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Assessment of the Possibility of using Different Kinds of Civil Aircraft by Terrorists

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Abstract

The aim of the research was to assess the possibility of using various types of civil aircraft for terrorist attacks. The main methods were: analysis and synthesis, analogy, generalization, comparison and inference. The research was based on the analysis of the literature as well as normative and doctrinal documents. Scientific observation where used, which focused on practical examples and attempts to use civil aircraft by terrorists to attack civilian objects from 2001 to 2020. Considering the large diversity of each types of aircraft, a criterion analysis was used to evaluate them in terms of their suitability for terrorist attacks. As a result of the conducted analytical research, three groups of aircraft were selected, which are particularly predisposed as potential tools of terrorist attacks on civilian objects. The first group consists of large-size structures such as passenger and transport planes, the use of which in attacks may cause the greatest losses, both material and human. The next group consists of small-sized light and very light airplanes, microlight, unmanned aerial vehicles and radio-controlled models. This type of aircraft and flying machines are in a period of dynamic development and, at the same time, of great interest on the part of terrorist groups. It was also found that in the case of attacks using explosives or taking into account aviation fuel (which, as a result of an aircraft collision with an object, usually explodes), greater possibilities give large aircraft, such as passenger and transport aircrafts.

KEY WORDS: *terrorism, aircraft, aviation, security and safety*

1. Introduction

Authors dealing with security issues consider air terrorism to be one of the new forms of international terrorism that can generate a serious threat to both civilian facilities and the population itself. There is no doubt that it is precisely air terrorism that can also be one of the most deadly forms of intimidating the international community by various types of fundamentalist-extremist groups. This form of terror showed its devastating power in particular in the terrorist attacks of September 11, 2001 carried out in the United States against the World Trade Centre and the headquarters of the US Department of Defence (Pentagon). This attack was the first successful operation of its kind and resulted in more casualties and material losses than any other act of terrorism in world history to date.

It was assumed that the aim of the research was to: assess the possibility of using various types of civil aircraft for terrorist attacks. Bearing in mind the achievement of the assumed goal, the main research problem was formulated in the form of the question: Which of the civil aircraft generate the greatest threat to critical infrastructure facilities and the civilian population when used as means of terrorist attacks?

The article identifies the characteristics of aircrafts, whether or not they prefer them to be used by terrorists. In this matter, it was important to diagnose individual types of civilian aircrafts and unmanned aerial vehicle from the point of view of their ability to cause material and human losses. The results of the research led to the conclusion that the possibility of counteracting this type of terrorist acts requires from the organizers close and multifaceted civil-military cooperation aimed at effective airspace management, including its permanent monitoring and control, as well as the preparation of specialized forces and defence measures. In addition, the use of an airplane with passengers as a kind of guided missile resembling Japanese kamikazes from the Second World War can be very dangerous to the health and life of civilians living in large urban agglomerations. The conducted analysis also showed that this type of terrorist activities can be carried out not only with the use of passenger planes, but also with unmanned aerial vehicles, radio-controlled aircrafts, from which it will be possible to drop an explosive or spray chemical substances or biological agents.

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The authors hope that the results of the above research will be able to be used in the practice of forecasting the threat of terrorist attacks using civilian manned and unmanned aerial vehicles and will contribute to the creation of effective systems to counteract this type of terrorist acts. The constant need to improve the air transport safety system, including increasing the effectiveness of counteracting air terrorism, will require changes in the methods and ways of using forces and means, modification of operating procedures and changes in legal regulations. The above statement suggests that the content presented in this article does not yet constitute a complete and exhaustive solution to the problem of effective counteracting air terrorism, therefore the above issues require further research.

2. Identification of Aviation Terrorism and Its Forms

Given that the interpretation of unlawful aviation interference has a broad and diverse context, it was considered appropriate to attempt to identify its basic forms.

The dynamic development of terrorist forms, methods and tools has led to the generation of a new form of action, namely aviation terrorism. Due to the development of this phenomenon, attempts have also been made to define it. According to one definition, aviation terrorism is equated with an act of unlawful interference in international civil aviation and its facilities, including unlawful capture of an aircraft, sabotage or armed attack against an international air transport aircraft or against ground equipment used by this means of transportation [8].

An Israeli scientist Hillel Avihai, who is involved in the field of aviation terrorism, has created an academic definition of this phenomenon, which reads the following: "aviation terrorism refers to intentional, sometimes indiscriminate acts of violence targeted against civilian/commercial aircraft and/or against passengers and/or crew on board, committed by individuals, secret agents or subnational groups in order to promote political objectives, which are unrelated to achieving personal gains"[2, p. 35-36]. Unfortunately, in light of existing legislation, this definition is incomplete [18] because it does not cover acts of violence directed against state infrastructure.

Moreover, the definition seems too narrow because it does not fully reflect the essence and extent of all possible threats to people, aircraft, aircraft equipment and infrastructure, as well as critical infrastructure facilities that may become the target of terrorist from the air [13]. Therefore, for the purpose of the study, the authors formulated a working definition of aviation terrorism, which assumes that it is any unlawful attack on an aircraft and people on board, unlawful capture of an aircraft with the intention of using it to attack civilians, important facilities ensuring the smooth implementation of air navigation, or critical infrastructure facilities of the state that ensure its smooth operation [15].

