TRENDS OF UNMANNED AERIAL VEHICLES’ DEVELOPMENT ON THE BASIS OF THE CURRENT USE IN THE SELECTED ARMED CONFLICTS

Abstract

Unmanned aerial vehicles (UAVs) are under a continuous development stage. Nevertheless, there is a wider range of their use for civilian and military purposes. We have to know, there are changes in the nature of conducted military activities. Nowadays, reconnaissance is conducted as regards the use of UAVs which allow to get the data concerning the opponent’s army. It is also possible from the areas affected by an increased level of risk.

Despite a modern technology, it is impossible to replace human’s work by machines. For this reason, methods of unmanned aerial vehicles used in selected military conflicts were described in this article. The paper also tries to make an attempt to determine probable directions of UAV’s evolution for military purposes. The first section of the paper briefly describes the history of UAVs. In the second part, there are presented some possible methods of unmanned aircraft’s classification. The further part of the article focuses on the previous military use and armament which are dedicated for an unmanned aircraft. Lastly, there are characterized expected trends of the development of unmanned aerial vehicles.

Keywords: unmanned aerial vehicle, armament, development, military conflict, modern technology.

Introduction

Unmanned aerial vehicles (UAVs) which are commonly known as drones are used very often, therefore there is a constantly growing demand for such a type of machines. The use of unmanned platforms is specifically related to military technologies.

Unmanned aerial vehicles are able to perform a number of tasks without an unnecessary risk which can be dangerous for human’s life on the battlefield. An important factor, which contributes to the development and implementation of these platforms as an equipment for armed forces, is a significant need to reduce the costs of production and purchase in comparison to manned systems. The constant
development of this technology greatly increases the possibility of identifying and tracking targets on the battlefield, the destruction of enemy air defense systems and as well to conduct fight in urban or difficult areas. The ability of unmanned aerial platforms to cooperate with manned systems is extremely important during military conflicts.

Such machines were more than six times more used in air raids during conflicts in the Middle East during Barrack Obama tenure in relation to the attacks conducted during the tenure of President Bush\(^1\).

There are many other possibilities to use unmanned aerial vehicles apart from military reasons and they include: law enforcement services, emergency management systems, building and industry.

**The historical perspective of unmanned aerial vehicles**

Contrary to a popular belief, UAVs were invented in the ancient times. It is evidenced in notes made by a Greek mathematician Architas of Tarantas about 400 B.C. There have been also examples of the military use of unmanned aircraft by the civilization of ancient China. It relied on the use of a kite with mounted a mirror for transmitting signals and determining the position of enemy\(^2\).

An interesting military method of UAVs use was during the Austrian’s soldiers insurrection in 1848, in Italy. They tried to make an air raid of the city with support of balloons filled with hot air. Unfortunately, the attack was unsuccessful due to variability of wind which has changed the direction of flight\(^3\).

It is worth mentioning the actions during the 1st World War. At that time, unmanned aerial vehicles were still significantly different from the currently used but their effectiveness was much better than their equivalents of 20th century. Unmanned aircraft from the early 20th century were called flying torpedoes due to the possibility of a one-time solo flight with the intention to strike and destroy a particular target\(^4\).

Then there was started the production of an unmanned aircraft controlled by radio waves in the interwar period and during the IInd World War. Despite that, there was still a difficulty to bring the machine back to the starting point after the performed task. Due to such problems, most of them were served as flying bombs\(^5\).

Unmanned aerial vehicles which could be used many times were developed in late 50’s of the 20th century\(^6\). It was caused by the development of anti-aircraft systems. The first portable anti-aircraft package was constructed in late 50’s of the 20th century. Thus, performing reconnaissance flights by manned full-size machines, which were exposed to combat by the above mentioned packages, became more difficult and more dangerous. On the contrary, smaller unmanned aircraft moving at a relatively high speed are difficult to be chased and therefore, there were possibilities to proceed safety flights over enemy territories.

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\(^5\) Ibidem, p. 25-27.

Currently, it can be observed the dynamic development of unmanned aircraft which results from the increasing number of methods of use (not only for the military purposes).

**Classification of unmanned aerial vehicles**

The initial period of the unmanned aircraft use was characterized by negligible differences in constructions and, therefore, the classification of these platforms was fairly simplistic. Currently, due to large differences in the design, performance, purpose and many other issues, there is a variety of classification criteria.

There is a common division prepared on the basis of types of armed forces according to three levels of activity: tactical, operational and strategic level\(^7\):
- mini- and micro-unmanned aerial vehicles (tactical level);
- small tactical unmanned aerial vehicles (tactical level);
- major tactical unmanned aerial vehicles (tactical level);
- continuous interaction unmanned aerial vehicles (operational level);
- penetrating unmanned aerial vehicles (strategic and operational level).

