisticated devices with high beam, adaptive optics and pointing control to successfully penetrate through atmosphere. HPM counterspace capabilities may damage satellite's electronics. Outcomes can be corrupted data, restart of the processors, or even permanent damage to processor and electric circuits. Two kinds of attacks are distinguished – "front door" – via satellite's antennas and – "back door" – through small seams and gaps around electrical connections and shielding. Unfortunately, there are several drawbacks – the waves disperse and weaken over distance and the Earth's atmosphere may interfere the signal, therefore, it would be convenient to strike with HPM from another space systems. Similarly to lasers, it is difficult to attribute the attack but also to recognize the outcomes. In addition, this category incorporates the effects of nuclear warhead – short-term electromagnetic pulse and long-term radiation damaging unshielded satellites (Harrison et al., 2018, pp. 3-4).

Albeit there is no evidence Russia wants to develop space-based high-power lasers, the advancements and proliferation of non-kinetic counterspace capabilities are obvious. Russia has offensive capability of ground-based satellite laser ranging facilities with the ability to dazzle the satellite sensor. Moreover, Russia develops an aircraft-borne lasers for targeting the optical sensor of imagery reconnaissance satellites (Weeden and Samson, 2018, p. 2-27).

China is also conducting advanced non-kinetic counterspace research with the aim to blind or damage satellite's sensors. There were reports by scientists of Chinese non-kinetic malicious actions already in 2005 and, in 2006, U.S. officials claimed China is dazzling U.S. satellites. China has capacities to blind adversary satellites and is most likely to continue further research towards more power lasers. Furthermore, China is interested in the development of air and missile defence HPM technology and could dispose of mobile high-powered microwaves devices, though, not miniatured enough for outer space application (Harrison et al., 2018, pp. 9-10).

The United States tested MIRACL laser that could be used as ASAT already in 1997 (Steinberg, 2012, pp. 256-257). Apart from mentioned states, some other actors such as India or Pakistan possess nuclear and ballistic missile technology that could be potentially delivered to LEO with electromagnetic impact (Harrison et al., 2018, p. 23).

4.3. Electronic Counterspace Capabilities

Electronic means of warfare focus on transmitted and received data. The most common electronic attacks are jamming and spoofing. Jamming interferes the radio frequency communications. Jamming is reversible, after the jammer is turned off or disrupted, the functions return to normal. Jamming may focus on both uplink and downlink satellite's signal. Uplink communication leads from the ground station to satellite and downlink from the satellite to the ground station. The advantage of downlink jamming is that jammers do not have to be as powerful as uplink jammers. Moreover, ground terminals with omnidirectional antennas as many GPS receivers have are extremely vulnerable to downlink jamming. The jamming technology is affordable and accessible. It is difficult to attribute the attacker from random interference. Spoofing refers to the sending of fake signals to the receivers. Downlink spoofing transmit corrupted data into the system. In case of uplink spoofing, the attack can even take control over the satellite. Encrypted military GPS proved to be vulnerable to spoofing. In addition, meaconing is a special kind of spoofing that does not require cracking into encryption because it only re-transmit the original signal. Spoofing technology is also relative available and easy to produce (Harrison et al., 2018, p. 4).

Russia is paying special attention to electronic warfare and its incorporation into military operations. The counterspace capabilities are most likely limited to jamming of user terminal within tactical ranges and cannot interfere with the GPS satellites themselves via radiofrequency interference. However, that means Russia is still able to jam GPS receivers, guidance systems or unmanned aerial vehicles, guided missiles, or precision guided munitions. Moreover, Russia dispose of mobile electronic warfare systems for tactical ranges and ground stations that could jam uplinks communication over a wide area. From the recent military operations, Russia gained operational experience in electronic warfare (Weeden and Samson, 2018, pp. 2-21-2-26). The United States has counterspace electronic warfare systems, namely the Counter Communications Systems (CCS) that is able to globally jam uplinks communications even against satellites in geostationary orbit. The U.S. likely can jam and spoof Global Navigation Satellite System (GNSS) receivers and the Navigation Warfare (NAVWAR) program focuses on both offensive and defensive capabilities to counter potential threat warfare (Weeden and Samson, 2018, pp. 3-12-3-15). China can also jam and spoof common satellite communication and GPS signals (Harrison et al., 2018, p. 10). In addition, some minor actors are interested in electronic warfare capabilities. For instance, in 2006, United Arab Emirates Thuraya Satellite Communications claimed Libya jammed their satellite. In 2013, Egyptian military reportedly jammed Qatar-based Al Jazeera’s broadcasting. In Ukraine, electronic warfare was involved in the strategy of Russia but also Ukraine that was jamming separatists broadcasting. Jamming technology could be potentially exploited by terrorist organizations and insurgent groups. At the beginning of the Operation Iraqi Freedom U SAT-COM commercial links were allegedly jammed. Terrorist organization Al-Qaeda was also accused of development of jamming technology (Harrison et al., 2018, p.24).

4.4. Cyber Counterspace Capabilities

Instead of electronic interfering of signals, cyberattacks focus on data and systems itself. They may target the antennas of the satellites or ground stations, landlines connecting ground stations to terrestrial networks, or the user's terminals. Efficient cyberattacks are complex with high level of precision and knowledge of the systems. However, they do not demand many resources and are a feasible option even for non-state actors, groups and individuals. Cyberattacks can be utilized for data monitoring but also for insertion of false or corrupted data, thus, many various kinds of cyber threats may be distinguished. The impact may vary from data loss or widespread disruptions to the loss of the satellite. Attribution of attacker is difficult since the attacker may cover his actions, for instance, by using hijacked servers (Harrison et al., 2018, pp. 4-5).

Secure World Foundation divided cyber threats into five categories. The first is the quality of hardware and software. For instance, the U.S. found faulty Chinese electronics and malicious Russian software packaged used by U.S. aerospace companies. Faulty hardware and software can also lead to cyber espionage. Secondly, cyberattacks can aim to links between ground station and space system. It is also possible, though more difficult, to focus on command and control (C2) links to acquire access to the satellite bus or payloads.

Many similar attacks are conducted, however, only a few of them are attributed. For example, between 2007 and 2009 NASA tracked numbers of attacks from China. In 2007, Tamil Tigers separatists took over U.S. commercial broadcasting satellite. The third option is to attack the C2 data relay stations. Similarly, many attacks are registered without clear attribution. The fourth, attack on segment of the space system. Those may be compared to computer cyberattack, nevertheless, the space systems are usually much less resilient. This was well-demonstrated in 2008, when Iridium satellites communications company and the client to Pentagon proclaimed that it is impossible to hack their systems. Immediately, the hackers eavesdropped the Iridium company traffic. Notably, in 2014 advanced persistent threat cyber espionage was registered by American CrowdStrike cybersecurity technology company that was tracked to China. Finally, connected to space, the last category involves satellites links utilized for hacking into other systems. The most notorious example is probably Russian Turla group that gets access to private networks via satellite-based internet since 2007 (Weeden and Samson, 2018, pp. 7-3-7-8).

Due to the limited amount of unclassified sources, it is burdensome to describe detailed cyberspace capabilities of every country. However, the cyberattack capabilities were registered in the possession of the United, Russia, China, North Korea, and Iran. Russia is a long-term serious space cyber threat. Already in 1998, U.S.-German ROSAT satellite was hacked by Russian hackers. Iranian cyber capabilities are increasing. Albeit there is no confirmed space cyberattack, Iran is recently cyber-offensive against other states. The same can be stated for North Korea that is responsible for WannaCry ransomware. Ground stations for space systems are vulnerable to similar attacks. To mention, US-China relations are affected by offensive cybers operation from the Chinese side (Weeden and Samson, 2018, pp. 7-1-7-11). Moreover, non-state actors are interested in the development of advanced offensive cyber capabilities. For instance, already in 1986, HBO was successfully attacked and during the broadcasting on the screen, there appeared a message from the attacker that called himself Captain Midnight. In 2002, a similar case happened in China when a spiritual group took spoofed television satellite to broadcast their own material (Harrison et al., 2018, p.24; Weeden and Samson, 2018, p. 7-1).

