STATIONARY UNMANNED AERIAL VEHICLE COUNTERMEASURE DEVICES: PRACTICAL ASPECTS OF THEIR APPLICATION

Oļegs Ignatjevs[1], Andrejs Korklis[2]

[1]Mg.soc.sc., Lecturer of the Military and Physical Training Department,
State Border Guard College, e-mail: olegs.ignatjevs@rs.gov.lv, Rezekne, Latvia
[2]Professional bachelor's degree, assistant, State Border Guard College,
e-mail: andrejs.korklis@rs.gov.lv, Rezekne, Latvia

Abstract. *The aim of this study is to investigate the limitations of using unmanned aerial vehicles (UAVs), to identify the legal and practical aspects of countermeasures, and to find the most suitable technical solutions for the State Border Guard operations. To achieve this objective, the following tasks were set: to examine the regulatory framework related to the use of UAVs, to identify the legal limitations of UAV usage; to investigate practical examples within the State Border Guard operations where technical solutions for combating UAVs were necessary; to describe the UAV countermeasure devices available on the market, comparing them with solutions already in use in Latvia; to propose potential pathways for developing the technical base in the field of UAV countermeasure devices. To accomplish these tasks, the following research methods were applied: the monographic method, document analysis, the logical-constructive method, and surveys. The structure of the work consists of four chapters: the first chapter examines the relevant legal regulations, the second chapter explores practical examples within the State Border Guard operations where UAVs have been used unlawfully, the third chapter analyzes the technical parameters and operating principles of UAV countermeasure devices, and the fourth chapter investigates the technical solutions of UAV countermeasure devices available on the market. The study concludes with a section of conclusions and proposals.*

Keywords: *flight restriction zone, special means, security, State border guard, unmanned aerial vehicles (UAVs).*

Introduction

For many years, unmanned aerial vehicles (hereinafter referred to as UAVs) have been used not only in the military but also in civilian life: for photography and videography, sports events, and entertainment. Although this technology appears to be peaceful, it can also be used for illegal activities. UAVs can be employed for reconnaissance - observing the routes and schedules of border guard patrols - as well as for transporting contraband across national borders. Moreover, considering the specific operational context of the State Border Guard (hereinafter referred to as SBG) and the current political situation, where the Russian Federation positions itself against NATO and the EU, of which Latvia is a member, it is crucial for the SBG to monitor both the trends and modus operandi of illegal activities as well as military threats.

Therefore, countering the illegal use of UAVs is a field that should be prioritized to enhance the effective performance of the SBG's duties and to strengthen national security overall. This study aims to improve the SBG's capacity to counter UAVs, focusing on one component of this capacity: stationary UAV countermeasure devices and their legal and practical aspects of application. The period of research is from 2021 till 2022 during which SBG officers observed a rising number of unauthorized UAV flights. The aim of this study is to investigate the limitations of using UAVs, to identify the legal and practical aspects of countermeasures, and to find the most suitable technical solutions for the SBG operations. To achieve this objective, the following tasks were set: to examine the regulatory framework related to the use of UAVs, to identify the legal limitations of UAV usage; to investigate practical examples within the SBG operations where technical solutions for combating UAVs were necessary; to describe the UAV countermeasure devices available on the market, comparing them with solutions already in use in Latvia; to propose potential pathways for developing the technical base in the field of UAV countermeasure devices. To accomplish these tasks, the following research methods were applied: the monographic method, document analysis, the logical-constructive method, and surveys.

1. LEGAL BASIS FOR COUNTERING UNMANNED AERIAL VEHICLES

Given the increasing popularity and accessibility of unmanned aerial vehicles to a broad user base, it is crucial for the state to limit UAV flights in areas where they pose a physical safety threat, such as near airports, or where they could gather sensitive information, such as State Border Guard facilities. This chapter focuses on the regulatory framework of the Republic of Latvia, which imposes restrictions and obligations on individuals regarding UAV usage.