At this point, however, it should be noted that because of the way in which the phenomenon of terrorism is defined (in a broader or narrower manner), it is clear that it constitutes one of the forms of violence which causes large media, psychological and propaganda reactions. It is so because its very purpose is to intimidate the population, disorganize the most important foundations of the state and its stability. As a result, it generates a disturbance in a sense of security among the international community. In the case of attacks or abductions of aircraft carried out by terrorist groups, a wide media coverage is a particularly important factor for terrorists. This is due to the fact that every case of an attack on a airplane or its hijacking is broadly commented on and publicized by the world's media. In this way, terrorists psychologically influence the international community, intimidate it and prove that the existing security systems organized by individual states are ineffective, and that declarations and assurances by politicians about the absence of a threat are not confirmed in practice [7, p 35]. The enormous media notoriety of aircraft attacks makes them a very good "tool" in the hands of terrorists.

Taking into account the development of methods and means of carrying out attacks by terrorists, it should be stated that also within the framework of aviation terrorism its various forms can be identified, which is shown in Figure 1.

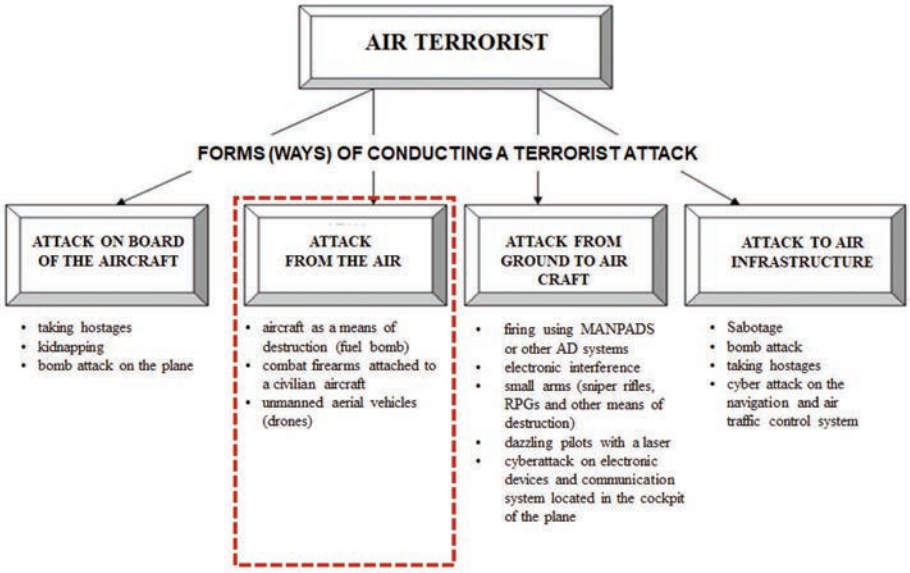

Fig. 1. Identified forms of aviation terrorism. Source: own work

Taking into consideration the focus of the paper, further examinations will concentrate on one form of aviation terrorism, i.e. the attack from the air. It stems from the fact that this form presupposes the use of aircraft to carry out an attack on civilian facilities and citizens of a given country. In this respect, it may be predicted that a passenger aircraft or other aircraft filled with fuel or explosives may be abducted and be used to attack the selected object in order to cause significant human or material damage. Terrorism experts theorize that one of the ways to attack civil facilities could be the use of UAVs, which would drop (spray) poisonous chemical, biological or radioactive substances [22]. In such anticipated scenarios, an aircraft would be merely a tool, which use could cause death of not only the passengers but, above all, a large group of people present in the facility. Such attacks can occur in the following situations [12]:

1. When a potential target of the attack is very difficult to attack from the land due to the very well-organized security of the facility, which is well guarded and monitored;

2. When terrorists want to cause large human and material losses in a short time (both in terms of aircraft and large, e.g. sports facilities, which accommodate big numbers of fans watching the game;

3. When terrorists want to gain a lot of media coverage, because such events (e.g. Olympic Games) are broadcast on a regular basis by many television and radio stations almost from all over the world.[5, p 22]

When creating specific scenarios for terrorist attacks, it should be assumed that the set of tools that can be used to carry out attacks may contain different types of aircraft (both manned and unmanned)[4]. The analysis of terrorist attack scenarios should be predict that the group of aircraft [21] that can be used to carry out attacks on large facilities may include both passenger aircraft and other types of aircraft like private business airplanes, helicopters, light aircraft and other ultralight aircraft such as paragliders, UAVs or models of radio-controlled aircraft (an extremely important issue to be taken into account is the analysis of the ability of individual aircraft to carry large quantities of aviation fuel, explosives and toxic materials).

3. Assessment of Aircraft Types as Potential Tools for Terrorist Attacks

Taking into account the wide diversity of aircraft types, it was considered appropriate to identify aircraft structures, which design and technical characteristics would best meet the expectations of terrorists. The analysis of each type of aircraft was carried out on the basis of the following criteria:

- the possibility for terrorists to capture (take possession of) an aircraft;
- the up-to-date use of aircraft in terrorist attacks;
- possibility of secret access to the area of the crowd-accommodating facilities;
- cargo transport options;
- the possibility of transporting passengers;
- the possibility of obtaining a surprise result caused by the use of a particular type of aircraft.