Cyberattacks can be also combined with electronic or kinetic ASAT weapons. Above that, cyber and electronic counterspace operations can complement or replace conventional forces with many advantages. Namely wide scope of impact, flexibility, accessibility, limited attribution, promptness, and affordable cost. As drawbacks may be considered limited strategic signalling and deterrence and battle damage assessment. Though, a combination of cyber and electronic warfare altogether with kinetic ASAT weapons may foster the capability and substitute disadvantages. Russia and China have widely considered such options that were clearly visible from both technical development and doctrinal side (Weeden and Samson, 2018, pp. 7-1-7-13).

Concluding, in this chapter, I have outlined the problematics of dual-use technology and potential counterspace capabilities. Finally, as mentioned, militarization does not mean weaponization. Therefore, dual-use technology itself cannot be considered as a weapon. However, we may distinguish systems that could dispose of a weapon potential. From stated above, I divided several technologies that have a latent offensive capability and, after adjustment, are likely to be turned into weapons. Namely, launch vehicles, satellites as weapons platforms, nanosatellites, cyber and electronic operations, and active debris removal systems. At the same time, we may distinguish basic challenges dual-use space weaponization nowadays face – orbital debris and international space law and doctrinal approaches of space actors.

5. Utilization of Dual-Use Technology as Space Weapons

In this chapter, I will elaborate on the distinguished non-military space-related technology that could be potentially relatively easy utilized for offensive counterspace operations or as space weapons. Based on the previous chapters, discussed dual-use technology involves space launch vehicles, the development of advanced small satellites and nanosatellite technology, satellites that may serve as weapon platforms, offensive cyber operations and the emerge of proposed active debris removal systems.

5.1. Space Launch Vehicles

The launch vehicles for the transportation of satellites and other payloads in orbit are the major potential threat to other systems since they have many in common with ballistic missiles and missile defence interceptors that can be modified into kinetic ASAT weapons (Harrison et. al, 2018, p. 2). This was highlighted by the fact that launch vehicles are of concern of non-proliferation ballistic missiles agenda and there are serious interconnections between ballistic missiles and space launch vehicles programs (Mistry and Gopalaswamy, 2012, pp. 126-127). The *Hague Code of Conduct against Ballistic Missile Proliferation* that was established in November 2002 and was signed by 139 states (Nti.org, 2018) directly refers to the space launch vehicles and states that *''Space Launch Vehicle programmes should not be used to conceal Ballistic Missile programmes''* (International Code of Conduct against Ballistic Missile Proliferation, 2003, p. 4; Mistry and Gopalaswamy, 2012, p. 127). The similarities between the launch vehicle and missile programs were examined by Mistry and Gopalaswamy on the examples of regional powers. However, with the exception of India, they do not involve any significant spacefaring actor. Despite the fact, they found cases of standalone missiles and space launchers as well as examples of missiles drawn from space launch vehicles and vice versa. They conclude that *"space launchers being used as ballistic missiles and ballistic missiles being used as space launch vehicles or even as anti-satellite systems—should not be ignored by analysts and policy makers"* (Mistry and Gopalaswamy, 2012, p. 145). Moreover, they advocate in their study they excluded dual-use industrial technology that could be transferred from the civilian sector to ballistic missiles. They mentioned Indian solid-fuel production plant was exploited for both civilian space launchers and Agni missiles production (Mistry and Gopalaswamy, 2012, p. 145).

It would be rather easy to proliferate kinetic ASAT capabilities based on existing missiles. I will demonstrate this possibility in the example of China. China conducted a successful ASAT test in 2007 by SC-19 direct-ascent (DA) ASAT weapons launched from a mobile Transporter–Erector–Launcher (TEL) from a pad at Xichang. The launch vehicle for this test was derived from DF-21 Intermediate Range Ballistic Missile and kinetic kill vehicle based on HQ-19 long-range Surface-to-Air Missile (SAM) system that was supported by active radar or passive multispectral Infra-Red homing guidance, or both. Such a weapon can efficiently operate in LEO. In 2013, China launched the new DA-ASAT labelled as Dong Ning-2 (DN-2) from TEL at Xichang. The multi-stage rocket was based on the Kuaizhou commercial satellite launch vehicle that has its basis in already mentioned DF-21C and was proposed by the same entity. This weapon reaches an altitude about 10 000 km, however, an apogee of this rocket was estimated to approximately 30 000 km and with some development and previously tested kinetic kill vehicle could endanger satellites even in GEO (Mahajan, 2016, pp. 174-175). This shows clear linkages between peaceful and offensive capabilities.

Eventually, it is worth mentioning that missiles and launching technology could be utilized for the delivery of not only kinetic but also weapons of mass destructions that raise even greater concerns regarding the dual-use space launch technology. In 2016, the United Nations Security Council denounced North Korea of testing missiles that should reach the U.S. mainland. On the other hand, North Korea claimed the intentions were only to deliver observation satellite into orbit. Mistry and Gopalaswamy mentioned a similar example from 2012 (Mistry and Gopalaswamy, 2012, pp. 126-127; McCurry and Gayle, 2016). This all demonstrates the ambiguity of problematics of space launch vehicles.

Ultimately, space launch vehicles may serve as a delivery system for space weapons. This issue could make connections between civilian and military more complex since private actors are exploited for the state's military contracts. SpaceX President and Chief Operating Officer Gwynne Shotwell even expressed the will to potentially deliver U.S. military weapons into space and raised concerns about the space activities of China and Russia (Trevithick, 2018; Erwin, 2018).

5.2. Small Satellites

The small satellites (small sats) are generally considered satellites with the weight lower than 500 kg. The subcategories of small satellites are then (1) mini satellites (100 - 500 kg); (2) micro satellites (10 - 100 kg); (3) nano satellites (1 – 10 kg); (4) pico satellites (0,1 – 1 kg); and (5) fenito satellites (less than 100 g) (Kopecny, 2004, p. 1; Straub, 2017, p. 78). The emerge of so-called NewSpace characterized by the commercialization of space sector will dramatically increase the numbers of satellites and produce advanced cheap small satellites technology by the deployment of satellite mega-constellations (Paikowsky, 2017, pp. 84-88; Quintana, 2017, pp. 88-109). There are currently about 5 000 satellites (approximately 2 000 functional) orbiting around the Earth (Pixalytics, 2019). However, the plans of private companies intend to deploy thousands of new small satellites. In 2018, SpaceX was approved by the Federal Communications Commission to launch 7 518 new satellites for their planned Starlink mega-constellation that should consist of about 12 000 small satellites. Starlink should provide unlimited global internet coverage by the mid-2020s (Grush, 2018). Similar projects will increase the density of space traffic and will require advanced space situational awareness and space traffic management. However, the real issue given by the dual-use nature of space technology is the utilization of small satellites as co-orbital space weapons. As Straub pointed out, *"[w]hen a $5,000 satellite can potentially damage a $50 million one, there is not a parity of risk levels: the less expensive craft's operator may be more prone to taking risks that may result in peril to the more expensive craft"* (Straub, 2017, p. 77).

Rendezvous and proximity operations are a good example of small sats threat. RPOs can be utilized for civilian peaceful operations as well as for malicious or even offensive activity. Russia conducted various RPOs for inspectional purposes. Speaking practically, in 2014, the U.S. airmen observed that Russian satellite that was previously deemed as space debris was unexpectedly spotted active conducting advanced close proximity manoeuvre to inspect the rocket booster. Russian Kosmos 2499 satellite is believed to be the actual space weapons with capacities to destroy other targets. A similar case is the Russian Luch satellite that was monitored spying in geosynchronous orbit with potential destructive potential (Sciutto and Rizzo, 2016; Weeden, 2015). But the scope of small sats capabilities may be much wider. The Chinese conducted many RPOs to their own satellites but in 2008 also to International Space Station with its BX-1 miniature imaging satellite potentially simulating co-orbital strike. The Chinese also tested grappling arms that could serve as efficient ASAT capabilities (Chow, 2017, p. 86; Sciutto and Rizzo, 2016; Barbosa, 2013; Clark 2018; Weeden, 2010; Harrison, 2018, pp. 8-9). Though not directly a small sat, the U.S. is testing classified experimental X-37B reusable spacecraft with manoeuvring capabilities and cargo space for potential counterspace equipment or small sats. Moreover, American microsatellites XSS-11 and MiTEx are constructed for advanced RPOs and could serve as potential co-orbital weapons (Sciutto and Rizzo, 2016; Clark, 2014; Weeden, 2017; XSS-11 Micro Satellite, 2011).