Firstly, the author examines the Commission Implementing Regulation (EU) 2019/947 of 24 May 2019 on the rules and procedures for the operation of unmanned aircraft. This regulation aims to establish rules for the operation of unmanned aerial vehicles and the activities of individuals and organizations involved in UAV operations. The regulation sets out general criteria for UAV operation, including flight altitude, the responsibilities of remote pilots, and examination criteria for pilots (EU, 2019). All national regulations are made to correspond this EU legal act.

Further, it is essential to review the Cabinet of Ministers Regulations No. 429 of 29 June 2021, "Rules on Unmanned Aircraft Flights," developed pursuant to Article 117.6, paragraphs two and three of the Aviation Law. These regulations prescribe the rules for UAV flights in the airspace of the Republic of Latvia, criteria and procedures for facilitating, restricting, and

prohibiting UAV flights, and procedures for the circulation and availability of information. According to these regulations, the State Border Guard has the right to propose the establishment of a geographic zone for UAV systems, changes in the conditions of UAV system geographic zones above its infrastructure facilities and within a 50-meter radius, as well as above event locations related to national border security (Cabinet of Ministers of Latvia, 2021).

Additionally, the provisions of the State Border Guard Law concerning UAV countermeasures must be considered. According to Article 16, paragraph 1, point 7 of the law, a border guard has the right to use special means to intercept, land, or destroy a remote or autonomously controlled device if it threatens or interferes with the execution of the Border Guard's duties or is suspected of being used for illegal border crossing or unauthorized transportation of persons or goods across the border.

However, in this context, it is necessary to examine another regulatory document - the Cabinet of Ministers Regulations No. 55 of 18 January 2011, "Regulations on the Types and Use of Special Means." Analyzing these regulations reveals a significant problem in the practical implementation of Article 16 of the State Border Guard Law: the regulations do not specify any special means designed for the early detection or forced landing (neutralization) of UAVs. Moreover, Article 17, paragraph 2, point 8 of the State Border Guard Law allows the use of a service firearm to intercept, land, or destroy a remote or autonomously controlled device. From a practical standpoint, however, hitting a fast-flying target at high altitude with standard service firearms (pistols or assault rifles) is extremely difficult and dangerous, as it is impossible to predict the bullet's fall point, posing a risk to individuals within the bullet's range (e.g., the G36 assault rifle bullet can travel over 2.8 km, depending on the barrel elevation angle).

Therefore, the most effective way to counter UAVs is through special means for their early detection and/or neutralization, which will be examined later in this paper.

From the above, it is clear that the State Border Guard has a wide range of legal instruments to restrict UAV usage that could threaten the performance of its functions. However, these legal instruments do not provide specific technical solutions for countering UAVs. Consequently, the author proposes that the State Border Guard initiate amendments to the Cabinet of Ministers Regulations No. 55 of 18 January 2011, "Regulations on the Types and Use of Special Means." These amendments should include new types of special means: "UAV detection devices" and "UAV forced landing devices," and specify their use with the following formulations: "UAV detection devices are used to monitor airspace and prevent unauthorized use of UAVs above the infrastructure facilities owned or possessed by the

Internal Security Bureau, the State Police, and the State Border Guard, and within a 50-meter horizontal plane from them, as well as in UAS geographic zones initiated by these institutions" and "UAV forced landing devices are used to terminate unauthorized use of UAVs above the infrastructure facilities owned or possessed by the Internal Security Bureau, the State Police, and the State Border Guard, and within a 50-meter horizontal plane from them, as well as in UAS geographic zones initiated by these institutions." These formulations would align with those specified in the Cabinet of Ministers Regulations No. 429 of 29 June 2021, "Rules on Unmanned Aircraft Flights," and would allow the State Border Guard to implement the aforementioned special means for UAV detection and neutralization.

2. Practical Justification for Countering Drones in the State Border Guard

From the previous chapter, it can be inferred that there are restrictions on UAV flights over the infrastructure of the State Border Guard. Current chapter examines practical examples demonstrating the increasing popularity of UAVs and investigates cases on the border of the Republic of Latvia where UAV operation restrictions were violated, leading State Border Guard officers to impose penalties on UAV operators. This study covers the years 2021 and 2022, during which State Border Guard officers observed a rising number of UAV flights.

