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PROTECTION AGINST DRONE ACTIVITY

ABSTRACT

The conducted research included on this article focused on determinat of protection aginst drone activity. On the begin off this article Authors wouldlike proposed one understandable appellation of Drone. It was necessary analysis air threats linked whith increasing used unmanned aerial vehicles or radio controlled aircraft, furthermore Authors divided Drones into technical capabilities. The next part of article describe possibility actions against Drones and possibility of recognize them. The mention research was based on available literature.

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 the people as a one of the main targets of the aviation attacks.

Further development of the aircraft has continually intensified the threat not only for the forces involved in the armed struggle, but also civil population. Historical experiences of Poland only confirm the suggestions forwarded by Douhet. An example of a military aviation operation which has left an imprit 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 has been destroyed. In the face of such a devastating force a few days later Warsaw had to capitulate.

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

Not only Poland`s experience is confirmed by the thesis developed at the beginning of the 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 have been deprived of electricity, gas or water for a certain period of time and 5 millions had to evacuate. One quarter of apartments were destroyed and about 305 thousand of people lost their lives[2].

However, the end of the World War II contrary to F. Fukuyama thesis publicated in „T*he 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 grown from year to year. The development of the aeronautical technology created modern means of battle, to which undoubtedly belong drones.

The growing signification of drones in the armed conflicts and their constant development causes the necessity of organizing a defence against that kind of aerial assault means. It requires considering the possibility of defence against drone actvity.

The purpose of the research in the presented article is to indicate the current state of defence against drones. The study was conducted by examining the literature of the research subject. Firstly, standardizing the meaning of the therm „DRON". Next, dividing drones 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 it is worth to explain the term „*drone"*[3]. The necessity is due to the alternative use of these three terms:

1. Dron.
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 meaning of these terms.

[2]See. *United States Strategic Bombing Survey*, T.4, New York, London 1976.
[3] The term – a word or expression of a special importance in a certain field, Polish dictionary [sjp.pwn.pl].

The United States department of the defence defines 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]. Contrary RCA is defined as a s*ubtype 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, diffrencies between UAV and RCA result significantly from the use of the autopilot BSP, and in each models – require a computer control upholding the flight[6].

Due to the diffrencies between each models it was purposeful to find one common feature for the UAV and RCA models. That kind of approach is presented by the US department where: *UAV or RCA is an aircraft without a human pilot aborad. Its flight is controlled either autpnomously 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]

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 autonomously, without human control or beyond line of sight*[8].

In accordance with the above considerations it should be assumed that, term *Drone* stands for any type of unmanned aircraft. Regardless of its specifications or way of navigation.

2. CHARACTERISTICS OF THE THREAT

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

[4] http://www.terroryzm.com/modele-samolotow-sterowanych-radiowo-%E2%80%93-nowa-bron-terrorystow/ [access: January 7th , 2017].

[5] Ibidem.

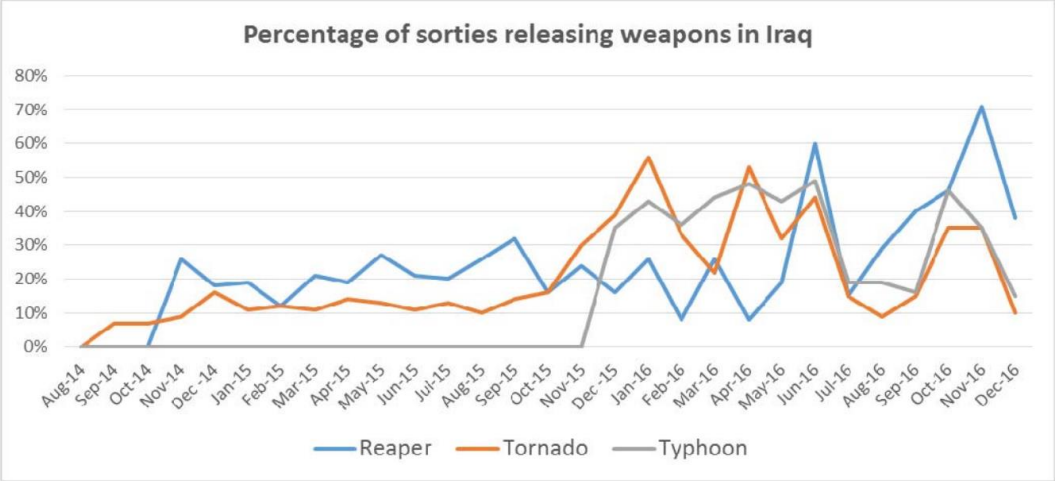
[6] See. Drones vs. Radio-Controlled Aircraft: A Look at the Differences between the Two. www.RCFlightLine.com [dostęp:07.01.2017].