It is difficult to distinguish which RPOs and satellites are tested for peaceful, offensive, or both purposes. However, although the detailed sources of malicious space activities may be classified and thus unclear, it is the matter of fact that all the United States, Russia and China conducted various rendezvous and proximity operations and possess the capability to develop and deploy co-orbital ASAT weapons in both LEO and GEO (Weeden and Samson, 2018, pp. x-xiv).

5.3. Satellites as Weapon Platforms

For curiosity, the first space weapon was probably placed into space in 1974. The Soviet Salyut 3/ Almaz military reconnaissance space station contained modified 23mm Nudelman cannon that reportedly proved to be operational in the space environment (Steinberg, 2012, p. 252). However, its practical utility was never accomplished.

Probably the most notorious project to place weapons in space is Reagan's Strategic Defense Initiative (SDI). In the 1980s, American president Reagan believed that space-based anti-ballistic missiles interceptors could protect the United States and make Soviet nuclear ballistic missiles inefficient. However, this so-called "Star Wars" project was technologically unfeasible since it required the development of more advanced technology that was unknown at that time. The initiative proposed many systems that involved space and ground-based lasers or missiles and tracking systems. Although the funding of the initiative was rapidly cut in the early 1990s and the project was never realized (Atomic Heritage Foundation, 2018).

In 2003, Spacy II wrote an article "Assessing the military utility of space-based weapons" referring to the feasibility of space-based weapons. He argued technological immaturity and costs of space-based systems will make proliferation of space-based weapons in the next 15-20 years inefficient (but not impossible) and that ASAT capabilities will be preferably sent from the ground. Basically, he was right in his assumptions, however, his analysis was mostly based on the systems addressing the proposals and costs of SDI. Moreover, he made his conclusions for the 15-20 years continuum that has practically elapsed and the technology progressed.

It is difficult to estimate the status of the current space-based capabilities while the detailed information is classified and no weapons are most likely deployed in outer space, however, I would argue the key issue for a space-based weapon is to create a device that would be both powerful and miniatured enough. Yet, similar systems may be not be only fantasy. Recent 2019 U.S. Missile Defense Review address to space-based missile interceptors.

"Much has changed since the United States last considered space-based interceptors in a potential architecture, including major improvements in technologies applicable to spacebasing and directed energy. Given the rapid advancement and diffusion of offensive missile threats and technology, and in response to the 2018 National Defense Authorization Act (NDAA), DoD will undertake a new and near-term examination of the concepts and technology for space-based defences. This examination may include on-orbit experiments and demonstrations. New DoD analysis will evaluate the possible effectiveness of space-based interceptor technologies and their cost-effectiveness when compared to other systems based on the land, sea, and in the air. This examination will provide an informed contemporary foundation for assessing the technological and operational potential of space-basing in the evolving security environment" (Missile Defence Review, 2019, p. 37).

Such claim is too general to make a definite conclusion, however, the Review focused not only on space-based interceptor but also on space-based sensors and related technology. Specifically, it states that *"[d]eveloping scalable, efficient, and compact high energy laser technology, and integrating it onto an airborne platform holds the potential to provide a future cost-effective capability to destroy boosting missiles in the early part of the trajectory* (Missile Defence Review, 2019, p. 57) and that *"MDA*[4] *is developing a Low-Power Laser Demonstrator to evaluate the technologies necessary for mounting a laser on an unmanned airborne platform to track and destroy missiles in their boost-phase"* (Missile Defence Review, 2019, p. 57). Moreover, Review mentions the Multi-Object Kill Vehicle (MOKV) program – "*next generation kinetic kill vehicle for the GBI*[5] *designed to improve the ability to engage ICBM warheads, decoys, and countermeasures using a single defensive interceptor"* (Missile Defence Review, 2019, p. 56). Notably, tactical aircraft F-35 Lighting II is able to track and destroy incoming cruise missiles and could be

[4] Missile Defense Agency

[5] Ground Based Interceptors

in the future deployed with systems to destroy ballistic missiles in their boost phase (Missile Defence Review, 2019, p. 55).

Overall, the above-mentioned technology can be potentially utilized for the construction of space-based weapons systems that could serve not only as ballistic missiles interceptors but also to target other space systems by both kinetic and non-kinetic means. It is worth noting American Under Secretary of Defense for Research and Engineering Michael Griffin does not perceive space-based ballistic missiles interceptors as a technological problem but as a policy-making decision. Moreover, he expressed his will to research directed energy space-based defence systems and possibly deploy anti-ballistic missile space-based laser by late 2020s (Freedberg, 2018; Selinger, 2018; McLeary, 2019). In case of electronic warfare, the China Electronic Technology Group Corporation suggested producing small satellites with jammers to disrupt the U.S. satellite communications (Harrison, 2018, p. 10) that would exploit already discussed small satellites as weapon platforms.

5.4. Cyber Operations

In my thesis, I have decided to label cyber operations as a potential dual-use technology because cyberspace can be exploited for peaceful purposes but can also be compromised by an enemy entity. Cyber weapons "use software and network techniques to compromise, control, interfere or destroy computer systems" (Samson and Weeden, 2018, xviii). States and military recognize the importance and possible vulnerabilities of cyber. In 2016, at the Warsaw Summit NATO acknowledged cyberspace as an independent strategic domain that needs to be protected (Ducaru, 2018). The summary of U.S. cyber strategy explicitly states that the U.S. *is "engaged in a long-term strategic competition with China and Russia"* (Cyber Strategy Summary, 2018, p. 1) and regard as a key issue to *"ensure the U.S. military's ability to fight and win wars in any domain, including cyberspace"* (Cyber Strategy Summary, 2018, p. 2).

Prague Security Studies Institute (PSSI) include cyber operations among space hybrid threats with difficult attribution. PSSI defines space hybrid operations as *"intentional, temporary, mostly reversible, and often harmful space actions/activities specifically designed to exploit the links to other domains and conducted just below the threshold of requiring meaningful military or political retaliatory responses"* (Robinson et al., 2018a, p. 3). Example of malicious space cyber operations can attack by Russian-led Turla group, which managed to gain access into satellites and stole confidential information about

Western embassies, government institutions, and military entities between 2008 and 2016 (Robinson, 2018a, p. 4).

However, cyber operations or cyberattacks may cause much more serious damage. It is important to note that space and cyberspace domain are linked operationally and *"[c]yberattacks will probably represent the preferred offensive strategies when the objective will be to disrupt an entire space system"* (Robinson et al., 2018b, p. 7). So-called advanced persistent threat (APT) attack aims to gain extended access to a system, permanent and undetected capacity to access system information or even take control of the system (Robinson et al., 2018, p. 6). Samson and Weeden argued *"[c]yber weapons offer tremendous utility as both a situational replacement for and complement to conventional counter-space capabilities"* (Samson and Weeden, 2018, p. 7-11). The options of a cyberattack may vary from theft or denial of information to control or destruction of satellites, their subcomponents, or supporting infrastructure (Samson and Weeden, 2018, p. 7-11). Moreover, the commercial space sector is not sufficiently cyber-protected and hardened. As mentioned, in 2008, Iridium communication company and client to Pentagon reportedly publicly bragged about the quality of their cyber satellite resilience. Immediately, a group of hackers eavesdropped Iridium traffic with basic and cheap equipment (Samson and Weeden, 2018, p. 7-6). The main advantages of cyber attacks are their flexibility in access and effects, costs, and difficult attribution (Samson and Weeden, 2018, p. 7-11–7-12).