According to information compiled by the author, in 2021, the State Border Guard received several signals regarding unauthorized UAV flights in the border area or at the state border in the Viļaka, Ludza, and Daugavpils districts, in 2022, even more similar cases were identified. It is essential to note that the reasons for these signals were according to activities of neighboring states, probable illegal activities and activities of civilian inhabitants that had no illegal intentions. Unfortunately, the author cannot expose all information on mentioned cases due to restricted access to this information.

Nevertheless, in addition to the previous information, a specific case of UAV use for smuggling goods across the state border should be mentioned. This case, which occurred in August 2021, is described in a study by Samuel Goudard, a Category 2 expert of the Frontex Agency's Permanent Corps. In this case, a large UAV was used to transport smuggled goods (cigarettes) across the state border between the Republic of Latvia and the Russian Federation (Goudard, 2021). In described case the Latvian Border Guard lacked any special means for UAV detection or neutralization, and the use of a service weapon in night conditions over long distances is neither safe nor practically feasible and the violator was not detained.

In addition to illegal activities involving UAVs, there is a more serious threat, namely potential military threats from neighboring countries that are not NATO members and thus not military allies of the Republic of Latvia—namely, the Russian Federation and the Republic of Belarus.

Currently, reconnaissance and monitoring of Latvian authorities and National Armed Forces activities can reasonably be considered the most significant threat from the Russian Federation and the Republic of Belarus. The validity of such threats can be proven by current situation in combat zone in Ukraine and, historically, considering various military exercises conducted by Russian Federation and the aircraft, including UAVs, used in those exercises. For example, a media source review reveals that more than 1,000 aircraft, including UAVs, were used in the Vostok-2018 exercises (the Guardian, 2018).

Additionally, the recent case of Russian battle UAV violating Latvian airspace should be mentioned. Thus, Latvian Ministry of Defense in its press-release stated that on 7th of September, 2024, a combat UAV that is used to perform so called suicide attacks, entered Latvian airspace from the territory of Belarus, crossed eastern part of Latvia and crashed in Gaigalava parish. Latvian Ministry of Defense states that the UAV lost its control during large scale attack on Ukraine (Ministry of Defense of the Republic of Latvia, 2024). This case should be viewed as a severe violation of international legislation and as a considerable threat on Latvian security.

Enhancing the capability to detect military threats within the State Border Guard can be related to the 2020 National Defense Concept, which states that Latvia's early warning systems must be improved to minimize the risk of a sudden military threat. These early warning systems must integrate the systems and infrastructure of the State Border Guard (the Parliament of the Republic of Latvia, 2020). Therefore, the introduction of UAV detection systems in the State Border Guard would not only enhance the agency's capacity but also improve the overall security of the Republic of Latvia.

Thus, it must be acknowledged that the level of various threats is sufficiently high, but the means available to the State Border Guard cannot improve the situation regarding unauthorized UAV use. The author of this study believes that the only way to improve the statistics on detecting unauthorized UAV operations and to prevent neighboring authorities from secretly using UAVs is by introducing technical means capable of electronically detecting and/or forcibly landing UAVs.

3. General Characteristics of Stationary Anti-Drone Systems

As previously noted, the implementation of countermeasures against drones is critical for the effective performance of the State Border Guard's

functions. This chapter examines the types, operational principles of stationary anti-drone systems to facilitate the potential acquisition of such systems for the State Border Guard.

