MANAGING THE THREAT OF MANPADS USE AGAINST CIVIL AVIATION

ABSTRACT

The research results presented in this study concern selected aspects of the threat to civil aviation with terrorist attacks using the Man-Portable Air Defense System – MANPADS. The authors assess the possibility of the development of this type of threat, paying attention to several most important premises resulting from the suitability of using this type of weapon by terrorists against civilian aircraft. On the basis of the results obtained from the conducted research, the authors assess the current state of possession of this type of weapon by terrorist organizations in the world and indicate the main sources of obtaining MANPADS. The cases of incidents related to attacks on civil aircraft presented in the material indicate a high mortality rate of this type of events, the main victims of which are passengers and aircraft crews. The last part of the discussion is an overview of modern on-board systems designed to protect civil aircraft against MANPADS attacks, which they may soon be equipped with.

Keywords:
aviation terrorism, civil aviation, MANPADS, missile attack

INTRODUCTION

Man-Portable Air Defense System (MANPADS) are shoulder-launched anti-aircraft surface-to-air missiles available in various types. They are relatively simple and effective weapon that can be operated by one, or two people. As confirmed by the uses of MANPADS, they may constitute a very dangerous weapon in the hands of terrorists, against civilian aircraft.

MANPADS was developed after the end of World War II, when the US military realized the need for weapons that would provide better direct protection of land facilities against attacks by enemy combat aircraft and helicopters. The need for weapons like that resulted mainly from the fact that the anti-aircraft cannons and rifles had too small damage rate as for military aircraft flying at high speeds in relation to the needs. Despite the fact that the American army started researching this type of weapon
as early as 1948, it was not until 1967 that the first shoulder-launched anti-aircraft missile – MANPADS – was introduced as an element of weaponry. It was the US-made FIM-43 Redeye short-range missile. Soon in 1968 the SA-7 Grail (Strela-2) missile was also introduced to the Armed Forces of the USSR. In 1972, the Americans began the production of the new version of MANPADS Redeye II, which in fact initiated the work on the new Stinger FIM-92 missile. It should be emphasized that Stinger, like the Soviet SA-7, has undergone multiple improvements over the years. To date, many other versions and weapons of this type have been created all over the world.

Over time, MANPADS has become the object of interest not only for the armed forces, but also for many rebel and terrorist groups. In this respect, each use of MANPADS by terrorists not only causes damage to or destruction of the aircraft itself, but usually also death of the passengers and crew. The Secretary of State Colin Powell also spoke about the serious threat posed by MANPADS. During the Asia-Pacific Economic Cooperation Forum he warned that “no threat is more serious to aviation than Man-Portable Air Defense System (MANPADS). Easy to use and easily available on the black market, MANPADS is indeed a direct and serious threat to military civilian aircraft”.

It must be also highlighted that the MANPADS attacks on civilian aircraft are usually accompanied by widespread media attention due to their tragic effects. They result from the fact that when shooting with MANPADS, or another anti-aircraft missile of a flying aircraft occurs, all the people on board have very limited, sometimes even scant chance of survival, and in the case of shooting at the aircraft with MANPADS during landing, or immediately after takeoff, the chance of survival is a slightly higher. Regardless of the location of the attack, experts estimate that every air disaster caused by terrorist draws global public attention to the event. As a result it cannot be ruled out that such activities may be an integral element of their strategy. This is also confirmed by Bruce Hoffman, in his monograph “Inside terrorism”.

In the context of a missile shelling threat to civilian aircraft, it has become a key issue to find countermeasures to reduce the susceptibility and vulnerability of civilian aircraft to attacks from the ground. In practice, it turns out that effective countering of threats generated by MANPADS requires multidirectional changes, including close international cooperation. In particular, this applies to controlling the proliferation of these measures, improving the procedures for the protection of aviation infrastructure and carrying out work on the development of technical countermeasures that will

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1 Beveridge, Dirk, "APEC Nations Agree to Limit Missile Sales," Associated Press, 18 October 2003
3 W wypadku ostrzelania przez MANPADS samoloty w czasie lądowanie lub bezpośrednio po jego starcie szanse przeżycia są już jednak nieco większe, R. Grocki, Vademecum zagrożeń, Dom Wyd. Bellona, Warszawa 2003, s. 63
4 Tamże, s. 63
5 B. Hoffman, Oblicza terroryzmu, Wyd. Bertelsmann Media, Warszawa 2001, s. 175
increase the safety of aircraft. Only the implementation of these projects can significantly improve the safety of civilian aircraft in the international air navigation.