Overall, cyber space can be exploited for offensive cyber operations and thus be considered as a mean of space warfare. Cyberattacks can potentially take over or disrupt satellites and thus may be classified as efficient space weapon with both kinetic and non-kinetic impact. In case the attack will overtake propulsion systems, it could not only make system obsolete but also could navigate satellite into other space systems.

5.5. Active Debris Removal Systems

Active debris removal (ADR) systems are the example of a new emerging space technology that is vital for maintaining access to outer space. However, at the same time, it is also an example of a potential space weapon. *"ADR systems aim to dislocate a dysfunctional system from the orbit disregarding previous consideration about their removal"* (Doboš and Pražák, 2019, p. 220). Various methods of ADR systems are being considered. Generally, laser technology is not mature enough to be soon applied, on the other hand, kinetic options could become reality in the near future. There are stiff and flexible principles of kinetic ADR systems. Stiff methods include tentacles, single arm, multiple arms, and mechanical effector. Flexible connection incorporates net capturing, tether-gripper, and harpoon mechanism. Each method has its own positives and drawbacks, thus, practical application requires a detailed evaluation of their availability and costs. Many proposals and specific drafts of ADR missions have been considered. Nevertheless, when using the ADR system, it is most desirable to de-orbit as many pieces as possible to reduce the costs. For instance, KTH Royal Institute of Technology in Stockholm proposed a mission with the goal to de-orbit 5 debris pieces within the high density of debris in an altitude between 750 and 800 with the emphasis on affordability, reliability, and impact. For the launch, SpaceX's Falcon 9 rocker was proposed as a most convenient launch vehicle (Doboš and Pražák, 2019, pp. 220-221). However, all of the proposed methods, in case of their proven capability, can also be exploited for malicious purposes as space weapons. During late 2018 and early 2019, a joint project led by University of Surrey tested space reconnaissance and navigation technology, with subsequent tests of net capturing and harpoon methods in the space environment (Surrey.ac.uk, 2018a; Surrey.ac.uk, 2018b; Surrey.ac.uk, 2019). This basically proved the practical availability of ADR (Doboš and Pražák, 2019, p. 221) and, thus, the practical existence of a new space weapon.

Although the mentioned net capturing test is presented as a *"first demonstration in the human history of active debris removal technology"* (Surrey.ac.uk, 2018b) it is important to point out the states had already conducted many space tests and operations the of potential ADR or space weapon technology. For example, in 2016, China launched small satellites the Aolong-1 (AL-1), also known as the Advanced Debris Removal Vehicle (ADRV) or "Roaming Dragon," that reportedly utilized robotic arm for the removal of space debris (Weeden and Samson, 2018, p. 1-5).

The main advantage of ADR systems as space weapons rests upon their dual-use capability and uncertain intentions. Thus, the target would not have a chance to escape the unsuspected attack. Moreover, the principle of ADR would allow disposing of the enemy satellite without the proliferation of additional space debris. In addition, ADR systems could be utilized for hybrid operations involving rendezvous and proximity operations under the threshold of military conflict. On the other hand, since ADR aims to de-orbit only several pieces of debris per single mission, to cause appreciable damage to the adversary, a considerable number of ADR systems must be deployed. Secondly, the attack would most likely result in a military response and Earth-based ASAT kinetic weapons could be used to target space-based offensive ADR systems (Doboš and Pražák, 2019, pp. 221-222). Nevertheless, the development of ADR systems is forthcoming and necessary for open access to outer space. Doboš and Pražák argued (2019, pp. 221-222) further commercialization of space sector could enhance the peaceful uses of ADR systems, however, as was suggested above, there is also a potential risk of collaboration between the private companies and the state in proliferation of space weapons, in which case the impact would be reversed and space weapons could become even more affordable.

6. Challenges for the Space Weaponization

While outer space is contested, congested, and competitive environment, proliferation of space debris and international space law and doctrinal approaches of leading space actors are fundamental challenges to potential dual-use weaponry. In this chapter, I will elaborate on these challenges in more detail to describe the issues regarding possible space weaponization and space warfare.

6.1. Orbital Debris

The proliferation of space debris is a serious issue for the space weaponization. In 2010, U.S. Space Surveillance Network (SSN) tracked 14 000 debris larger than 10 centimetres (Liemer a Chyba, 2010, pp. 151-152). However, up to date, over 23 000 objects are recognized by SSN, from which only a small fraction are operational satellites. SSN tracks objects between 5-10 cm in low Earth orbit and 30 cm to 1 m in geosynchronous orbit. Since 1961, more than 290 in-orbit fragmentation events took place, most of them were explosions of spacecrafts or upper stages (ESA, 2018a). Majority of the debris is located in LEO, the most occupied orbit. Overall, it was estimated about 500 000 orbital debris larger than 1 centimetre are orbiting around the Earth. Notably, they exceed high velocities and possess a danger to other systems. Objects larger than 10 cm can be easily torn apart into smaller pieces. NASA[6] already predicted the amount of debris will be increasing and the risk of collision will be higher (Liemer a Chyba, 2010, pp. 151-152). So-called Kessler's Syndrome considers that fact that space debris will be multiplying by unavoidable collisions (La Vone, 2018) and it was estimated that in current conditions, even without introducing new systems, some collision will happen every 2-3 years (Black and Butt, 2010, pp. 3-4; Biesbrok, 2015).

Inter-Agency Space Debris Coordination Committee (IADC) endorsed the intentional destruction of space assets should be avoided. Moreover, they established guidelines regarding appropriate behaviour in outer space. These rules are generally accepted by the international community. The Scientific Subcommittee of the United Nations Committee on the Peaceful Uses of Outer Space (UNOCOPUOUS) came up with the guidelines regarding space debris mitigation coherent with United Nations (UN) principles and treaties on outer space (Rajapaksa and Wijerathna, 2017, p. 66). IADC proposed three

[6] National Aeronautics and Space Administration

passive mitigation options on how to get rid of obsolete systems. First, to move the non-functional satellite debris into an orbit with a lifetime lower than 25 years. Second, to navigate the orbital debris at least 235 km above the GEO. Last, to place the system into a region between the LEO and GEO, with a minimum altitude of 2 000 km above the Earth´s surface and the maximum of 200 km below the GEO (Sorge and Peterson, 2015). On the other hand, there are no legal responses and binding mechanisms and states are, therefore, not obliged to obey those guidelines and tend to follow their own rules with reference to the UN treaties and principles (Rajapaksa and Wijerathna, 2017, p. 66). The emergence of "New Space" actors with an increased number of space actors and private companies will require further space debris mitigation. For instance, SpaceX company intends to provide unlimited global internet coverage by mid-2020s. This project called Starlink counts with the deployment of up to 12 000 small satellites (Grush, 2018). These satellites often lack any propulsion for the mitigation of space debris creation (Chowdhury, 2018).

Since the beginning of space exploration, overall 489 confirmed on-orbit fragmentation events happened. According to recent ESA's Annual Space Environment Report, *"the amount of objects, their combined mass, and there combined area has been steadily rising since the beginning of the space age, leading to the appearance of involuntary collisions between operational payloads and space debris"* (ESA's Annual Space Environment Report, 2018, p. 69). Regarding the mitigation, *"between 30 and 60% of all payload mass recently reaching end-of-life in the LEO protected region does so in orbits which adhere to the space debris mitigation measures"* and *"between 15 and 20% of payloads recently reaching end-of-life in the LEO protected region in a non-compliant orbit attempt to comply with the space debris mitigation measures. Around 5% do so successfully"* (ESA's Annual Space Environment Report, 2018, p. 69). For GEO, *"around 90% of all payloads recently reaching end-of-life in the GEO protected region attempt to comply with the space debris mitigation measures. Around 80 % do so successfully"* (ESA's Annual Space Environment Report, 2018, p. 69). Those numbers are merely illustrative, however, they show that space mitigation still has significant gaps. Moreover, numbers of small satellites are rapidly increasing in the LEO protected regions that are contributing to the density of space traffic (ESA's Annual Space Environment Report, 2018, p. 69), therefore, enhanced space situational awareness and space traffic management must be considered to maintain open access to outer space. Space situational awareness (SSA) is a key component of successful debris management and mitigation. According to ESA, *"SSA aims, ultimately,* *to enable Europe to autonomously detect, predict and assess the risk to life and property due to man-made space debris objects, reentries, in-orbit explosions, in-orbit collisions, disruption of missions and satellite-based service capabilities, potential impacts of Near-Earth Objects (NEOs), and the effects of space weather phenomena on space- and ground-based infrastructure"* (ESA, 2018b). However, components involving SSA may have further implications incorporating military planning, the United States Air Force even describes Space Situational Awareness as a Space Battle Management that is enabled to win the war in space (Salinas, 2018).