It was assumed that the assessment of the fulfilment of the distinguished criteria will be mapped on a three-step scale determined by a numerical factor from 1 to 3. The sum of the partial marks from different criteria will be

rounded to the overall assessment. The indicated value will point at the usefulness of the analyzed aircraft for carrying out aerial terrorist attacks. The obtained general assessments will be interpreted as follows:

1 - significant limitations for the use of the aircraft in terrorist attacks;

2 - the aerial design enabling using the aircraft for terrorist attacks;

3 - the aircraft well fit to carry out terrorist attacks.

The criterion relating to the past use of aircraft in terrorist attacks corresponds to a direct analysis of the historical occurrence of such incidents. At the same time, it is assumed that a successful attack carried out by the aeronautical structure (aircraft) in question may motivate its re-implementation. The aircraft already used is a proven (tested) tool, the re-use of which can generate effects already known to terrorists. Hence, the assessment of aircraft according to the criterion adopted looks as following:

1 - no such aircraft has been used for terrorist attacks;

2 - attacks with the use of this type of aircraft were ineffective;

3 - these aircraft were used to carry out successful terrorist attacks.

The criterion of capture or illegal seizing of an aircraft depends on factors such as the universality of the access to the aircraft, the number of units in service, the level of ground (airport or airfield) security, and the level of internal security of the aircraft. The assessment of this criterion shall also take into account the possibility of purchasing, renting or building an aircraft on one's own. It was assumed that the assessment of aircraft capture (seizing) will be based on the following values:

1 - very small;

2 - large;

3 - very large.

The ability to reach the area where the facilities are located is a criterion determined primarily by two parameters: the maximum flight speed of aircraft and its range. They directly affect the response time of the air defense system, its ability to detect, identify and counteract. In this case, this applies mainly to aircraft on duty. This includes the calculation of the area of their entry into combat S_{PRWW} and the minimum detection distance of aircraft with the status "Renegade". Having calculated these two indicators, it is possible to answer the question whether the use of interceptors will be possible under the adopted spatial-time conditions and a certain type of aircraft with the Renegade status. Following the above assumptions, the following relationship was used to calculate the necessary area for the aircraft to enter into combat:

$$S_{PRWW} = \frac{a + d - d_{rk}}{m - 1} + d + V_c \cdot t_{rk} + V_c \cdot (ti + to)$$

where:[6]

S_{PRWW} - the necessary distance of the area to entry into battle from the further border of the no-fly zone;

a - linear distance measurement error occurring during the guidance of aircraft by means of a radio station; an error value of 1500 m ≈ the calculation;

d - the prescribed distance to bring the fighter aircraft to its destination; a distance of 300 m was used for the calculation;

($d_{rk)}$ - the distance of use of the means of destruction by the fighter aircraft under the assumptions made equal to the prescribed distance of bringing the fighter aircraft to its destination d = d_{rk} (m);

t_{rk} - the flight time of the projectile to the target (s), respectively for:

a) artillery shells of The GSZ-30-1 (V= 875-900 m/s) ≈ 0.33 s;

b) M-61A artillery shells (1050 m/s) = 0,28 s;

In the calculations the average value was adopted ≈ of 0.3 s;

t_{and} - reconnaissance time - dictated by the requirement of visual recognition of the aerial target by the interceptor aircraft and the decision to overpower it - 20 s;

t_o - time of departure maneuver of the identifying aircraft - 10 s;

V_c - flight speed of the air target (m/s);

a) for a Boeing 737-820 km/h passenger aircraft ≈ 230 m/s;

m - the ratio of the flight speed of a fighter aircraft to the flight speed of the target. The calculation assumes the

maximum subsonic cruising speeds of the F-16 and MiG-29 aircraft, which carry out interception maneuvers of 1050 km/h ≈ 290 m/s. For Boeing 747 m=1.26; (In the air, at 15°C and normal pressure, the sound propagation speed shall be 340,3 m/s ≈ 1225 km/h.)

After the data were adopted, calculations were made to determine the distance at which F-16, Mig-29 aircraft should be introduced in order to intercept a civil aircraft before it crossed the further no-fly zone, which is introduced to protect important civilian facilities (e.g. White House, nuclear power plants). The obtained results indicate that the distance at which the area of the introduction of the aircraft to intercept the Renegade-type objects is determined mainly by the aircraft's flight speed and the time needed to identify it.

