PROTECTION AGAINST DRONE ACTIVITY

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ABSTRACT
The research presented in the article focused on the determinants of protection aginst drone activity. At the beginning of the article the authors would like to propose one understandable definition of a drone. It was necessary to analyse air threats linked with the increased use of unmanned aerial vehicles or radio controlled aircraft. Furthermore, the authors divided drones by their technical capabilities. The next part of the article describes possible actions against drones and the possibility of recognizing them. The research was based on available literature.

KEY WORDS
Dron, Air safety, security, Drones protection system

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Introduction

Since the origin of the military aviation it has been claimed that unlimited airspace creates conditions for performing bomb raids, against which the defence is impossible, and airspace domination may be sufficient to win the entire conflict. General`s Douhet Giulio publication released in 1921 *Domination in the air*[1] defines the will of people as a one of the main targets of the aviation attacks.

Further development of aircraft has continually intensified a threat not only for the forces involved in the armed struggle, but also civil population. The historical experiences of Poland only confirm the suggestions put forward by Douhet. An example of a military aviation operation which had an impact on the civil population is the air raid carried out on Warsaw September 25th, 1939 by Luftwaffe, which caused the death of 10,000 people and left about 35 thousand of people wounded. It is estimated that nearly 12% of the urban development was destroyed. In the face of such a devastating force a few days later Warsaw had to capitulate.

Not only the experience of Poland is affirmed by the thesis developed at the beginning of aviation. Postwar estimates of the allies reported that about one third of the German population was directly affected by the bombings, and about 14 million of people lost their property, more than 20 million of people were deprived of electricity, gas or water for a certain period of time and 5 millions had to be evacuated. One quarter of apartments were destroyed and about 305 thousand of people lost their lives[2].

[1] G. Douhet, *The Command of the Air – translated by Dino Ferrari*, Wyd. Air Force History and Museums Program, Washington, D.C., 1998.

[2] See. *United States Strategic Bombing Survey*, T. 4, New York, London 1976.

However, the end of the World War II, contrary to F. Fukuyama thesis published in *„The end of the history and the last man"*, did not mean the end of the conflict. Several nations actively participated in the arms race, and defence expenditures in the most global countries grew from year to year. The development of the aeronautical technology created the modern means of battle, to which drones belong undoubtedly.

The growing signification of drones in armed conflicts and their constant development make it is necessary to defend against that kind of aerial assault means. It requires considering the possibility of defence against drone actvity.

The purpose of research presented in the article is to show the current state of defence against drones. The study was conducted by examining the relevant literature. Firstly, the meaning of the term "drone" was standardized. Next, drones were divided by their tactical and technical capabilities in order to determine the possibilities of destroying them. The last stage of the study was an analysis of the possibility of recognizing and defeating drones.

1. Semantics

Before proceeding to consider the issue of danger that is generated by drones, the term *„drone"*[3] needs to be explained. This is due to the alternative use of these three terms:

1. Drone.
2. Unmanned Aerial Vehicle (UAV).
3. Radio Controlled Aircraft (RCA).

Literature analysis indicates that various departments dealing with problematic matters concerning UAV and RCA in the United States present various approaches within a meaning of these terms.

The United States Department of Defence defines an UAV as a *self-flying apparatus, unable to carry the operator, with a possibility of conducting flights independently or remotedly, controlled by one or more operators, carrying on board a combat load or not*[4]. In contrast, a RCA is defined as a *subtype of the UAV, produced comercially or provisional, requiring one operator for the whole period of a remote flight, with the ability of operating in the air for up to 2 hours*[5].

The approach of the Federal Aviation Administration, differs from the statements mentioned above. The Federal Aviation Administration states that differences between UAVs and RCAs result significantly from the use of the BSP autopilot, and in each model requires a computer control upholding the flight[6].

Due to the differences between each model it was necessary to find one common feature for UAV and RCA models. That kind of approach is presented by the US Department where: an *UAV or RCA is an aircraft without a human pilot aboard. Its flight is controlled either autonomously by onboard computers or by the remote control of a pilot on the ground or in another vehicle. The typical launch and recovery method of an unmanned aircraft is by the function of an automatic system or an external operator on the ground*[7].