Another method of UAVs classification is represented by the North Atlantic Alliance - NATO (Table 1.). For this purpose, the discussed platforms are divided into three classes depending on weight. The division is also considered on the basis of the applicable maximum height of operations and a range of activities.

**Table 1. Classification of unmanned aerial vehicles in the North Atlantic Treaty Organization**

<table>
<thead>
<tr>
<th>Class</th>
<th>Category</th>
<th>Way of use</th>
<th>Altitude</th>
<th>Radius of action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class I</td>
<td>small up to 20kg</td>
<td>tactical</td>
<td>up to 1600m</td>
<td>50km</td>
</tr>
<tr>
<td>Class I</td>
<td>mini 2-20kg</td>
<td>tactical</td>
<td>up to 1000m</td>
<td>25km</td>
</tr>
<tr>
<td>Class I</td>
<td>micro – below 2kg</td>
<td>tactical</td>
<td>up to 60m</td>
<td>5km</td>
</tr>
<tr>
<td>Class II</td>
<td>tactical purpose</td>
<td>tactical</td>
<td>up to 3100m</td>
<td>200km</td>
</tr>
<tr>
<td>Class II</td>
<td>Medium Altitude Long Endurance (MALE)</td>
<td>operational</td>
<td>up to 14000m</td>
<td>without limits</td>
</tr>
<tr>
<td>Class III over 600kg</td>
<td>Strike</td>
<td>strategic</td>
<td>up to 20000m</td>
<td>without limits</td>
</tr>
<tr>
<td>Class III over 600kg</td>
<td>High Altitude Long Endurance (HALE)</td>
<td>strategic</td>
<td>up to 20000m</td>
<td>without limits</td>
</tr>
</tbody>
</table>


Unfortunately, the classification presented in Table 1 does not fully reflect the division of unmanned aircraft according to their purposes. This type of division was conducted by specialists of the General Staff of the Polish Army (Fig. 1).

According to the division included in Figure 1, there are three groups of unmanned aircrafts: exploratory designed to conduct electro-optical reconnaissance, special - designed to perform only specific tasks and strike UAVs which are intended for destruction ground, water and air targets.

**The previous use of unmanned aerial vehicles in the selected armed conflicts**

Constant technological progress has a significant impact on the conduct of hostilities. The crucial element of art of war is to perform effective reconnaissance and thus to obtain reliable information on the location, equipment, a number of troops and intentions of the enemy as well. Regardless of the nature of activities (ground, water, air), one of the ways used to gain information about the enemy army is air
reconnaissance. There have been used observation balloons filled with hot air and reconnaissance airships for this purpose at the beginning. Then, in case of aviation development, the mentioned platforms have been replaced by airplanes which due to the features like speed, a long range and an ability to maneuver, appeared to be more effective in collecting necessary data than the previous aerial vehicles. Furthermore, balloons and airships have become easy targets for air forces. It also contributed to almost the complete withdrawal of these types of reconnaissance platforms.

It should be noted that the conduct reconnaissance with a manned aircraft is affected by certain restrictions. The most important are ones are of a psychological nature. Additionally, the possibility to loss reconnaissance aircraft’s crew members in case of shooting down is important. The mentioned factors contributed to start activities which refer to the improvement of unmanned aerial vehicles construction to enable them able to perform reconnaissance missions. A significant event regarding the use of this kind of platforms was a shot down reconnaissance U-2 aircraft over Soviet territory.

**Vietnam War (1962–1975)**

The first armed conflict during which an unmanned aircraft was used broadly was the war in Vietnam. These machines were used primarily for reconnaissance flights. The need to replace manned machines by unmanned platforms resulted from the growing losses among pilots and aircraft. This was tantamount to not obtaining the required photographic pictures which were perceived as a source of information about the positions occupied by the enemy.

Information provided after the positively completed reconnaissance missions includes data about location of airports, air defense positions or military activity of Vietnam armed forces.

Many of the UAVs were crashed during landing in the initial period of their use due to a difficult terrain. For this reason, the armed forces developed and introduced the MARS system (Mid - air Retrieval System). Because of that, unmanned aircraft were intercepted in the air by a specially adapted for this purpose helicopter and then delivered to the destination point. This resulted in a longer service of machines to about 3.5 mission. From all 3435 reconnaissance missions, the recovery rate of these platforms was 84% (2870) as a result of the MARS system and growing experience in use of unmanned aerial vehicles.