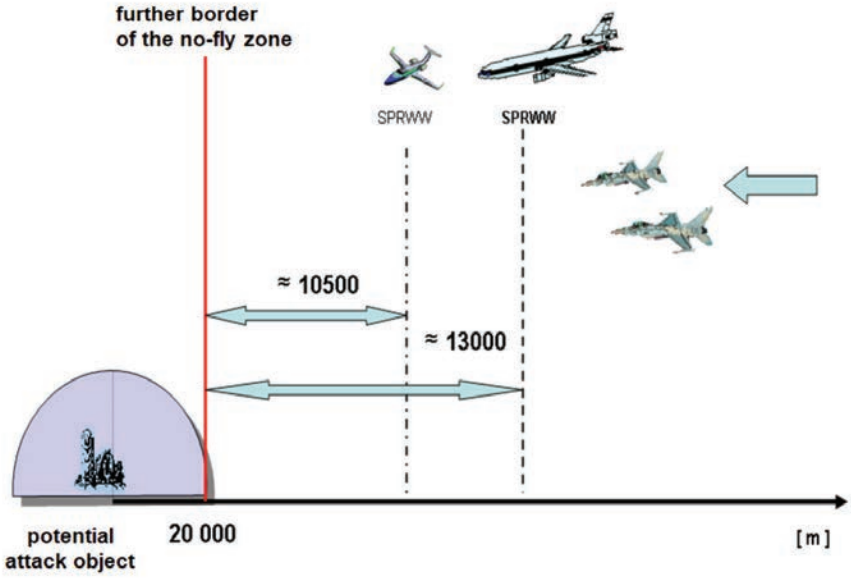

Fig. 2. The distance of the area for sending the interceptors for two types of intercepted aircraft: Lear Jet and Boeing 737. [17, p 106].

In order to fully assess the possibility of protecting facilities at risk of terrorist attack, it is also necessary to set a minimum (critical) detection distance for Renegade aircraft [19]. Based on the obtained results, it can be concluded that the critical detection distance of Renegade air targets, which allows the use of fighter aviation against them, is about 330 km (It should be noted that the calculations carried out assume the most favorable position of airports of interceptors in relation to shielded objects which were located in the middle of the no-fly zone). Thus, it can be noted that there is a relatively large zone where interception aircraft cannot effectively counter renegade air facilities. In this respect, the minimum detection distances of the Renegade obtained by military aircraft are largely dependent on the time of combat readiness for the take-off, which takes place 15 minutes after receiving the Renegade object detection signal. During this time, Boeing and Lear Jet aircraft are able to travel a distance of about 300 km, which significantly reduces the ability of the military aircraft to intercept. Therefore, it can be concluded that the closer a civilian aircraft is seized by terrorists from a potential attack site, it will be more difficult for military aircraft to react more effectively due to the time standards adopted for achieving readiness for action.

Based on the obtained results, in relation to the criterion of aircraft's ability to reach the attack area, the speed of the civilian aircraft and the possibility of its identification were adopted. In this case, it is assumed that passenger and transport aircraft are the easiest to identify because they are constantly monitored by flight control services from take-off to landing. Larger flight control problems occur for smaller aircraft, UAVs, micro-light aircraft and radio-controlled models.

Taking into consideration the reasoning followed in the case the ability of a civil aircraft to reach the attack object, its values were given the following scale:

1 - small
2 - large;
3 - very large.

The capacity to transport cargo shall specify the extent of the volume of cargo taken on board aircraft, and for certain structures it is also possible to discharge them. The group of cargoes placed on board aircraft may include conventional means including explosives and incendiary substances as well as unconventional CBRN (Chemical,

Biological, Radiological, Nuclear) weapons. Their purpose would be to cause explosions and release additional energy coming from the collision of the aircraft with the ground facility or causing mass casualties by spreading toxic cargo to significant areas. This criterion takes the following value depending on the transport characteristics:

1- the inability to transport or the possibility of transporting very small loads weighing up to 10 kg;

2- the possibility of transporting small loads with a load not exceeding 100 kg;

3- transport of large and very large loads in the weight range 0.1 – 250 t.

Passenger transport capacity is a criterion which characterizes aircraft as means of transporting passengers. It is assumed that the aircraft is a more valuable tool for attacks for terrorists, the more it is able to transport people. Aircraft passengers are considered as potential hostages, whose death strengthens the effect of the attack. For this criterion, the following assessments were adopted:

1- inability to transport passengers;

2- limited to the crew;

3- able to transport passengers.

The criterion for the possibility of using aircraft as a new attack tool reflects the use of known but not yet used aircraft structures for terrorist purposes. Their new use by terrorists would give them the opportunity to have a surprise effect. The risk assessment against this criterion was carried out as follows:

1- small;

2- large;

3- very large.

It assumes that a failed assessment of individual aircraft will identify those aircraft that will be particularly predisposed for the use in terrorist attacks. It is assumed that the assessment of compliance with the highlighted criteria will correspond to a three-stage (descriptive) scale by which the aircraft can be classified into one of three groups:

1. structures with significant limitations entirely defying the ability to be used in terrorist attacks;

2. structures that can be used for terrorist attacks;

3. structures well fit for carrying out terrorist attacks.

The first group is passenger aircraft**.** They are among the most widespread aircraft structures in the world. Their dominant role is particularly evident in transport aviation (passenger and transport). Currently, it is estimated that the number of passenger aircraft flying for airlines is about 23,600 [10]. The rapid growth of air passenger services, mainly due to the rapidly growing number of customers of low-cost airlines, which have already overrun more than a quarter of the market, means that the ever-increasing number of passengers and air service providers still poses a high risk of terrorist attacks. A beneficial factor for terrorists is that the use of passenger aircraft generally causes high mortality for both passengers and people who are in the attacked facilities and who may become victims of the terrorist attacks (the scale of the risk can be demonstrated by the capacity of aircraft such as Boeing 747 taking on board, depending on version and configuration, from 336 to 588 passengers, or currently the largest passenger aircraft in the world Airbus A380, which holds up to 853 people).