A common definition of the UAV and RCA mentioned above is identical with the general definition of a drone, understood as *an unmanned aircraft or ship that can navigate utonomously, without human control or beyond line of sight*[8].

In accordance with the above discussion, it should be assumed that a term *drone*

[3] A term – a word or expression of a special importance in a certain field, Polish dictionary (sjp.pwn.pl).

[4] http://www.terroryzm.com/modele-samolotow-sterowanych-radiowo-%E2%80%93-nowa-bron-terrorystow/ (access January 07, 2017).

[5] Ibidem.

[6] See. Drones vs. Radio-Controlled Aircraft: A Look at the Differences between the Two. www.RCFlightLine.com (access January 07, 2017).

[7] Departament of the USA army installation management command HQ., U.S. Army Garrison-red cloud, 22 January 2015.

[8] http://www.dictionary.com (access March 02, 2017).

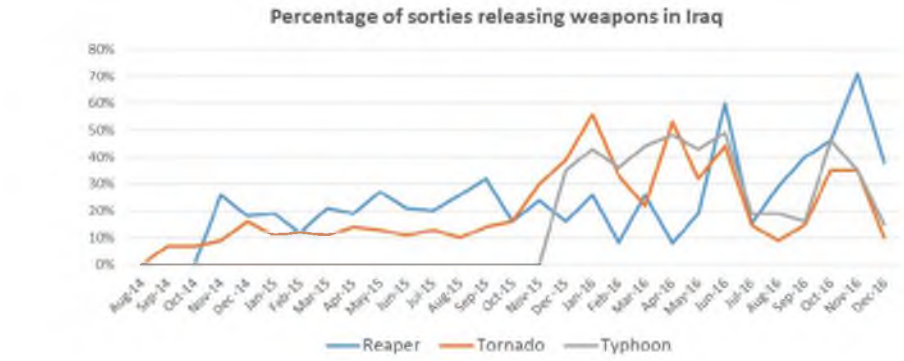
stands for any type of unmanned aircraft, regardless of its specifications or a way of navigation.

2. The description of a threat

Drone development is associated directly with a wider range of possibilities of their use in armed conflicts, life saving, reconnaisance, photography, etc. A wide range of possibilities of the use of drones creates also new threats, due to their increased general tactical and technical capabilities.

Over several years drones have been used in the army not only for reconnaissance, but also for destroying ground targets. Therefore, a certain analogy can be distinguished between the initial use of the aircraft and drones.

In accordance with the predictions, the significance of drones in air operations is constantly increasing. It is shown by the juxtaposition of the air operations with the use of drones and manned aeroplanes conducted by the Army of the United Kingdom in Iraq.



Source: British drone operations aginst Isis, 2014-2016, dornewars.net, 02.2017, p. 7.

The data presented prove the upward trend of the use of drones in air operations. Taking into consideration the above facts, it should be noted that as much as 22% of the UK's 726 air strikes in Iraq and Syria in 2016 were carried out by Reaper drones.

Recently, the Massachussets Institute of Technology revealed its research on creating an autonomus system consisting of hundreds of drones. A *Predix* system was tested by the Army of the United States where three jet fighters F/A-18 Super Hornest released over the military training ground about 103 micro drones. *Due to the complex nature of the battelfield, Predix is not individually programmed units, but they create one, collective organism sharing a managing process and adapting to the situation as the swarms do in the nature*[9].

The involvment of drones in the battle with ground targets causes also losses in the civil population, like with the use of the aerial assault means.

Despite carrying over 1,200 strikes and launching more than 2,500 missiles and bombs (until December, 2016) MoD of the UK officially denies the allegations of wounding or killing civil population. The US Army claims only 188 killed civilians.