For further consideration, it is also important to highlight some features of the Cosmos/ Iridium satellite collision in 2009, since it represents the greatest accidental kinetic impact collision and is similar to the impact of kinetic ASAT weapons. In a time of the collision, Satellite Orbital Conjunction Reports Assessing Threatening Encounters in Space (SOCRATES) estimated the close approach of 548 m between Iridium 33 and Cosmos 2251 satellite. Despite the fact, no countermeasures were taken into consideration. However, the close approaches are quite usual in outer space and the previous SOCRATES report stated a much closer approach of tight 117 m. Yet, in the latter, no accident happened and the satellites were moving away thereafter. Though, enhanced data sharing between the operators and government should be considered to avoid miscalculations in tracking the space debris, conjunctions and possibility of collision. In 2012, there were still 598 pieces of debris (with only 93 decayed until then) from Iridium 33 and 1 603 pieces (222 decayed) from Cosmos 2251 orbiting around the Earth (Celestrak.com, 2012b).

Last but not least, the upper stages of rockets possess a danger of in-orbit explosions. Russian Briz-M rockets registered several in-orbit breakups in recent years potentially endangering, for instance, international space station (Spaceflight101.com, 2016) that was also the case of Chinese and Indian ASAT debris. ISS is hardened up to withstand and impact with the debris of size of up to 1 cm. However, pieces larger than 1 cm can penetrate the station (Kelso, 2007, p.325).

6.1.1. ASAT Weapons Implications for Space Environment

The direct-ascend kinetic ASAT weapons are a serious threat to the proliferation of orbital debris. Up to date, kinetic ASAT weapons are in possession of the U.S., Russia, China, and India. During the Cold War, the U.S. and Soviet Union researched and tested various systems for potential use as a kinetic ASAT. This incorporated the development of direct-ascend as well as co-orbital ASAT weapons. China, and most recently India, decided to catch up and aimed to develop their own advanced ASAT capabilities. However, in practical terms, such weapons, if successfully launched, will expand the orbital debris and potentially endanger other space assets.

The U.S. conducted the latest ASAT test in 2008, notwithstanding, with the adequate response to outer space and debris decayed shortly after. However, this was not a case of the ASM-135 ASAT test in 1985 that may be considered as a milestone of ASAT testing and the study of space debris. The ASM-135 ASAT test was conducted on 13th September 1985, fired from F-15A Eagle flying in an altitude of 11,6 km aimed for the P78 Solwind satellite. The successful hit at an altitude of 530 km in advance considered the creation of orbiting space debris. However, due to political pressures, no other viable option was found. Despite some debris reaching an altitude of 1 150 km, all pieces decayed by 2005. NASA raised awareness and greatly protested against similar test and activities and contributed to the study of space debris (Matney and Anz-Meandor, 2015, pp. 4-6).

On January 2007, China shot down their own satellite Fengyun-1C (FY-1C) with a modified two-stage ballistic missile DF-21 with a payload of 600 km at an altitude of 863 km (Weeden, 2010, pp. 1-3). The test showed two significant outcomes. Firstly, China is able to successfully destroy low Earth orbit satellites (Mahajan, 2016, pp. 174-180) and possibly reach up to geostationary orbit (Forden, 2007, p. 30). Considering the following Chinese ballistic missiles and ASAT tests, we may deem this capability as proven (Mahajan, 2016, pp. 174-180; Weeden, 2013, pp. 1-3). Secondly, irresponsible ASAT testing or attacks result in the creation of a tremendous amount of space debris with high velocities in the orbits. Though the risk of space debris was well-known, the Chinese ASAT test generated the largest debris cloud ever made, counting over 3 000 trackable objects by Space Surveillance Network. After the test, 97 % of debris remained orbiting at an altitude between 175 km and 3 600 km. Until 2017, only 6 % of debris decayed, an estimated 79 % of debris will be still orbiting in 2108. This caused serious harm to the space environment, possesses a threat to a considerable number of other space systems (Weeden, 2010, pp. 1-3). Considering the Chinese ASAT test, China violated the debris mitigation guidelines and principles despite its membership in IADC. The test had a severe impact on the space environment. The number of tracked objects increased by 25 % (ESA, 2018a) and probably up to 150 000 pieces larger than 1 cm were proliferated

(Celestrak.com, 2012a, Liemer and Chyba, 2010, p. 152). Nevertheless, no punishment or other sanctions could legally follow (Liemer and Chyba, 2010, pp. 149-152).

6.2. Space Law and Doctrinal Approaches

Apart from the serious risk of proliferation of space debris in case of space war, space law and in this connection also the doctrinal approaches of space powers are the important determinant for the trigger and escalation of space conflict.

6.2.1. Space Law

Space law regarding the utilization of space weapons in outer space does not establish a proper legal framework. I argue the laws regulating space weapons that were formed in the context of Cold War are outdated and do not reflect the reality of new technology.

In 1963 Treaty Banning Nuclear Weapon Tests in the Atmosphere, in Outer Space and Under Water, also known as the Limited Test Ban Treaty (LTBT) entered into force. The treaty was a reaction to increased nuclear testing that took place also in outer space starting in 1958 by the United States. In 1962, the U.S. conducted the Starfish Prime nuclear experiment in an altitude of 400 with 1,4 megaton bomb. EMP affected satellites, disrupted communication and even blew fuses in Hawaii. Although the treaty banned testing of nuclear weapons in outer space, it did not focus directly on the regulation of space weapons (Hebert, 2014, pp. 4-5).

The milestone for space law was the year 1967, when the Treaty on Principles Governing the Activities of States in the Exploration and use of Outer Space, Including the Moon and Other Celestial Bodies, or just Outer Space Treaty (OST) was adopted. The treaty set the basic norms of space international law and was the basis for later treaties. Though the treaty is not focused restrictively on space weapon regulation, article IV outlines what we may consider as an effort of the arms control in outer space (Hebert, 2014, pp. 4-8).

"States Parties to the Treaty undertake not to place in orbit around the Earth any objects carrying nuclear weapons or any other kinds of weapons of mass destruction, install such weapons on celestial bodies, or station such weapons in outer space in any other manner.

The Moon and other celestial bodies shall be used by all States Parties to the Treaty exclusively for peaceful purposes. The establishment of military bases, installations and fortifications, the testing of any type of weapons and the conduct of military manoeuvres on celestial bodies shall be forbidden. The use of military personnel for scientific research

or for any other peaceful purposes shall not be prohibited. The use of any equipment or facility necessary for peaceful exploration of the Moon and other celestial bodies shall also not be prohibited" (United Nations treaties and principles on outer space, 2008, p. 4).
However, the formulation has significant drawbacks. Outer Space Treaty does not provide any definition especially for a term of "peaceful" and what is meant by weapons of mass destruction (WMD). Generally speaking, WMD are nuclear, radiological, biological, and chemical weapons. Thus, other kinds of space weapons are allowed. The term "peaceful" is similarly vague. The U.S. defines "peaceful" as non-aggressive, therefore, it does not limit further space militarization. Moreover, the second paragraph refers to the "Moon and other celestial bodies", though, it does not address to the near-Earth orbit in which the satellites operate (Hebert, 2014, pp. 4-8).