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

[8] http://www.dictionary.com [access March 2nd, 2017].

Over several years drones were 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 the air operations constantly increases. It is depicted 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.

Presented data confirm the upward trend of the use of drones in the 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 hundrets of drones. *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 are not individually programmed units, but they create one, collective organism sharing 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 as well as due to the use of the aerial assault means.

Despite carrying over 1200 strikes and launching more than 2 500 missiles and bombs (untill December, 2016) MoD of the UK officially denies allegations of wounding or killing civil population. The US Army claims only 188 killed civilians.

[9] http://technowinki.onet.pl/militaria/predix-roj-wojskowych-dronow-zrzucony-przez-mysliwce/3g4gep [access: January 7th , 2017].

Unlikely data concerning victims meets with criticism of various non-governmental organizations. Proposing an independent 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 causes, that independent organizations collect their data concerning drones and civilian killed due to their activity, especially Bureau of the Investigative Journalism and New American Foundation. The data gathered by these organizations indicates that as a consequence of drone strikes carried out in Pakistan, Yemen, Somalia and Afghanistan from 736 to 1391 civilians lost their lifes.

Presented data only confirm the thesis regarding the increasment of the significance of drones in the current armed conflicts. However, there should be put attention to the continuous development of drones technology. Their technical and tactical capabilities are constantly increasing which are expressed i.e.by tactical radius of operation, capacity and time of remaining in the air. However, it should be noted that the threat of the possibility of using drones is not only a domain of the wartime or armed conflict. Such a threat exist 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 primarly are focused on the UAV, whereas the terrorist threats will be caused mainly by RCA. 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, radar cross section (RCS).

Tab. 1 Drones specifications

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 pages 14, 18, 20.

[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 7th, 2017].

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

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

- Firs class of drones are 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;
- last class of drones are objects weighing more than 600 kg with a flight time capability up to 40 h.[11]

The above division of drones is limited to classification solely due to 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 there might be found a a similar classifications dividing drones into 5 categories. The typhology is presented below.

Tab. 2 Drones classification in accordance to their weight

CLASS	CATEGORY	WEIGHT	AN 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 basing on Mech Eng 3016 Aeronautical Engineering dr Maziar Arjomandi, Classification of unmanned aerial vehicles str. 9.

The division of drones presented above introduces an additional inconsistency in distinguishing drone types. Consequently, the first division will be adopted for further consideration.

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

[12] An example is Dron „Pionnier" with weight 125 kg , lifting capacity 65 kg range 373 km a ceiling 4,5 km which is difficult to be qualified to one class only.

Figure 1 1st Class drones

Source: https://en.wikipedia.org/wiki/Northrop_Grumman_RQ-4_Global_Hawk, https://pl.wikipedia.org/wiki/A160_Hummingbird

Figure 2 2nd Class drones

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

Figure 3 3rd Class drones

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

Stating the conducted reflections it can be said, that recently a high ratio of drones activity has been noticed in a military operations, having a direct impact on a human`s 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 affection. According to the authors, first and the most important point of the efficient counteract against threats carried by Drones is specyfing their characterictics. This will allow to select means of recognision and destruction

of this aerial assault means. The data presented above show, that in the literature of the subject matter the division of the 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 drones classification for the sake of their tactical and technical capabilities.