A significant nuance that distinguishes technical specifications for countering drone threats at the state border from other areas, such as airport security or the protection of military installations, is the overall area of the protected object. According to information available in the Electronic Drone Browser, the flight restriction zone over Riga Airport (EVX11 zone) is approximately 54 km^2, while the zone over the headquarters of the National Guard 3rd Latgale Brigade and the 32nd Infantry Battalion in Rezekne (EVR RPAS NBS33 zone) is approximately 3.5 km^2. In comparison, the zone over the Latvian-Russian and Latvian-Belarusian state borders (EVR17 zone) is 407 km long and its width ranges from 3 to 6 km, providing at least 1221 km^2 of area (Latvijas Gaisa Satiksme, 2022) to be covered by anti-drone systems. Protecting only State Border Guard infrastructure (e.g., border guard stations or territorial units) from drone surveillance would not be efficient since the majority of unauthorized drone use cases have been detected on the "green" border.

Furthermore, the use of only portable anti-drone systems would be inadequate for such large areas due to their significant weight, dimensions, and technical limitations. Therefore, it is concluded that stationary anti-drone systems are the most effective means for the State Border Guard to counter drone threats.

General information about stationary anti-drone systems reveals that drones can be detected using various technical solutions: radio frequency analyzers, acoustic sensors, optical sensors, and radars. Radio frequency detectors and analyzers are easier to install but do not provide a 100% guarantee of drone detection, as the control frequency can be encrypted or otherwise protected (e.g., military-grade drones or pre-programmed drone flights). On the other hand, installing radars, which offer a higher probability of detection, involves more bureaucratic obstacles and higher maintenance costs (ROBIN Radar Systems, 2022).

Studies suggest that the most effective method for drone detection is through radio frequency analyzers. This is supported by the fact that industrially produced drones use specific radio frequency bands (2.4 GHz, 5.8 GHz, or 433 MHz), which significantly simplifies detection and location determination (Hindle, 2017). Therefore, radio frequency analyzers are deemed most suitable for the State Border Guard's needs, as it is reasonable to assume that most illegal activities involve commercially produced drones.

Once a drone is detected, it is necessary to intercept it to prevent its use for illegal activities. There are two primary methods for forced drone landing: disrupting the drone's communication with its operator and/or GPS

system, or physically destroying the drone. The latter is considered a last resort due to the additional risk of collateral damage. Consequently, devices that jam or disrupt the drone's radio and/or GPS signals are deemed most appropriate for the State Border Guard's tasks.

4. Potential Solutions for Stationary Anti-Drone Systems in State Border Guard Operations

From the information compiled in the previous chapter, it is evident that there is a wide range of stationary anti-drone systems, each with its own advantages and disadvantages. These can be mitigated by combining different types of equipment into a single system, a strategy that is common in the security systems market. The author has surveyed the range of available solutions and identified that the companies "SKYLOCK" and "AARONIA" offer systems specifically designed for border surveillance needs. This chapter delves into the technical specifications of these companies' systems.

"SKYLOCK" is an Israeli company specializing in the development and production of anti-drone technologies, including detection, identification, and neutralization equipment. According to the manufacturer, the company creates modular systems that provide multi-level protection by combining various anti-drone devices in a single system. This ensures protection from unauthorized drone flights for critical infrastructure, airports, military bases, and mass events. "SKYLOCK" offers solutions not only to private companies but also to government and municipal institutions (SKYLOCK, 2022).

"SKYLOCK" offers a system specifically designed for protecting national borders from unauthorized drone flights in restricted or prohibited areas. According to information on the manufacturer's website, the system includes components such as radars, radio frequency detectors, jammers, and disruptors, allowing it to autonomously counter drones (SKYLOCK, 2022).

Similarly, "AARONIA" is a German company specializing in the production of measuring instruments, tracking, and monitoring technologies. The company's anti-drone equipment is described as highly accurate, intelligent, and wide-spectrum with a large operational radius. It is claimed that "AARONIA" developed drone detection system "AARTOS," which has evolved to its sixth generation by 2019 (AARONIA, 2022). All "AARONIA" equipment is manufactured in Germany, which, according to the author, could simplify and reduce logistics costs if these systems were procured for the State Border Guard.