After the terrorist attacks of September 11, 2001, tightened security regimes were put in place at airports around the world, but subsequent thwarted attempts of that kind of hijacking indicate that terrorists are constantly looking for ways to find new and increasingly sophisticated ways to take control of such aircraft [14, pp. 1121-1127]. A tangible example was the events in the Great Britain in August 2006, when there was an attempt to use liquid chemicals smuggled in hand luggage. Only when mixed together on board, they produced explosive material. The terrorists planned to attack seven aircraft flying from London to large agglomerations in the United States [11]. The identified characteristics of passenger aircraft and the attempts to illegally take control of them make it possible to presume that the likelihood of these aircraft being used in future terrorist attacks is relatively high [16].

Table 1.

Assessment of the possibility of using passenger aircraft to carry out terrorist attacks. Source: own work

Assessment criterion of the aircraft suitability to carry out terrorist attacks	Score
Past use in terrorist attacks	3
Capture capability	3
Ability to reach the area of the target	3
Ability to carry loads	2
Ability to carry passengers	3
Ability to be used as a new way of attack (surprise effect)	2
Rating (arithmetic mean)	2,66

Another group of the analyzed aircraft was the aircraft used for transportation. The competitiveness of air freight, compared to other modes of transport, is mainly due to three basic features: speed, long range and payload capacity. A preliminary assessment of the possibility of using transport aircraft to carry out terrorist attacks indicates that their hijacking may be seemingly easier than a passenger plane. The carriers are not equipped with reinforced pilot cabin doors and there are no support staff and passengers on board to prevent people from the outside from attempting to take over these aircraft. However, so far there has been no attempts to hijack a transport air plane for terrorist purposes. This is mainly due to the difficulty for terrorists to get on board. In this case, it is also important that the crowd of passengers is not able to move freely. As a result, this requires, for example, impersonation of airport staff. This is a much more difficult task to perform i.a. due to the internal control system in cargo airports and terminals, which do not deviate from the control standards adopted for passenger services. An additional security employed in the air transport system is a detailed inspection of cargo shipments, which are subjected to i.a. ground pressure test reproducing the flight conditions of the aircraft at an altitude of 10 thousand meters. This is done to detect explosives that have mechanisms that cause explosions due to pressure differences. On the other hand, the particular feature of transport aircraft, which is the ability to carry significant cargo over very long distances, can be a tempting alternative to terrorist groups. These aircraft can be used either in suicide missions or as platforms to transport and discharge cargo to crowded facilities.

Table 2.

Assessment of the possibility of using transport aircraft to carry out terrorist attacks. Source: own work

Assessment criterion of the aircraft suitability to prevent terrorist attack	Score
Past use in terrorist attacks	1
Capture capability	2
Ability to reach the area of the target	3
Ability to carry load	3
Ability to carry passengers	1
Ability to be used as a new way of attack (surprise effect)	3
Rating (arithmetic mean)	2,16

On the basis of the obtained assessment, it can be concluded that, compared to passenger aircraft, there is a lower risk of aircraft being used to carry out terrorist attacks. This is mainly due to the expected lower media coverage of such the attacks (possible fewer human casualties in situations where the aircraft is destroyed before it reaches the object of the attack). Moreover, the possibility of seizing such aircraft appears to be much more difficult than being able to control a passenger aircraft, which one can board after purchasing the ticket. On the other hand, the factors which support the use of such aircraft are similar abilities of passenger aircraft to reach the area of the ground facility (target) and the possibility of obtaining a surprise effect, which may be manifested, for example, by the use of a specific cargo transported by the aircraft.

Another group of aircraft underestimated even by terrorism experts is small-sized light and very light aircraft. Statistically, the largest number of aircraft with small and very light designs is used by General Aviation. A distinctive feature distinguishing general aviation from aviation is that such aircraft do not carry out commercial flights on scheduled or non-scheduled air transport. The interest and activity of general aviation is to provide flights for both personal and corporate use. In most cases, these are air-class tourist ships popularly called avionics. The possibility of using small aircraft to carry out terrorist attacks is very real.

The dynamic growth of users of small aircraft observed in recent years is due to the increasing wealth of society and the reduction of production costs and prices of such aircraft. The main representative of private aviation in the world is the Aircraft Owners and Pilots Association (AOPA), which brings together more than 400,000 aircraft owners and 700,000 pilots in more than 50 countries. In most cases, these are tourist class aircraft. When analyzing the use of such small aircraft as an attack tool, they have so far been marginal. In this respect, it can be assumed that the lack of use by terrorists of this type of aircraft is due to their small size and relatively low speeds, which limit the obtaining of high kinetic energy when the aircraft hits a ground object. On the other hand, the advantage of using such aircraft for terrorist attacks is their ability to travel significant spaces at very low altitudes. Flying at low altitude avoids detection by ground-based radiolocation systems and thus allows covert penetration into the area of the attack object (i.e. the use of this feature of small aircraft was Matthias Rust's landing in the Red Square in Moscow in in 1987). An important feature that can significantly affect the use of such ships by terrorist groups is their ability to take off and land at airports of different surfaces. Small aircraft can use both concrete and grass runways, as well as short road sections, which can be crucial for a surprise effect. It should also be noted that the growing general aviation

department using small-sized aircraft is economic and service aviation, which includes: agro-aviation also called bio-aviation, aerial photogrammetry, observation flights. One of the main areas of activity of these aircraft is aviation work involving: fertilization, pest destruction, firefighting, gathering information for geologists and forest guards. Of particular note are the bio-aircraft structures, which have the ability to spray and fog at minimum flight altitude not exceeding 5 meters above the sea level. These aircraft, thanks to specially installed tanks and spray systems, can become an ideal tool for spreading unconventional, toxic chemicals or biological agents over a significant area. For example, the most popular agro-aircraft in Poland – M-18 Dromader has a tank for chemicals with a capacity of up to 2500 liters. Apart from sports, and commercial airplanes, the aircraft offering individual passenger transport are becoming increasingly important. An significant role here is played by the of the so-called Light Business Jet class constructions or business jets. They are small jet-powered aircraft that take on board five to seven passengers and two crew members. They allow to travel at distances and at speeds comparable to cruise passenger aircraft.