3. THE CAPABILITIES OF RECOGNIZING DRONES

Bearing in mind the above characteristic and typology of drones, for the purpose of this article there was made analysis of possibilities of detecting Drones in the airspace. Capabilities of Drones detectection by a specialist airspace reconnaisance means are largely based on the objects data constants.

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

The conclusion of the above considerations allows to state, that in order to define the capabilities of Drones detection there has to be known their RCS. 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.

Below is presented Drones typology proposed by the authors due to their RCS parameter on the assumption of parameters of the radars operating in bandwidth „L” (1,2-1,4 GHz).

Tab. 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
	1	1,25
	3	1,99
III	8	6,31
	11	12,58
	15	79,43
	20	100,00

Source: own study.

The data presented above present theoretical classification of Drones in comparison to RCS and possibilities of their detection. 1st class Drones are characterized with a small RCS, therefore, the detection of that kind of object is on a level below 80%. 2nd class Drones are of similar RCS value up to $1m^2$, a level of detection of that kind of Drones is optimal at level 80%. Drones with the easiest possibility of detection possess RCS higher than $1m^{2,}$ the level of detection for that kind of Drones is from 80% to 99%.

A system that can be only for reconnaissance and warning of a Drone activity in the restricted area are radars, of radio engineering military units and civilian airports. Impact on a detection of a Drone by radar are influenced by numerous factors, not only technical capabilities but also weather conditions. Depending on numerous features, radars maintain possiblity of a second and third class Drone detection (Fig.1, Fig.2), unfortunately it is the only positive aspect, since detection of a Drone is not similar to capturing or destroying it and 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 possessing similar parameters, it is caused mainly by, result of the presented objects on the radar screen.

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

Fig. 4 Surveillance radar NUR-31MK

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

Concluding the presented data, it has to be clarified that, the smallest RCS of a Drone the more difficult is to identify a Drone by the surveillance radars. Therefore, in order to detect a Drone of a I class a visual method or with the use of a thermovision is believed to be sufficient enough. Therefore, 2nd and 3rd class Drones can be easily detected by the surveillance radars.

4. MILITARY ASSETS DESIGNATED TO COMBAT DRONES

A Drone detection itself is not sufficient to provide a security against that kind of aerial assult means. An efficient fire or incapacitation system is necessary to achieve a 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 is training Eagles in order to capture Drones and land with them on the ground. This method is based on the experience of the Dutch police, using birds to combat small drones. *Eagles have the ability of tracking Drones from a few thousand meters, 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 Drones classified as a class 1 (Fig.1, Fig.2).

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

Fig. 5 A method of capturing a Drone 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 academys are developing systems to combat drones. Military University of Technology along with the company Ellopsis are working on a system intended to fight drones with the use of *mobile launching platforms for a high-powered Drones.*[16] SAN system is designed to capture Drones with the use of a net with a mounted parachute and it will be ready till 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 SAN system may be used to combat Drones from the 1st group which are characterized by a low level technical parameters (Fig.1, Fig.2).

Recently, there can be noticed a high ratio of an air incidents due to the Drones activity. On July 20th ,2015 at the Warsaw Airport Okęcie at 4:00 PM of local time Embraer airplane 195 of the Lufthansa Airlines while landing passed a Drone at a distance of 100m. A similar accident was in March 2014 when in the military part of the airport Kraków-Balice in a controlled zone a Drone activity was noticed thus violating the air traffic regulations. The above events caused the creation of an idea in order to combat Drones, where 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 a Drone detection SafeSky will be warning the right person, or it can deactivate the Drone. How? Probably by interfering with the signal controlling the machine.*[17]. This kind of system can handle Drones of each class specified by

[16] http://www.polska-zbrojna.pl/home/articleshow/19744?t=Obrona-przed-dronem [March 19th , 2017].
[17] http://www.swiatdronow.pl/safesky-polski-system-do-wykrywania-dronow [March 19th , 2017].

the authors (Fig.1, Fig.2) and what is more in the nearest future these systems will be setup on approach routes for the landing planes.