Like "SKYLOCK," "AARONIA" also offers a system specifically designed to protect national borders from unauthorized drone flights in restricted or prohibited areas. According to information on the manufacturer's website,

the "AARTOS" system can be adapted for border protection, offering a large detection radius and high precision, thereby requiring a minimal number of devices for effective operation. The manufacturer emphasizes that the "AARTOS" system is capable of covering large surveillance areas, making it particularly suitable for border monitoring functions. Publicly available information indicates that the latest generation "AARTOS" system provides the following technical solutions: it can analyze a wide radio frequency spectrum, detecting up to 99% of commercially produced drones (including future models), determine both the drone's and operator's location, and has an operational radius of up to 50 km per workstation. Additionally, the system includes radio frequency jamming sensors with a range of up to 10 km (AARONIA, 2022).

In conclusion, based on the above information, the author believes that the anti-drone systems offered by "SKYLOCK" and "AARONIA" are equally suitable for the State Border Guard's operations. Both systems are versatile, providing not only detection but also neutralization capabilities. This solution enables the quick identification and termination of unauthorized drone flights over State Border Guard infrastructure and/or within the EVR17 flight restriction zone. Furthermore, a modular solution facilitates procurement, logistics, and installation processes by eliminating the need for separate detection and neutralization equipment. Additionally, training personnel on a single, unified system will significantly reduce training costs. The universal nature of both systems also favors lower maintenance costs, as separate contracts for detection and neutralization system maintenance will not be necessary. Unfortunately, without an official procurement process, the author cannot determine the exact list of components or provide estimated costs for system installation, personnel training, and maintenance. However, the author proposes that the technical solutions from the aforementioned manufacturers would be highly beneficial for the State Border Guard in the realm of drone countermeasures.

Conclusions and suggestions

Completing the current research, the author has analyzed appropriate legal regulation, made case study that suggests the necessity of development in the field of drone countermeasures in State Border Guard and has studied technical solutions in the sphere. After making current research, the author has made following conclusions:
1. Cabinet of Ministers Regulations No. 55 of 18 January 2011, "Regulations on the Types and Use of Special Means" does not identify any special mean that is specified for drone countermeasures.
2. There were stated several cases of unallowed UAVs usage within the period of research in the border surveillance districts in Latvia and one

case of an evident military threat violating Latvian airspace with an armed UAV.

3. The stationary anti-drone systems are classified as detection devices and interception devices. The author states that most effective way of drone-countermeasures is the combination of both devices in one system.

4. "SKYLOCK" and "AARONIA" manufacturers provides technical solutions that are useful for border surveillance sphere. These solutions combine several UAV detection devices and UAV interception devices and provide large range capability, that could cover whole EVR 17 flight restriction zone and prevent unauthorized UAV flights within this zone.

Based on previous conclusions, the author of the current article makes following suggestions:

1. State Border Guard initiate amendments to the Cabinet of Ministers Regulations No. 55 of 18 January 2011, "Regulations on the Types and Use of Special Means." These amendments should include new types of special means: "UAV detection devices" and "UAV forced landing devices," and specify their use with the following formulations: "UAV detection devices are used to monitor airspace and prevent unauthorized use of UAVs above the infrastructure facilities owned or possessed by the Internal Security Bureau, the State Police, and the State Border Guard, and within a 50-meter horizontal plane from them, as well as in UAS geographic zones initiated by these institutions" and "UAV forced landing devices are used to terminate unauthorized use of UAVs above the infrastructure facilities owned or possessed by the Internal Security Bureau, the State Police, and the State Border Guard, and within a 50-meter horizontal plane from them, as well as in UAS geographic zones initiated by these institutions." These formulations would align with those specified in the Cabinet of Ministers Regulations No. 429 of 29 June 2021, "Rules on Unmanned Aircraft Flights," and would allow the State Border Guard to implement the aforementioned special means for UAV detection and neutralization.

2. Within perspective competitive proposal procedure in anti-drone system purchase, the State Border Guard should pay attention to "SKYLOCK" and "AARONIA" manufactured systems that are created specifically for border surveillance tasks. These systems combine several UAV detection devices and UAV interception devices and provide large range capability, that could cover whole EVR 17 flight restriction zone and prevent unauthorized UAV flights within this zone.

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