The identification analysis of light and very light small-sized structures distinguishes the three main types of aircraft to be considered in relation to the criteria determining their possible use in terrorist attacks (Table 3). These are a small tourist (sports) aircraft, a service aircraft and a business jets.

Table 3.

Assessment of the possibility of using small aircraft to carry out terrorist attacks. Source: own work

Assessment criterion of the aircraft suitability to carry out terrorist attacks	Score		
	tourist (sports) aircraft	commercial use aircraft	business jet
Past use in terrorist attacks	3	1	1
Capture capability	3	2	2
Ability to reach the area of the target	3	3	3
Ability to carry loads	2	3	2
Ability to carry passengers	3	1	3
Ability to be used as a new way of attack (surprise effect)	3	3	3
Rating (arithmetic mean)	2,83	2,16	2,33

The obtained evaluations make it possible to conclude that among the small-sized structures the most advantageous qualities from the perspective of their potential use in terrorist attacks are tourist (sports) aircraft. The obtained result was significantly influenced by the criterion of the possibility of acquiring aircraft of this type – the are many aircraft available and their variety is the highest. On the other hand, the possibility of using aircraft carrying out commercial tasks and business jests is at a similar, but slightly lower level [9, pp. 51-66].

Another group of the analyzed aircraft that can disrupt large events is micro-light aircraft (ultralight aircraft, powered gliders and gliders, gyroplanes, mor gliders, powered moto-paragliders and paragliders). Their intrusion into the airspace above e.g. stadiums may not be dangerous and be caused by the desire to observe such events from the air or to advertise some products or services among wide audience gathered in the stadium. However, it cannot be ruled out that terrorist groups cannot use such aircraft to achieve their own objectives. It is possible that we can see a systematic increase in the number of owners of private aircraft used for sports or recreational purposes. A significant group in this category consists of the smallest aircraft structures capable of carrying passengers and small loads. These are both fixed-wing aircraft with stationary support surfaces, tilt rotor aircraft with transmissible support surfaces, and soft-wing aircraft, which wing areas can deform under the exposure of aerodynamic forces. Thanks to the mounted power units, they have the ability to move independently (from air currents and potential energy) in airspace. These ultralight motor-powered structures began to be called micro-light aircraft in the early 1970s. The micro-light aircraft in question are mostly single-seater, rarely two-seater structures with limited transport capacity. They move within the speed range from the fastest 330 km/h to the slowest 70km/h and reaching maximum altitude of 3,000-6,000 meters above the sea level. Based on these parameters, we can conclude that they are are relatively slow aircraft that can be intercepted by on-call military aircraft. Nevertheless, the essential features for the use of such structures in terrorist attacks include the ability to take off from small sections of paved airport lanes or even roads, the ability to fly at very low altitudes, and small reflection area, which makes them very difficult to be detected by military radar systems. An additional advantage is also that they can be built by enthusiasts or purchased for little money in a specialty store.

Table 4.

Assessment of the possibility of using micro-lots to carry out terrorist attacks. Source: own work.

Assessment criterion of the aircraft suitability to carry out terrorist attacks	Score
Past use in terrorist attacks	1
Capture capability	3
Ability to reach the area of the target	3
Ability to carry loads	2
Ability to carry passengers	1
Ability to be used as a new way of attack (surprise effect)	3
Rating (arithmetic mean)	1.83

The last group of aircraft in question to be analyzed if the unmanned aerial vehicles (UAVs) and Radio-Controlled Aircrafts (RCA) category. These structures are self-propelled flying devices incapable of carrying an operator, able to move autonomously along a planned flight path, and can be controlled remotely by one or more operators. These devices are capable of carrying combat payloads or optical and radio observation equipment. Nowadays, the size of flying devices can be very small, from a size of bird and even a large insect. For terrorists, who are constantly searching for new means of destruction, the prospect of using remote-controlled air strike means that can carry different loads like explosives, toxic substances and be used for precision strikes on selected objects. Experts do not rule out the possibility that terrorist organizations can work on arming a flying apparatus with improvised explosive devices (IEDEs). The possibility of using UAVs in attacks began to be particularly noticeable after 2006, when terrorists from the Hezbollah group used three Ababil UAVs against Israel (these devices have a remote range of 240 kilometers and can carry 40 kilograms of explosives). Moreover, Hezbollah has in possession the UAVs of the Mirsad-1 type, which have been successively conducting observation missions since 2004 violating Israel's airspace. The fundamentalists do not rule out the possibility of equipping the devices with chemical, biological and radioactive loads and use them to attack civilian populations and industrial facilities. The obstacle to obtaining such aircraft is their high purchase cost and limited availability at the market. The intricate design and materials used exclude their production in the workshop. At the same time, the sale of UAVs is subject to international regulations within the umbrella of the Missile Technology Control Regime (MTCR). Currently, however, commercially exploited UAVs are much more accessible to terrorists.