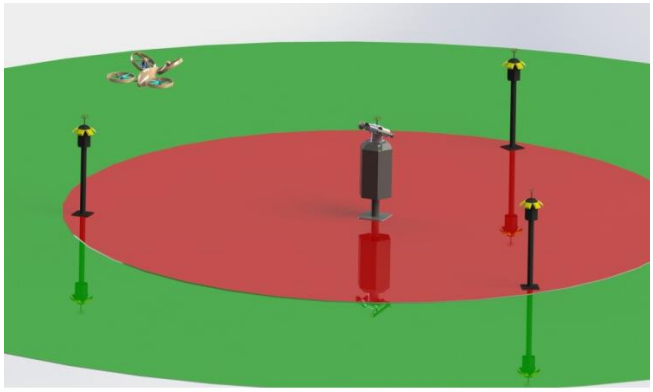


Figure 6 Safe Sky system visualization

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 diagnose current possibilities of countering these threats, it was deliberate to conduct study targeted at opportunies of fighting drones by a 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 the technical and tactical capabilities of these systems they can be used only for fighting 3rd class Drones (Fig.1, Fig.2). It means that the use of such a system is efficient only in combat with Drones of a very large size. Additionally, important factor is that air defence missile systems during the peacetime are not in a combat readiness status what unables their use against terrorist acts.

Figure 6 Missile system KUB

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 destroy low-altitude flying air objects including airships, planes and helicopters. The presented air defence asset is designated to combat Drones. It is equipped with a photodetector included in the tracking system. Optical filters used in this system allow to distinguish the proper target on the background of natural and artificially generated harassments.[18] Unfortunately, there is a need to notice that nowadays there is no precise division and characteristic of Drones elements that have termic capabilities allowing to detect them. To sum up, it can not be clearly defined to which class of Drones that kind of a portable system could be dedicated.

ZU-23-2 is next system that can be included in the defence assets agains Drones . The system acts as an ordinary firearms, using optical method of an object detection. The presented system is dedicated to combat low-altitude flying objects at the distance up to 2,5 km what means that this system combats 1st and 2nd class drones.

Figure 7 From the left is an anti-aircraft cannon ZU-23-2 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

From the examples presented above we can infer that, the present state of the 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 use the of the nation and present systems are insufficient.

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

CONCLUSION

Conducted considerations, concerning the abilities of the defence against air threat caused by Drones allow to assume that the meaning of drones in the armed conflicts is not a perspective vision, but a fact. It has been confirmed by the analysis of conducted tasks by manned and unmanned aircraft of the United Kingdom.

Further research allowed to determine the term Drone what enabled to analyse characteristic of these aerial assault means. In this respect presented results of the studies resulted in defining drones typhology for 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 the conducted 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 confirmed the necessity of drones division by tactical and technical parameters and enabled to clarify the kinds of drones that can be destroyed by the air defence.

The study results allow us to deduce that there is a lack of means and assets in poland enabling to detect, track and combat all types of drones. Moreover, it is certain that the use of missile air defence systems may be ineffective. Significant in this respect are words of a general Perkins'a commander of the Land Forces of the US Army who reveald that 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 that what is needed the most is information passed to the air defence system. If it would be a plane instead of a drone, the use of a missile can be appriopriate. But the difficulty is we do not always know that. It may be maneuvering missile, but it also can be a slowly flying plane. So there is a need to possess a better sensors, which will distinguish the target*[19]".

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

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

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