Unlikely data concerning victims are criticized by various non-governmental organizations. Proposing an independ-

[9] http://technowinki.onet.pl/militaria/predix-roj-wojskowych-dronow-zrzucony-przez-mysliwce/3g4gep (access January 07, 2017).

ent assessment of the conducted strikes, *given the statistical improbability of the UK having killed no civilians in more than 1,000 airstrikes, this suggests the MoD's monitoring capabilities may not at present be fit for purpose. We therefore recommend that the MoD commissions an independent review - which is able to examine the validity of classified civilian casualty assessments. We also call for the key findings of such a review to be made public*[10].

The information presented above makes independent organizations, especially Bureau of the Investigative Journalism and the New American Foundation, collect their data on drones and civilians killed due to their activity. The data gathered by these organizations indicate that as a consequence of drone strikes carried out in Pakistan, Yemen, Somalia and Afghanistan from 736 to 1391 civilians lost their lives.

The data presented only prove the thesis regarding the increased significance of drones in current armed conflicts. However, attention should be paid to the continuous development of drone technology. Their technical and tactical capabilities are constantly increasing, which is expressed by the tactical radius of operation, capacity and time of their remaining in the air. However, it should be noted that a threat of the possibility of using drones is not only a domain of the wartime or armed conflict. Such a threat exists also during the peacetime where drones may be used as an instrument for terrorist attacks. In this case, the possibility of using various types of drones should be distinguished. Technologies implemented and developed by armies of various states are primarly focused on UAVs, whereas terrorist threats will be caused mainly by RCAs. It is a significant difference due to their use. And that determines the protection means against these threats.

It was deliberate, therefore, to create specifications and analysis of these aerial assault means. The relevant data will include range, ceiling, lifting capacity, and radar cross section (RCS).

Table 1. Specifications of drones

IDENTYFICATION	Flight time	Range	Ceiling	Capacity
HIGH	> 24 h	> 1500 km	> 10000 m	> 100 kg
MEDIUM	5 – 24 h	100 – 400 km	1000 – 10000 m	50 – 100 kg
LOW	< 5 h	< 100 km	< 1000 m	< 50 kg

Source: Mech Eng 3016 Aeronautical Engineering dr Maziar Arjomandi, Classification of unmanned aerial vehicles pp. 14, 18, 20.

According to the data presented, it was possible to divide drones into three various classes.

A different division of drones can be found in the NATO classification made in 2009, where drones were divided into three main classes:

– First-class objects weighing less than 150kg and with a flight time capability up to 6 hours;
– Second-class drones ranging from 150 kg to 600 kg with a flight time capability up to 24 hours;
– Third-class objects weighing more than 600 kg with a flight time capability up to 40 h[11].

[10] Limited Accountability: A transparency audit of the Coalition air war against so-called Islamic State. Airwars, December 2016, https://airwars.org/wp-content/uploads/2016/12/Airwars-report_Web-FINAL1.compressed.pdf [access January 07, 2017]

[11] See. Mech Eng 3016 Aeronautical Engineering dr Maziar Arjomandi, Classification of unmanned aerial vehicles, p. 8.

The above division of drones is limited to the classification solely by its weight. Due to continuous miniaturization of the aviation technology caused by technological progress, the proposed classification does not reflect the real possibilities of drones[12]. In the subject matter of the study, a similar classification dividing drones into five categories can be found. The typology is presented below.

Table 2. Classification of drones by their weight

CLASS	CATEGORY	WEIGHT	EXAMPLE OF DRONE
2 / 3	Very heavy	> 2000 kg	RQ-4 Global Hawk
	Heavy	200 – 2000 kg	A-160
1 / 2	Medium heavy	50 – 200 kg	Raven
1	Light	5 – 50 kg	RPO Midget
	Very light	< 5 kg	Dragon Eye

Source: Own study based on Mech Eng 3016 Aeronautical Engineering dr Maziar Arjomandi, Classification of unmanned aerial vehicles p. 9.

The division of drones presented above indicates additional inconsistency in distinguishing the types of drones. Consequently, the first division will be adopted for further discussion.