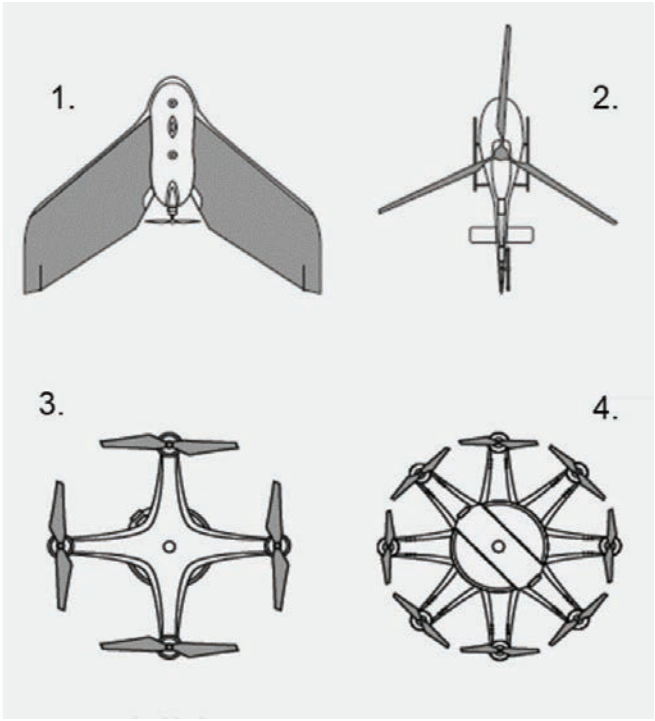

Fig. 3. Types of commercially used unmanned aerial vehicles

Legend:
1. Fixed wing - UAVs with aircraft-like wings;
2. Rotary wing - UAVs that resemble traditional helicopters;
3. Quadcopters - UAVs with four extensions, each with propeller (most popular);
4. Multi-copters - UAVs with multiple (more than four) propellers.

In this respect, it can be stated that they are widely available and are increasingly used in different sectors of the economy. However, at this point, it is difficult to fully assess how widespread the use of UAVs will become in areas where they are still being tested today.

Apart from the UAVs, the models of radio-controlled aircraft (RCAs) were analyzed. The advent of RCA in retail in the mid-1980s immediately caught the attention of terrorists and sparked attempts to use them as terror facilitators[1]. Nevertheless, for technical reasons (the imperfection of radio control systems and the absence of additional accessories such as cameras or video cameras), the practical use of RCAs in terrorist activities became possible only in the early 21st century. This was mainly due to the technological progress of the miniaturization of electronics and the uptake of composite materials.

RCAs can be made in house conditions or modeling studios. Their appearance does not attract special attention, and their reflecting surface is in the order of tenths of a square meter, which makes them practically undetectable by terrestrial radiolocation systems. RCAs equipped with incendiary or explosive charges can be used as controlled flying missiles [3, p. 186]. Their targets could be plants producing hazardous materials, petrochemicals, explosives and chemical storage sites, power plants, water intakes, but also population clusters. The terrorists' interest in RCAs is confirmed by an example from the US where Rezwan Ferdaus, a Massachusetts resident, was arrested in September 2011. As it turned out, he was inspired by al-Qaeda's ideology and admitted that he was preparing an assassination attempt in which he was to use a remote-controlled F-86 Sabre fighter aircraft filled with explosives (C4). The planned targets were the Pentagon and the Capitol. Restrictions on the use of RCA by terrorists are mainly due to the limited range and short flight time resulting from the low capacity of the fuel tank. In addition, another drawback is that the operator has to stay in the range of the radio and the difficulty in using RCA in adverse weather conditions (rain, snow, fog, strong wind). It should be noted that this technology is continually developed, and new RCAs adopt more and more UAVs' characteristics, including the possibility of self-flight. RCA systems equipped with Global Positioning System (GPS) satellite navigation systems are already available on the market. Thus, their use for precision bombings over long distances seems highly likely. In addition, the firepower of these devices can be increased by using the swarm tactics, i.e. attacking an object simultaneously by several RCAs from different directions. For these reasons, the characteristics of the UAVs and RCAs should be included into the category of the aircraft well fit for terrorist use.

Table 5. Assessment of the possible use of BSP and RCA to carry out terrorist attacks. Source: own work.

Factors determining the use of UAVs and RCAs in terrorist attacks	UAVs	RCA
Past use	2	1
Ability to reach the area of the target without risk	3	3
Ability to carry loads	1	1
Capture capability (take-possession)	2	3
Ability to be used as a new way of attack (surprise effect)	2	3
Rating (arithmetic mean)	2	2,2

The assessment of the characteristics of the UAVs and RCAs indicates that there is a high risk of them being used in terrorist attacks. These opportunities will increase with universal access to new, hitherto proprietary or too expensive technologies for private users.