The Anti-Ballistic Missile Treaty (ABM) between the U.S. and Soviet Union from 1972 theoretically permitted only research but restricted the development and testing of anti-ballistic missile defence components, notwithstanding that in reality, already in 1985, Reagan Administration proclaimed ABM does not limit the Strategic Defence Initiative and the U.S. are allowed to test advanced space-based weapons. Moreover, ABM put no restrictions on ASAT development, thus, it did not regulate the space weapons. Above, after the U.S. withdrawal in 2002, the treaty lost all relevance (Von Kries, 2002, pp. 175-178).

In 2011, The Institute for Security and Cooperation in Outer Space (ISCOS) proposed the Outer Space Security and Development Treaty that intends to limit the utilization of space weapons. Notwithstanding, the treaty has no signatories and again does not define the term "peaceful". Therefore, deterrent space-based weapons could be still justified. In addition, the treaty wanted to ban space-based weapons but do not restrict militarization or Earth-based space weapons. To mention, the treaty proposed the UN Peace in Space Office as an oversight body, although questions its ability to successfully monitor the obligations (Hebert, 2014, pp. 4-8). Hebert argues the treaty could not be applied because the prohibition of space weapons and its development is already in progress and is unthinkable to stop and only the treaty that would limit debris-causing space weapons could reach the efficiency (Hebert, 2014, p. 8). However, I would suggest the emerging dual-use technology e.g. active debris removal systems that would allow for a non-destructive removal of the enemy system without a clear distinction of a weapon could question Hebert's assumption.

The last treaty that attempts to regulate space weapons started in 2008 by the draft of the Treaty on Prevention of the Placement of Weapons in Outer Space (PPWT) proposed by China and Russia. The treaty provides definitions of space weapons, use of force, and the threat of the use of force and aims to ban all space-based weapons. Nevertheless, it does not provide verification tools and does not restrict ground-based systems and weaponry (Hebert, 2014, pp. 4-8). Hebert suggests that the treaty was purposely proposed 13 months after the Chinese ASAT test that raised concerns about space weaponization and should intimidate the U.S. to sign the treaty (Hebert, 2014, p. 8), though, the U.S. opposed the treaty, among others because China would still be allowed to develop further ground-based ASAT capabilities (Foust, 2014). To mention, the new draft was presented in 2014, failing to fix the flaws. Interestingly, the treaty would only complicate issues regarding the thesis. According to the treaty, the states could comply with ADR systems as space weapons without the consideration of its legitimacy (Listner and Rajagopalan, 2014).

To conclude, the regulation of space weapons basically incorporates the weapons of mass destruction, nevertheless, it should be noted space weapons are not generally banned, moreover, the utilization of nuclear weapons would be inconvenient for the space warfare since it will most likely result in a destruction of own systems. Worth mentioning, in 2017, the Commander of the U.S. Strategic Command General John E. Hyten tweeted that *"[s]pace is the only domain where we don't have rules of engagement, because we don't have international norms. I support establishing international norms."*[7] This underlines the reality that space law is highly driven by the code of conduct with the constant risk of conflict. The latest efforts in space arms control were the establishment of "Group of Governmental Experts on further effective measures for the prevention of an arms race in outer space" under the United Nations Office For Disarmament Affairs in 2017 that hosted a space security workshop on January 30, 2019 (Un.org, 2019).

6.2.2. Doctrinal Approaches

For the illustration of tensions currently withstanding in outer space given by the increased congestion, contest, and competition, I have decided to briefly describe the doctrinal approaches of the recent major space powers – the U.S., China, Russia, and India that all successfully demonstrated their ASAT capabilities in the past.

[7] Tweeted by the United States Strategic Command on December 2, 2017, see: https://twitter.com/US_Stratcom/status/937013673180188672

6.2.1.1. China

The Chinese perceived the U.S. and India as a potential space threat. Many authors claimed the military and offensive intentions of the Chinese space program (Shabbir and Sarosh, 2018, pp. 6-7). For instance, Tellis (2007, pp. 41-72) or Cheng (2012, pp. 55-77) emphasize the militarization and counterspace efforts. On the other hand, contrary to Tellis and others, Zhang (2013, pp. 113-120) pointed out that important space programs such as Program 863 or Program 921 do not have direct military implications. Notwithstanding, according to Lele (2013, pp. 91-92) Chinese space program can be understood as an integrated part of China's grand strategy that well understand the prospects of dual-use technology and they possibly develop its technology towards further utilization as i.e. small strategic satellites that could lead altogether with ASAT research and development to space weaponization.

6.2.1.2. India

India recognizes its satellites as their center of gravities for conducting Earth operations. Indian Air Force is responsible for the defence of attack from space. However, the Air Force doctrine does not directly refer to space weaponization. Another official document, “Technology Perspective and Capability Roadmap” from 2013 issued by Indian Integrated Defense Staff setting the space industry goals for the next 15 years do not mention the development of ASAT capabilities, despite the fact, the version from 2010 supposedly incorporated it. However, the reality of the Indian space program seems to be different from Air Force doctrinal claims and approaches. The development of “weapons platform for space” was already mentioned in 2003 by then-Chief of Air Staff of Indian Air Force Srinivasapuram Krishnaswamy. Moreover, the Chinese ASAT test in 2007 threatened India and led towards further development of ASAT weapons and Indian counterspace operations are regularly stressed in academic journals. Above that, Pakistan presents a more immediate danger of direct conflict than China (Shabbir and Sarosh, 2018, pp. 8-9). The recent Indian ASAT test proved Indian willingness to build-up offensive counterspace capabilities with intend to send a clear signal of willingness to fight to its adversaries.

6.2.1.3. Russia

The Russian "National Military Doctrine" was approved by a president Putin in December 2014. The original text is not publicly available, nevertheless, the press release by the

Russian Embassy in London provided some details. The efforts in outer space policy should focus on the finalizing the treaty abandoning weapons in outer space and adopt a regulatory framework under the direction of the United Nations. The seemingly noble aim, however, has much broader implications. Based on the World War II experience, Russia adopted "assured survivability" approach and recently on the cases of Crimea, Ukraine or Syria showed their will to project its power and deploy forces. Moreover, the Soviet Union was the second country that successfully tested ASAT weapons. The Russian “peaceful” notions towards the “Prevention of the Placement of Weapons in Outer Space” treaty (PPWT) that would ban weapons in outer space suggesting Russia gave up its ambitions of development of advanced co-orbital ASAT weapons or bombardment systems, though, probably because of the economic and efficiency inconvenience. On the other hand, Russia is still active in Earth-based ASAT research and development. The air-borne ASAT laser Eshelon for A-50 or A-60 Beriev and kinetic ASAT deployed on Mig-31 are likely receiving funding. Moreover, Russia repeatedly conducted successful tests with the PL-19 Nudol missile interceptor that is at the same time an LEO ASAT. Thus, Russia still invests into offensive space technology that should assure their survivability (Shabbir and Sarosh, 2018, pp. 9-10; Harrison et al., 2018, pp. 14-15) and with PPWT initiative aims to limit the U.S. as most likely the only country capable of deployment of space weapons.

6.2.1.4. USA

The Commander of the United States Strategic Command (USSTRATCOM) is responsible for the Joint Space Operations defined by the Joint Doctrine of Space Operations (Joint Chiefs of Staff, 2018; Shabbir and Sarosh, 2018, p. 10). Counterspace operations are then specifically mentioned in the Annex 3-14 Counterspace Operations of the U.S Air Force Doctrine (Counterspace Operations, 2018). Shabbir and Sarosh (2018, pp. 10-11) argue that although doctrines’ rhetoric leads to US space dominance it is important to note that at the same time, they have the most to lose since most of the satellites belong to the U.S. Moreover, the U.S. enforcing the "freedom of action" in outer space. On the contrary, the U.S. space war games and exercises suggesting the U.S. are prepared to wage war if space will be seriously contested.