Figure 1. First – class drones Source: https://en.wikipedia.org/wiki/Northrop_Grumman_RQ-4_Global_Hawk,

https://pl.wikipedia.org/wiki/A160_Hummingbird

Figure 2. Second – class drones

Source: http://www.asimo.pl/modele/raven.php, http://kulturalnikpoznanski.blogspot.com/2015/09/drony-bezzaogowe-statki-powietrzne.html

[12] An example is „Pionnier" Drone with the weight of 125 kg , lifting capacity 65 kg, range 373 km, ceiling 4.5 km, which is difficult to be qualified to one class only

Figure 3. Third-class drones

Source: Mech Eng 3016 Aeronautical Engineering dr Maziar Arjomandi, Classification of unmanned aerial vehicles p. 9.

Recently, a high ratio of drone activity has been noticed in military operations, having a direct impact on human life. The intensified use of drones, as an aerial assault means, increased the activity in order to level the consequences of reconnaissance and defence systems. According to the authors, first and the most important point of the efficient counteract against threats posed by drones is specyfing their characterictics. This will allow for selecting the means of recognition and destruction of this aerial assault means. The data presented above show that in the relevant literature, the division of drones was based primarly on their weight, without taking into account their combat potential determining the defence measures against them. In conjunction with the information presented above, the authors proposed the classification of drones by their tactical and technical capabilities.

3. The possibilities of drone detection

Bearing in mind the above characteristics and typology of drones, for the purpose of the article the possibilities of detecting drones in the airspace were analysed. The possibilities of drone detection by a specialist airspace reconnaisance means are largely based on the objects data constants.

From the technical point of view, one possibility of drone detection is the radiolocation reconnaisance of the objects. Radar cross section (RCS) ia a parameter defining the ability of reflecting electromagnetic waves, depending on the size of object surface and type of the material used. The probability of object detection is about 80% next to an object having RCS equalling $1m^2$ and the capability of regular wave reflection. It can be said that technological and technical progress aims to minimaze the capability of detecting objects by creating smaller objects of varied structure.

The conclusion is that in order to define the capabilities of drone detection, their RCS has to be known. It should be noted that RCS is a surface not suppressing the electromagnetic wave falling on it, but reflecting it in the direction of the receiving antenna. Depending on the radar parameters, object distance, ceiling, material, size of drone and direction of the radiation, RCS will be equal. Due to various shapes and material used, RCS for drones is experimentally determined in laboratory conditions.

The following is the typology of drones by their RCS parameter proposed by the authors, based on the assumption of parameters of the radars operating in bandwidth „L" (1,2-1,4 GHz).

Table 3. RCS parameters for the radars operating in bandwidth „L"

Section	dBsm[13]	RCS (m^2)[14]
I	-20	0.01
	-15	0.03
	-11	0.07
	-8	0.15
II	-3	0.50
	-1	0.79

[13] Formula for calculating dBsm = 10xlog(SPO).
[14] Formula for calculating RCS = 10^(dBsm/10).

II	1	1.25
	3	1.99
III	8	6.31
	11	12.58
	15	79.43
	20	100.00

Source: Own study.

The data above present the theoretical classification of drones by RCS and the possibilities of their detection. First-class drones have small RCS, therefore, the detection of that kind of object is at a level below 80%. Second-class drones have similar RCS value up to $1m^2$, and the degree of detection of that kind of drones is optimal at the level of 80%. Drones with the easiest possibility of detection have RCS higher than $1m^2$ and the level of their detection is from 80% to 99%.

A system that can be only for reconnaissance and warning of a drone activity in the restricted area is the radars of radio engineering military units and civilian airports. The detection of a drone by a radar is influenced by numerous factors, not only technical capabilities, but also weather conditions. Depending on numerous features, radars maintain the possiblity of detecting second and third-class drones (Fig. 1 and 2), unfortunately it is the only positive aspect, since the detection of a drone is not similar to capturing or destroying it and the time of the state security service may be to extended. Additionally, it is not possible to clearly specify whether the detected object is a drone or a different object with similar parameters.