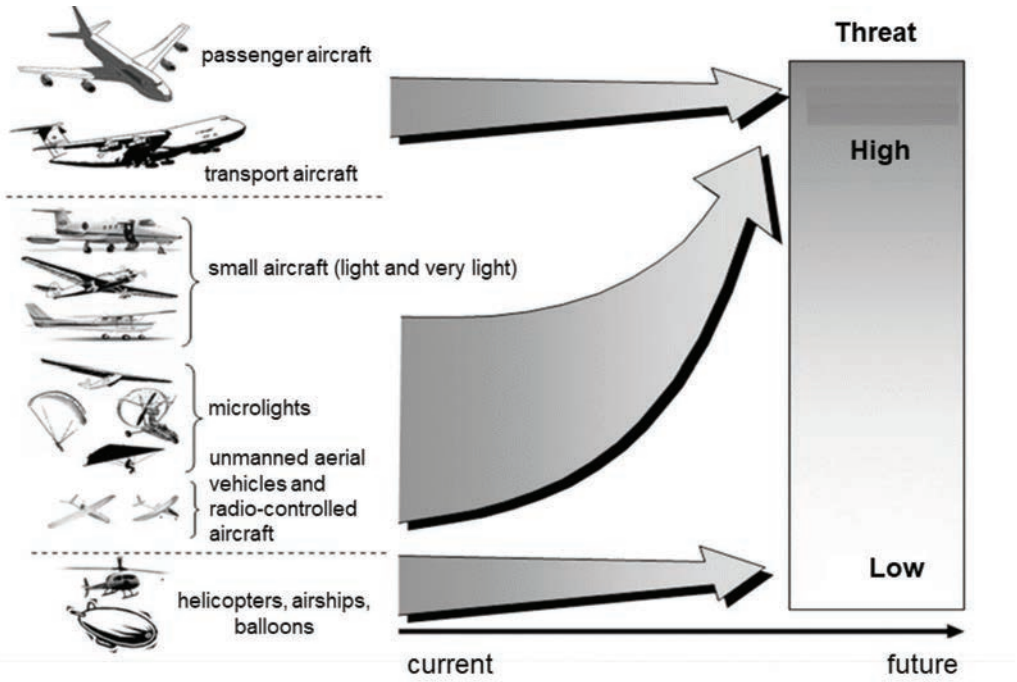

Fig. 4. Projected trends in the use of different types of aircraft by terrorists to carry out attacks on civilian facilities in the 21st century. Source: own work

When assessing aircraft structures, it should also be pointed out that some of them will be very little usable by terrorists. Among them we can distinguish i.a. airships or gliders. The exploitation of the former generates huge costs, which is why only a small number of airships are in the hands of private users. By contrast, gliders, due to their design, in-flight unopened cockpit, lack of cargo area and dependence on air masses of maneuvers, generate little risk of being used in terrorist attacks.

4. Conclusions

The research results confirmed that the organization of an effective counteraction system requires the state to apply a wide range of political, legal, economic and order measures, as well as the involvement of specialized and very modern technical devices on board airplanes and in the entire aviation infrastructure. Thus, the interdisciplinary nature of the threat means that security problems of civilian facilities must be solved at various levels with the cooperation of many civilian state institutions and services, including the armed forces. In summing up the carried out research, it should be stated that three groups of aircraft have been identified as ones that should be particularly analyzed as possible tools of terrorists for carrying out attack on civilian objects. The first group consists of large-scale structures such as passenger and transport aircraft, the use of which in attacks can cause the greatest damage to both infrastructure and people. These aircraft have been previously used in terrorist attacks and are still very likely to be used again. Another group are small-scale light and very light aircraft, micro-light aircraft, unmanned aerial vehicles (UAVs) and radio-controlled aircraft (RCAs). These devices are in a period of dynamic development and at the same time they are subject to significant interest of terrorist groups. Their use, in particular through the proliferation of ICT techniques, wider access to aerial image devices and composite materials, can be particularly instilling for terrorists.

Based on the obtained results, it can also be noted that in the case of attacks using explosives, including aviation fuel (which, as a result of the collision of the aircraft with the target explodes), large aircraft such as passenger and transport aircraft provide greater capabilities and thus threat. On the other hand, in the case of terrorist attacks using unconventional (chemical, biological and radioactive) measures, small and ultralight aircraft with the ability to dump or spray the load are more attractive. At the same time, it can be assumed that among unconventional cargoes, terrorists can use various double-purpose chemical agents. Unlike in the case of chemical warfare agents (CWA), biological weapons and radioactive compounds, it is relatively easy to take possession of them, as they are commonly used in industry.

On the basis of the considerations and the presented facts, it can be concluded that aviation terrorism is a particularly dangerous form of terrorism, since the counter-terrorism system requires a wide range of political, legal, economic and law enforcement measures, as well as the involvement of specialized and very modern technological

equipment on board aircraft and throughout the aviation infrastructure. Therefore, the interdisciplinary nature of the threat means that the security problems of civilian facilities must be addressed at different levels with the cooperation of many civilian state institutions and services, including the armed forces. It should also be emphasized that aviation terrorism is not only an act of violence or a threat to carry out such a threat, it is also a psychological condition present in the consciousness of the public – the victim – long after the attack [20, p. 24].

It should be also stated that any case of the use of aircraft to carry out attacks causes a great deal of media coverage, which terrorist groups are particularly seeking.

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