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8 Air reconnaissance is a collection of information using visual observation or air sensors (Source: B. Zdrodowski, Słownik terminów z zakresu Bezpieczeństwa Narodowego, AON, Warszawa 2008, p. 128).
11 M. Adamski, J. Rajchel, Bezzałogowe statki…, p. 108.
12 Mid – air Retrieval System (MARS) – is a technique used in atmospheric reentry when the reentering vehicle is incapable of a satisfactory unassisted landing. The vehicle is slowed by means of parachutes, and then a specially-equipped aircraft matches the vehicle's trajectory and catches it in mid-air. This is a risky technique, and so is only used when other forms of landing are infeasible. Successful mid-air retrieval requires a correct operation of the retrieving aircraft, favourable atmospheric conditions, and successful execution of a tricky manoeuvre, in addition to a correct operation of the vehicle itself. (Source: https://en.wikipedia.org/wiki/Mid-air_retrieval, 18.08.2016).
14 D. Kompala, Użycie bezzałogowych…, s. 139.
Yom Kippur War (1973)

The next military conflict in which unmanned aircraft played a significant role was the Yom Kippur War. These machines were used by the Israeli army for the following tasks: missile guidance for targets, identifying and disrupting signals, radar detection of air targets, conducting electronic warfare and photo reconnaissance of air defense sets positions.

The command of Israel used only manned aviation in the initial stage of the war. However, large losses in the first days of activities (estimated at around 80 aircraft) have forced to change the tactics.

Unmanned aircraft have brought huge benefits concerning planning processes in a work interference of enemy rocket sets and anti-radar missiles. That was performed by fly near air defense sets which enforced their launch. After that, unmanned aircraft recorded parameters of sets work and these data was used to plan attacks. It should be added that such actions caused fatigue and as a consequence a lack of vigilance of soldiers serving air defence sets. It could resulted in reducing the effectiveness of the defence efforts.

What is more, unmanned aircraft also performed flights at altitudes 4000-5000 m to detect an enemy combat aircraft and facilitate the attack by "focusing attention on itself" or reduce readiness of enemy combat aviation.

The use of such platforms enable to limit losses among the Israeli aviation which already amounted to 25%. Moreover, thanks to the growing experience, Israeli specialists developed the concept of using unmanned aircraft. Because of that, unmanned aircraft Mastiff and Scout were produced for Israel armed forces in 1981 and 1982.

Bekaa Valley (1982)

The Lebanese conflict is an example of a war in which unmanned aircraft played a key role as well. It was possible due to the experience gained by the Israel soldiers in the Yom Kippur War.

The operations have been initiated by conducting reconnaissance by the Chukar-R UAVs flying at altitude of 5000 m. Due to a small and thus a low reflection surface, these machines were extremely difficult to be detected. The Samson platforms equipped with surface reflective enhancing screens flew 65 km away at the same time. This kind of operations caused an imitation of radar-echo which were similar to combat aircraft on radar displays. Then, radar parameters were recorded by the Mastiff UAVs and transmitted to ground control stations. Then, the Scout UAVs were sent to destroy positions of air defense. After that, F-4G and F-16 had to add the finishing touches.

The comprehensive use of unmanned aerial vehicles and cooperation with combat aircraft led to the destruction of the Syrian air defense system, and thus contributed to the success by the Israeli forces.

15 J. Karpowicz, Bezzałogowe aparaty latające w operacjach powietrznych, AON, Warszawa 2003, p. 43.
17 Z. Gołąb, Wykorzystanie lotnictwa na Bliskim Wschodzie, Myśl Wojskowa, nr 4/77, p. 89.
18 D. Kompała, Użycie bezzałogowych..., p. 140-141.
19 M. Adamski, J. Rajchel, Bezzałogowe statki..., p. 111-112.
Afghanistan War 2001–2002 (Operation Enduring Freedom)

Unmanned aircraft have been used in a much wider range than in the previous conflicts during the war in Afghanistan. These machines have been included in the air force command system and special groups as well.

Unmanned platforms had been used to highlight targets which were destroyed by F-15E Strike Eagle and F-14D Bombcat. Additionally, with their support there were determined targets coordinates which were sent to bombers B-1B and B-2B via satellite connection link. Due to that, the time from a target detection to its destruction became much shorter. Unmanned aircraft became famous for conducting attacks on the targets detected during flight in this conflict as well. Unfortunately, the details concerning UAVs independent operations are kept in secret.

Pakistan

Unmanned aircraft have found a wide range of use in the war against terrorism, which the Americans began after attacks of 11th September 2001. The war in Pakistan constitutes a good example. As it has been said before, bigger intensification of unmanned aircraft use occurred after choosing Barack Obama for the President of the USA.