Figure 4. Surveillance radar NUR-31MK

Source: http://www.polot.net/zarys_historii_nawigacji_radary_1990r_2010r_wojska_lotnicze_sily_powietrzne_

Concluding the data presented, it has to be clarified that the smaller RCS of a drone, the more difficult it is to identify a drone by surveillance radars. Therefore, in order to detect a first-class drone, a visual method or a thermovision should be used. Therefore, second and third – class drones can be easily detected by surveillance radars.

4. Military assets to combat drones

Drone detection itself is not sufficient to provide security against that kind of aerial assult means. An efficient fire or incapacitation system is necessary to achieve success in defeating a drone.

There are several methods of fighting drones with the use of fire assets as well as fire assets classified as unconventional.

Unconventional methods include the use of birds as means intended to combat drones. The French Army trains eagles in order to capture drones and land with them on the ground. This method is based on the experience of the Dutch police, who used birds to combat small drones. *Eagles have the ability of tracking drones from a few thousand meter in order to neutralize them – General commander of the Air Forces Gen. Jean-Christophe*[15] Unfortunately, that kind of method is efficient in combating drones of a small surface and durability as well as first-class drones (Fig. 1, Fig. 2).

Figure 5. A method of capturing a rone with the use of birds

Source: http://wiadomosci.wp.pl/query,dron,szukaj.html?ticaid=118d11

There have been several dangerous incidents involving drones. Therefore, various companies and academies are developing systems to combat them. Military University of Technology along with the Ellopsis company are working on a system intended to fight drones with the use of *mobile launching platforms for high-powered drones*[16]. A SAN system is designed to capture drones with the use of a net with a mounted parachute and it will have been ready by the end of 2017. The means of fighting Drones mentioned above is in the center of attention of the state security services. In the future, the SAN system may be used to combat first-class drones which are characterized by low level technical parameters (Fig. 1, Fig. 2).

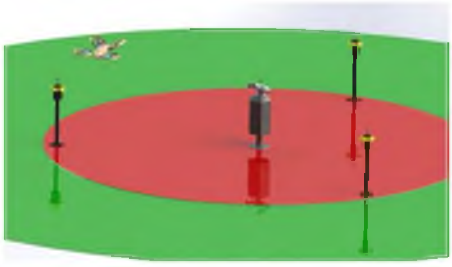
Recently, a high rate of air incidents involving drones can be noticed. On July 20, 2015 at the Okęcie Warsaw Airport at 4:00 PM of local time, Embraer airplane 195 of the Lufthansa Airlines passed a drone at a distance of 100 m while it was landing. A similar accident was in March 2014 when in the military part of the Kraków-Balice airport in a controlled zone, a drone activity was noticed, thus violating air traffic regulations. The above events led to an idea to combat drones, and three companies from Gdynia – Bonda.pl, Bioseco and SIRC were the main originators. Safe Sky is a system designed to *detect drones on the area where their presence is not welcomed or they are considered to be a threat in a given airspace. After drone detection, SafeSky will warn the right person, or it can deactivate the drone, probably by interfering with the signal controlling the machine*[17]. This kind of a system can handle drones of each class specified by the authors (Fig. 1, Fig. 2). Moreover, in the nearest future these systems will be placed on approach routes for the landing planes.

[15] http://www.radiozet.pl/Wiadomosci/Swiat/Zwalczanie-dronow-za-pomoca-ptakow-00032189 (access March 19, 2017).

[16] http://www.polska-zbrojna.pl/home/articleshow/19744?t=Obrona-przed-dronem (access March 19, 2017).

[17] http://www.swiatdronow.pl/safesky-polski-system-do-wykrywania-dronow (access March 19, 2017).

Figure 6. Safe Sky system visualization



Source: http://www.swiatdronow.pl/safesky-polski-system-do-wykrywania-dronow

Considering the above examples of drones defence systems, they are only a perspective view of the aerial assault means combat possibilities. In order to identify the current possibilities of countering these threats, it was deliberate to conduct a study focused on the opportunies of fighting drones by Polish defence systems.