Recently, the establishment of Space Force as a sixth branch of the military is widely discussed in the U.S. In February of 2019, the U.S. president Donald Trump signed a Space Policy Directive 4 and made another step towards independent Space Force.

However, according to the directive, the Space Force should be at first under the directiveness of Air Force, led by the civilian undersecretary of Air Force and a four-star general serving as the Space Force chief of staff (Insinna, 2019). Notwithstanding, it is too early to predict any detailed implications of the actions of Trump's Administration.

To conclude, all four major spacefaring nations with counterspace capabilities are willing to use force in outer space despite the risks. Finally, it is also useful to bear in mind the risks of international trade. The states would not want to supply their adversaries with endangering dual-use technology (Von der Dunk, 2009, p. 102) and vice versa, states should secure their space technology suppliers since the hardware and software products can be utilized for cyber espionage (Weeden and Samson, 2018, pp. 7-3-7-4). Moreover, Russia and China aim to fund underdeveloped space nations that are willing to accept the authoritarian model of dependency on those states (Robinson et al., 2018, p. 4).

7. Interpretation – Feasibility of Space Warfare

In the previous chapters, I have defined the space warfare premises, described dual-use technology and outlined its possible utilization for space warfare and evaluated the counterspace capabilities. Finally, in this part, I would like to assess the feasibility of space warfare by answering the research questions.

7.1. Is the existing space technology plausible for the conduct of extensive space warfare?

First of all, I have argued outer space has its own limitations and rules the space warfare must take into consideration. Generally, the satellites are moving in the limited number of stable orbits and can be thus relatively easily tracked and attacked. Moreover, majority of the space systems are located in LEO in the altitude up to approximately 2 000 km. Earth-based kinetic ASAT weapons are capable to efficiently operate in such altitudes and can destroy the enemy satellites. Moreover, given the wide scale of counterspace capabilities, the space warfare can be supported by cyber and electronic operations, or even lasers to disrupt or for instance blind the enemy assets. Counterspace capabilities often have limited or difficult attribution and space systems are not sufficiently resilient against those threats. Except the weapons of mass destruction, space law does not limit space weaponization. The space actors are encouraged to develop and proliferate offensive counterspace capabilities such as kinetic DA-ASAT or cyber and electronic means or warfare that only increase the tensions between states. The potentially weaponized dual-use technology is then the issue that remains unaddressed. I have demonstrated that even seemingly peaceful and in essence beneficial technology can be turned into an offensive capability that could be characterized as a space weapon. However, no definition of space weapon presumes the destructive potential of dual-use weaponry. Considering Hebert's definition, every manoeuvrable space asset is a "sleeping" space weapon. From this perspective, it could be claimed that outer space been weaponized. Therefore, I am suggesting the concept of space weaponry should be revisited to suitably address the existence of the wide scale of malicious counterspace capabilities and potentially hazardous dual-use technology. In this connection, space law should be revitalized to incorporate these threats. However, space warfare would be still significantly affected by the space debris proliferation since many offensive counterspace operations would still result in disintegration of attacked satellites.

To mitigate the risk of space debris, space warfare would have significant boundaries because it would have to consider the removal of dysfunctional satellites and orbital debris. Moreover, it does not seem that any state possessing the sufficient offensive capabilities would intend to become a spoiler actor that would be willing to risk the destruction of own space assets since their reliance on space systems is too high to be given in stake. Thus, albeit space warfare is conceivable and may likely take place, I would argue the existing space technology is *not* plausible for the conduct of extensive space warfare. However, increased space congestion and rapid development of space technology by commercial actors may soon change this. For example, reduced costs of space launches and advancements in satellite technology could lead to the construction of a considerable number of manoeuvrable small satellites that may be utilized to gain an advantage in orbits and reach space dominance.

7.2. Which of the space assets could be turned into effective space weapons?

In my thesis, I have deduced five kinds of technology that are primarily or in the basis focused on exploitation for peaceful uses of outer space, nevertheless, at the same time they may be easily turned into destructive devices. Specifically, I have dealt with space launch vehicles, small satellites, satellites as weapon platforms, cyber operations and active debris removal systems. In principle, launch vehicles are resting kinetic ASAT weapons or missile interceptor that can be both deployed for the destruction of space systems. Moreover, launch vehicles are the facilitator of space weapon delivery in outer space. Small satellites are the emerging phenomena that aim to be beneficial to everyday life. Nevertheless, every single of thousands of planned satellites could become the space bullet and even without the ability to manoeuvre they possess a great challenge to space security and space traffic management. Following, satellites may serve as platforms for space weapons. For example, the U.S. claims they could deploy space-based missile defence. In such a case, without further legal consideration, a substantial number of satellites would be able to shoot on both Earth and space assets. Besides, since the satellites may serve many purposes, satellites could be secondarily designed to bear a space weapon. Next, cyberspace can be exploited for harmful activity with destructive potential. The cyber resilience of space assets is underestimated and satellites are not sufficiently cyber-protected and can be overtaken by enemy actors. Last but not least, active debris removal systems that will be vital to maintain open access to outer space can remove both orbital debris as well as functional systems and are thus efficient space weapons. Overall, all the discussed technology has destructive potential and may eventually become part of a comprehensive counterspace strategy.

8. Conclusion

In my thesis, I have considered the feasibility of space warfare with an emphasis on the malicious potential of dual-use technology. Firstly, I have described the orbital principles and set the presumptions of space warfare and the principles for space warfare strategy. Subsequently, I briefly introduced dual-use technology and its connections to space weapons. Hereafter, I paid focus on existing counterspace capabilities and its impact. Then, I was able to elaborate on the utilization of dual-use technology as space weapons. Following chapter described the challenges for space warfare and utilization of counterspace capabilities. Finally, in the interpretation, I have answered the research questions and proposed some of the issues regarding the weaponization of outer space.

I have reached the conclusion that current space technology does not allow to lead extensive space warfare. Thus, I have confirmed that there are considerable limits for conduct of space warfare. However, counterspace technology is mature enough for the conduct of destructive space operations and states are encouraged to proliferate advanced offensive counterspace capabilities that are not sufficiently addressed and bounded to international law. Though, despite it seems space warfare is unlikely, the situation may soon change. Outer space is congested, contested, and competitive environment with an increasing number of satellites that are not sufficiently protected. The orbital mechanics limits their movements and they may easily become a target to hostile actors. Thus, space warfare remains a possibility and its extension will be given by the growing tensions of state space actors and rapid development of new technology that is currently mostly driven by the commercial actors. Potentially destructive dual-use technology may then increase the risk and probability of space warfare. In my thesis, I have described several options of destructive dual-technology technology that could be turned into space weapons. Without the clear distinction and regulation, they may become the part of counterspace strategy that could lead to the weaponization of space and eventually to space conflict that would be the definitive end of perceiving outer space as a sanctuary.

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Univerzita Karlova

Fakulta sociálních věd

Institut politologických studií

Diploma thesis project

Weaponization of Outer Space: Double-Edged Blade of Dual-Use Technology

Name: Bc. Jakub Pražák
Academic advisor: Mgr. Bohumil Doboš, Ph.D.
Study programme: Bezpečnostní studia
Year of project submission: 2018

Introduction to the topic

Outer space is together with land, sea, air and cyberspace a strategic domain (Lonsdale, 1999, pp.137-157). However. with the sharp development of technology, outer space is becoming increasingly contested. The rising number of state and non-state actors are gradually overrunning the seemingly vast area of outer space. Yet, especially Low Earth Orbit (LEO) located approximately between 200 and 2000 km already possess a significant amount of space assets (Liemer and Chyba, 2010, pp.151-152). Regulations for space weapons are only vaguely formulated (Hebert, 2014, pp.20-24), therefore, security concerns regarding peaceful uses of outer space are in place. Moreover, approximately 95 % of space technology can be utilized for both, military and civilian reasons (Johnson-Freese, 2006, p.131). This raises awareness and uncertainty of space actors as the majority of the space assets can be utilized for offensive actions. Eventually, some technologies can be turned into weapons. Generally, outer space has been militarized, yet, it is doubtful whether it was weaponized. Anti-satellite weapons proved to be operational (Pražák, 2017) and dual-use technology could support further potential weaponization. Therefore, in my thesis, I will consider the possibilities of space weapons and their utilization. I intend to focus on the existing ground-based systems as well as on deployed space assets that could somehow endanger the peaceful usage of outer space. Moreover, the topic became strongly relevant after Trump's decision to establish the space force and claimed the space to be a warfighting domain (The Independent, 2018). Thus, my thesis contemplates outer space as a warfighting domain and the risks it possesses.