According to the statistical data, Americans conducted more than 350 air raids with the use of these platforms since 2004 to the half of 2013, but a climax it means 122 air raids, were in 2010 (Fig. 2).

![Number of UAVs air raids in Pakistan](image)

Fig. 2. Number of unmanned aerial vehicles air raids in Pakistan in 2004-2013


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24 P. Bergen, Drone Wars…, p. 2.
As a result of the attacks, there were killed about 2003 to 3321 people. It is estimated that during the raids approved by the current US President, which took place between 2009 and 2013, there were killed more than four times people more than during the raids conducted by the US army during the tenure of a former president since 2004 to 2008\textsuperscript{25}.

Yemen

Another example of a conflict within the framework of the fight against terrorism is the war in Yemen. Similarly like during the war in Pakistan there was noticed a significant increase of UAVs use after assuming the position of the US President by Barack Obama\textsuperscript{26}. Being precise, the first attack occurred in 2002 and another seven years later in 2009 (Fig. 3).

![Fig. 3. Number of unmanned aerial vehicles air raids in Yemen between 2002 and 2013](image)

As a result of air raids, there were killed about 427 to 679 people\textsuperscript{27}. On the basis of the analysis of figures 1 and 2, it is possible to notice that the number of unmanned platforms attacks in Yemen increased fast when there was a reduction of these operations in Pakistan.

Armament designed for unmanned aerial vehicles

Despite being in a relatively early stage of the development, unmanned aerial vehicles appear to be an important element in nowadays armed conflicts. This is due to a wide range of use in conflicts of low intensity by the armed forces of the United States and Israel.

\textsuperscript{25} Ibidem, p. 2.
\textsuperscript{26} Ibidem, p. 3.
\textsuperscript{27} Ibidem, p. 12.
The development speed of armed unmanned aircraft constructions has been increased after the publication of the concept of use of UAV Technologies and Combat Operations in 1996. The author recommended development of works concerning armed versions of UAVs. He claimed it would be helpful to gain an advantage over the enemy air defense systems during conflicts\(^\text{28}\).

Initial versions of combat UAVs were equipped with armament dedicated for manned aircraft, for example missiles Hellfire II. Unfortunately, conventional missiles did not fulfill the expected requirements. Therefore, the US Land Forces and Air Force began to test other means. Among others, there were BAT (Brilliant Antiarmor Technology) missiles manufactured by Northrop Grumman. These are mini rockets without propulsion, guided on target by IR. It provided greater precision and helped to minimize unnecessary losses\(^\text{29}\).

Similar solutions offered other manufacturers of armaments, for example RAFAEL company produced Spike missiles which are used by French Armed Forces or Lockheed Martin, which created Direct Attack Guided Rockets\(^\text{30}\). Another example are missiles built by MBDA company whose print heads will be used to destroy bunkers, armored vehicles and even fortified earthen structures\(^\text{31}\). There are also solutions based on rebuilding currently used conventional armament for unmanned aerial vehicles\(^\text{32}\).

**Trends of unmanned aerial vehicles development**

Speed and directions of unmanned aerial vehicles development (in particularly combat ones) depend also on economic, business, political, scientific and social factors. The previous combat use of unmanned platforms indicates that these machines were used to conduct the following tasks\(^\text{33}\):
- conduct reconnaissance and observation from the air;
- destruction of enemy air defense systems;
- conducting electronic warfare;
- combating water and ground targets.

Certainly, it should be expected to expand opportunities for reconnaissance and observation in the future. The constant development of aviation technology allows to assume that there will be also a developed unmanned aircraft with a relatively small weight and significant duration of flight (up to 20 hours). This will increasingly reduce the cost of production and acquisition\(^\text{34}\).

The prospects for the development of these platforms presented by the US planners indicate the need for cooperation between operations of manned and unmanned aircraft. To facilitate, there will be created Manned-Unmanned Teaming System (MUM-T) which will allow to implement the following tasks\(^\text{35}\):
- ensuring mobility of troops during combat operations;
- combating navy and land forces from greater distances than in the past;

\(^{28}\) L. Cwojdziński, Bezzalogowe systemy..., p. 133.


\(^{30}\) Ibidem, p. 136-138.

\(^{31}\) Ibidem, p. 137.

\(^{32}\) Ibidem, p. 137.


\(^{35}\) Unmanned Systems..., p. 19.
– enable performance constant observation, reconnaissance, protect own armies and elimination of identified hazards;
– possibility to maintain longer communication and logistics lines in readiness to work.