Anti-aircraft and portable missile defence systems are included in these defence assets. The most popular are KUB, OSA or NEWA air defence systems. Due to their technical and tactical capabilities, they can be used only for fighting third-class drones (Fig. 1, Fig. 2). It means that the use of such a system is efficient only when combating drones of a very large size. Additionally, an important factor is that during the peacetime, air defence missile systems are not in a combat readiness status, which prevents their use against terrorist acts.

Figure 7. KUB missile system

Source: http://odwaszegofotokorespondenta.blogspot.com/2012/09/open-air-day-2012-malbork.html

GROM is a portable missile system included in the air defence means of Poland. The system is dedicated to destroying low-altitude flying air objects including airships, planes and helicopters. The presented air defence asset is designed to combat drones. It is equipped with a photodetector included in the tracking system. Optical filters used in this system allow for distinguishing the proper target on the background of natural and artificially generated harassments[18]. Unfortunately, it should be noted that nowadays, there is no precise division and description of drone elements that have thermic capabilities allowing their detection. To sum up, it can not be clearly defined to which class of drones that kind of a portable system could be dedicated.

[18] https://pl.wikipedia.org/wiki/Grom_(przeciwlotniczy_zestaw_rakietowy).

ZU-23-2 is another system that can be included in the defence assets against drones. The system acts as an ordinary firearms, using an optical method of object detection. The presented system is dedicated to combating low-altitude flying objects at the distance up to 2.5 km, which means that this system combats first-class and second-class drones.

Figure 8. From the left, ZU-23-2 anti-aircraft cannon and a portable missile launcher GROM

Source: http://www.mojehobby.pl/products/ZU-23-2-3025187.html and http://militarium75.blogspot.com/2014/06/rakieta-grom-nowoczesna-polska.html

The examples presented above show that the present state of security against drones is still insufficient to provide protection for both forces involved in the armed conflict and as well as during peacetime. Modern defence systems against drones are not in the use of the nation and present systems are insufficient.

Conclusion

The discussion on the defence abilities against an air threat posed by drones allows for assuming that the significance of drones in armed conflicts is not a perspective vision, but a fact. It was proven by the analysis of conducted tasks by manned and unmanned aircraft of the United Kingdom.

Further research allowed for defining a term drone, which enabled an analysis of the characteristics of these aerial assault means. In this respect, the presented results of the studies resulted in defining the classification of drones by their tactical and technical capabilities. The division enabled the possibility of fighting drones, taking into consideration not their tactical and technical parameters, determining the possibilities of impact on the aerial assault means by the specialist assets of reconnaissance and fire.

The most important element of research was defining the possibilities of reconnaissance and destruction of drones by the anti-aircraft and radiolocation means of the Polish Armed Forces. Conducted analysis proved the need for the division of drones by tactical and technical parameters and enabled for clarifying the kinds of drones that can be destroyed by air defence.

Research findings allow us to deduce that there is a lack of means and assets in Poland intended to detect, track and combat all types of drones. Moreover, it is certain that the use of missile air defence systems may be ineffective. In this respect, the words of General Perkins'a Commander of the Land Forces of the US Army are significant, who reveald that the missiles of the patriot system were used not only to destroy commercial drones. Explaining such activities, the general said: *„When something emerges on a radar display as an echo, it can not be known that it is a drone costing at Amazon 200 dollars. On the*

radar screen it is simply an echo. So what is needed the most is information passed to the air defence system. If it was a plane instead of a drone, the use of a missile can be appriopriate. But the difficulty is that we do not always know that. It may be a maneuvering missile, but it also can be a slowly flying plane. So there is a need to possess better sensors, which will distinguish the target"[9].

The above implies the necessity of conducting further research aimed at defining the possibilities of reconnaissance and destruction of drones by a specialist air defence system.

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http://www.defence24.pl/565341,rakietowe-strzelanie-armata-do-wrobla.

[19] http://www.defence24.pl/565341,rakletowe-strzelanie-armata-do-wrobla (access April 23, 2017).