Research target, research question

My thesis will be conceptualized as a case study focused on the space technology development. The thesis will explain the interconnections between the military and civilian uses of outer space. While the most systems are primarily deployed for "peaceful" or civilian exploitation, they may be turned into harmful devices. Therefore, it should be considered what are the risks of dual-use technology, how destructive they can be, and if they can be utilized as space weapons. On top of that, ASAT weapons are sometimes considered to be space weapons, thus, they must be taken into consideration as well (Ensuring Space Security, 2006, p.1).

The possibilities of space warfare have been proved by ASAT tests, however, considering purely systems that are primarily labelled as a weapon, the impact would be only limited. Thereby, I intend to incorporate the assets that are not generally considered as weapons.

My research question states:

Is the existing space technology plausible for a conduct of extensive space warfare?

- For this research question, I will consider operational ASAT weapons as well as dual-use technology. I take into consideration the impact of the utilization of such technology and its feasibility.

Therefore, my secondary research question states:

- Which of the space assets could be turned into effective space weapons?

Literature review

The theoretical framework for my thesis will be based on the Everett Dolman's realist approach to outer space called Astropolitik. He described his thoughts in article Geostrategy in the space age: An astropolitical analysis (Dolman, 1999) and broadened his analysis in the book Astropolitik: Classical Geopolitics in the Space Age (Dolman, 2002). Dolman brought into attention the principles of the space warfare and tried to depict the strategic areas on the orbits important for maintaining space dominance and access to space, therefore, possibly control the Earth. He was inspired by famous concepts and theories applicable to the traditional strategic domains. For example, Dolman derived from Mackinder's geopolitical theory of Heartland and laid out the strategic locations to control in outer space. Similarly, sourced from Mahan's sea warfare theory, Dolman recognized the space lines of communication, chokepoints, or common space routes. To conclude, he set the course to space battlefield (Dolman, 1999, pp.83-106).

Following, John J. Klein (2006) elaborated further on the theory of space warfare and explained interconnections between the space environment and land, maritime and air strategies. I intend to support my arguments by the books and articles by Johnson-Freese (2006, 2007, 2016), concerning the problematics of space rivalry.

I believe the realist approach is suitable for the dual-use weaponry logic. The states are well aware of the importance of space and major powers desire to exploit it. The Cold War resulted in the space race of two superpowers. However, after the Cold War, new actors encouraged to penetrate further into outer space emerged. The so-called NewSpace actors who wish to exploit outer space commercially are more most likely to bring more assets to the orbit and enhance the technological development (Paikowsky, 2017, pp.84-88). Concurrently, state actors pursue to gain an advantage over the space sector. For instance, China is developing advanced space technologies with uncertain intentions (Johnson-Freese, 2016, p.71) controlled by the military (Aliberti, 2015, p.23). On the other hand, the United States is willing to maintain its space dominance (Milowicki and Johnson-Freese, 2008, pp.1-21) and declare it in their Air Force Doctrine (US Air Force, 2004).

Speaking practically, China conducted a successful ASAT test in 2007 followed by the US in 2008. Though not publicly confessed, the demonstration of functional ASAT capabilities was clear (Martindale, 2015 p.112). To mention, the United States firstly managed to test their kinetic ASAT weapon already in 1985 (Pražák, 2017, p.19). Moreover, ASAT technology should possess also Russia and India (Pražák, 2017, p.25-27). Despite no ASAT test officially exceeded Lower Earth Orbit, awareness is in place. For instance, the Chinese test 2007 was deemed to be significantly advanced (Pražák, 2017, p.22,23) with the potential to reach Geostationary Orbit (Forden, 2007, p.29).

To outline the issue of the potential for dual-use technology exploitation as space weapons, I introduce the example of active debris removal. The proposed Active Debris Removal systems are designed to remove a dysfunctional system using another vehicle in the process. Nevertheless, that means it would be able to dispose of the functional system as well. Some of the methods involving e.g. space tug or laser have been already suggested (Sorge and Peterson, 2015). Currently, the joint project co-funded by the European Commission is conducting a series of active debris removal experiments involving a capturing net and a harpoon (University of Surrey). However, other kinds of actions such as rendezvous and proximity operations can be similarly utilized for offensive operations. In my thesis, therefore, I intend to focus on different dual-use systems into more details and find their weaponized potential.

The considerable challenge for my thesis will be to manage the space debris issue during space warfare. Space debris possesses a threat for the operating space assets and its increase would endanger both, enemies and allied space systems. For illustration, the Chinese ASAT test was conducted irresponsibly without the consideration of long-term debris, resulting in the extension of trackable objects in outer space by 25 % (European Space Agency, 2018).

Conceptual and theoretical framework, research hypotheses

In my thesis, I intend to apply the realistic approach to outer space rivalry. Specifically, I will utilize Dolman's outer space analysis of space to the possible exploitation of space systems as space weapons. For the theoretical background about the basic orbital moves and different kinds of orbits for particular purposes, I will derive from the books and articles by Everett Dolman. My intention will be to reveal whether the current space systems are able to gain an advantage in the space sector through military offensive actions.

The hypotheses for my thesis will consider outer space as a warfighting domain with the proven existence of possible space weapons. I reckon I will recognize the considerable limits and boundaries of the space warfare, nevertheless, I aim to distinguish, or at least outline the opportunities for the space military operations.

The primary research question will be answered positively if I conclude that the actor is able to successfully attack the enemy systems with considerably greater damage than caused to itself or, in case of identification of relevant spoiler actors, to be capable to avert access to outer space to its adversary.

Empirical data and analytical technique

Since I intend to research dual-technology utilization as a traditional weapon, I have to formulate the definition of a space weapon. For the purposes of my research, I will define a space weapon as a system that can destroy, neutralize, or take over space system or systems in outer space.

Secondly, for the positive answer to the research question, some criteria have to be met. The outcome of the offensive action has to provide a visible advantage over the opponent. Altogether, the attack should result in a damage to enemy systems, yet, own systems should be preserved or only minorly affected. The specific results will be based on the data from the final analysis.

My thesis will be written as a comparative case study with the results for the possible conflict scenarios. In my methodology, firstly, I will take into consideration the possible space weapons and thoroughly describe and analyze them. Simultaneously, I recognize the importance of space orbits, routes, lines of communications and especially the risk of potential space debris that may result from the conducted space operations. Furthermore, I analyze the outcomes of the practical utilization of space weapons. Since I am unable to make detailed calculations on my own due to the lack of unclassified data and the requested high proficiency in mathematics and astrophysics, I will derive from the already known data and figures. Specifically, I take over reports, analyses and models of the historic incidents. The focus will be aimed at the altitude, the debris spread, extension and its lifespan. Namely, I will consider a controversial Chinese 2007 ASAT test. Similarly, I believe other ASAT tests such as the US 1985 and 2008 ASAT tests could provide complementary information. Moreover, other kinds of space incidents could enhance the final analysis. I will try to involve Russian Briz-Z rocket accident and 2009 Cosmos/ Iridium satellite collision. Finally, based on the gathered data, I will predict the possible outcomes of space warfare.

Planned thesis outline

- Introduction to outer space and space warfare
- Methodology/ Conceptualization
- Theoretical approaches to outer space and premises for space warfare
- Space Weapons and dual-use technology
- Utilization of dual-use technology as space weapons
- Space debris and limitations of dual-use technology as space weapons
- Interpretation, feasibility of space warfare
- Conclusions

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