Creating the MUM-T system will mean the development of UAVs to support troops transport. There will be an increase in the production of specialized unmanned platforms for air transport. Currently, such machines are mainly used by special forces but it is planned to expand a range of transport UAVs users\textsuperscript{36}. The above mentioned information is confirmed by an innovative US program: Joint Capability Demonstration Program which concern development of transport UAVs constructions able to load 4,5-9 tons for 150 NM\textsuperscript{37}.

There is an innovative idea to build a multi-purpose unmanned aircraft to be used for military and civilian purposes. The unmanned helicopter ILX-27 constructed by the Military Aviation Factory No. 1 in Łódź on the basis of the project created the Air Force Institute of Technology and Institute of Aviation is a good example (Img. 1).

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{ilx27.jpg}
\caption{The unmanned helicopter ILX-27}
\end{figure}


Currently, it is expected that the helicopter will be dedicated to support the land forces, navy or border guards however an exact method of its use will depend on its equipment\textsuperscript{38}.

It should be added that there are constant modifications of unmanned aircraft power sources. Modern sources are represented by pulse and jet engines. Nowadays, there are testing unmanned machines powered by solar energy or hydrogen fuel. Their examples are described below.

The Zephyr is a representative of platforms powered by solar energy (Fig. 5). The first test flight of this machine, which weights 50 kg, lasted seven days. It is the typical UAV designed to perform long distance flights at high altitudes. According to plans, the Zephyr can be used to observe the Earth's surface or as a relay in radio-television communication\textsuperscript{39}.

\textsuperscript{36} L. Cwojdziński, \textit{Bezzałogowe systemy…}, p. 151.
\textsuperscript{37} M. Adamski, J. Rajchel, \textit{Bezzałogowe statki…}, p. 337-338.
\textsuperscript{39} M. Adamski, J. Rajchel, \textit{Bezzałogowe statki…}, p. 338-339.
An example of an unmanned aircraft powered by hydrogen fuel is the Phantom EYE constructed by Boeing company (Img. 3). It is a high-wing UAV powered by two turbocharged reciprocating engines. During the first test flight, which lasted 28 minutes, the Phantom Eye climbed to 1200 meters reaching 115 km/h\textsuperscript{40}.

The evolution of unmanned aerial vehicles probably will be the cause of modifications in dedicated armament. Due to this fact, there will be a development to increase precision of targets hitting which will result in decrease of civilian victims. Contemporary air-to-ground missiles will be replaced by micro ammunition. It will be mainly used in unmanned aerial vehicles made in a stealth technology. This will reduce a size of platforms, thus characteristics associated with possibility of detection will be improved as well\textsuperscript{41}.

\textsuperscript{40} Ibidem, p. 342.
\textsuperscript{41} L. Cwojdziński, Bezzałogowe systemy..., p. 139.
Currently, there are proceeding activities to design air-to-air missiles which will be used for defence purposes. These types of missiles will be characterized by the possibility of supersonic cruising speed, high maneuverability and strike precision\textsuperscript{42}.

There will be production of e-bombs as an alternative for conventional armament in the near future. E-bombs will be used to incapacitate or destroy electronic systems by using electromagnetic pulse\textsuperscript{43}.

The current use and presented prospects for the development of unmanned aircraft allow to expect that there will be a dynamic development of these machines. What is more, UAVs will be used on daily basis in armed forces which will provide new possibilities concerning military conflicts.

**Conclusion**

The development of aviation technology and such factors like economic, business, or political are not the only elements which propel new designs in unmanned aerial vehicles constructions. Extremely important is a human factor which limits the development of modern manned combat aircraft. It is possible to expect that elimination of human as a pilot will enable to develop unmanned platforms able to fly faster, higher and to be more durable for overload. As it was mentioned before, this kind of solution will reduce unnecessary losses among own soldiers.

On the basis of the current UAVs use in armed conflicts, it can be noticed that these platforms can perform many missions successfully completed which have been conducted by manned aircrafts up to this time. Implementation of assigned tasks will be even easier in case of the use of specialized platforms designed to perform only certain tasks. This will minimize the risk of unnecessary losses in equipment and bring significant financial benefits.

The development and a wider range of possible use will contribute to defeat enemy air defence systems, increase opportunities for reconnaissance, improve the ability to conduct military operations in urban or difficult for human areas and thus increase the survivability of troops.

Despite of the above mentioned benefits, it should be remembered that it is impossible to eliminate man completely from UAVs operations. Nowadays and in the future, people will take control and oversee unmanned aircraft operations and make decision in the most important issues related to such activities.

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