Bearing in mind the outlined problem and the adopted research subject, it was assumed that the purpose of the article will be to present the scale and extent of the threat to civilian aircraft with missile fire from the ground using MANPADS and other anti-aircraft missile systems, and to indicate methods and ways of protecting them.

With a view to achieving the intended purpose it was necessary to address the following research problems:

- What is the scope and scale of the threat to civilian aircraft by terrorist attack using anti-aircraft missiles?
- What makes the portable anti-aircraft missiles dangerous to civilian aircraft?
- What are the methods and ways to limit terrorist attacks using MANPADS?

**LAND-BASED MISSILE ATTACKS AS A FORM OF TERRORISM**

Attempting to place land-based missile attacks on civilian aircraft in the structure of terrorism, it was justified to refer to the phenomenon of terrorism itself. Given the complexity of the phenomenon of terrorism, it can be concluded that it is also defined in modern professional literature in many ways. Among the definitions most frequently found in studies there is the definition officially recognized by the US Department of State saying that terrorism is: “unlawful use – or threat of use - of power, or violence against persons, or property intended to coerce, or intimidate governments, or societies, often to attain political, religious, or ideological goals”\(^6\). Despite the many definitions of terrorism, they contain recurring elements meaning especially the term “violence”, which is a typical feature that characterizes the phenomenon of terrorism. It is connected with the fact that terrorists usually attack civilians – bystanders and those who are not involved in the fight in order to create a state of intimidation and terror in the society, and thus to force changes, or concessions on the ruling elite.\(^7\) Of course, not all acts of violence are terrorist acts, so it must be said that terrorism is a specific form of violence.\(^8\)

This also applies to the sector of international air transport, where the International Civil Aviation Organization – ICAO – already in the Convention on Offenses and Certain Other Acts Committed on Board Aircraft, drawn in Tokyo on September 14, 1963, specifies what acts are to be prosecuted. In addition, an important

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\(^6\) B. Hoffman, *Oblicza terroryzmu*, Bertelsmann Media 2001, s. 27.


\(^8\) B. Bolechów „Terroryzm w świecie po dwubiegunowym” Adam Marszałek, Toruń 2002.
issue is that it also defines the concept of an aircraft in flight,\textsuperscript{9} which is significant from the point of view of the research area adopted in the article. The document defines the concept of an aircraft in flight: „For the purposes of this Convention, an aircraft is considered to be in flight from the moment the propulsion is used to take off until the end of landing”.\textsuperscript{10}

In this regard, one may be tempted to say that terrorism in aviation is a particularly dangerous variation of this phenomenon due to the fact that the counteraction system requires the use of a wide spectrum of political, legal, economic and orderly measures, as well as the involvement of specialized and very modern technical devices not only on board aircraft, but also in aviation infrastructure. Analyzing the spectrum of threats in civilian aviation, four main forms of aviation terrorism can be distinguished:

- attack on board,
- air attack using an aircraft,
- land-based anti-aircraft missile attack or using other weapon systems,
- attack on infrastructure securing flight operations.\textsuperscript{11}

What is more, it should be noted that when analyzing terrorist threats to airports MANPADS is listed and one of them, too:

1. using explosives;
2. using portable anti-aircraft missiles to destroy taking off and landing aircraft;
3. using grenade launchers and small arms, as well as anti-tank measures to destroy aircraft on the ground, or airport infrastructure;
4. using a hijacked aircraft to commit a terrorist attack on a major airport infrastructure object or taking off or landing aircraft;
5. using anti-aircraft mines against aircraft;
6. cyberterrorism.\textsuperscript{12}

In addition to MANPADS, other weapon systems, shown in Figure 1, may also be dangerous for civilian aircraft, especially at the take-off, landing or overflight stages.


\textsuperscript{10} Iblem, art. 1, ust. 3.

\textsuperscript{11} K. Jałoszyński, Współczesne zagrożenie terroryzmem powietrznym, kierunki przedsięwzięć w zakresie przeciwdziałania mu oraz walki z tym zjawiskiem [w:] Bezpieczne niebo, AON, Warszawa 2002.

\textsuperscript{12} S. Zajas, Przeciwdziałanie zagrożeniom terrorystycznym na lotniskach, „Zeszyty Naukowe” AON, Warszawa 2007, nr 2
An example confirming the threat to military aircraft may be one of the reports for the period from October 25, 2003 to January 2004. During this period, nine US military helicopters crashed during landing after being hit by enemy anti-aircraft missiles, resulting in the deaths of 39 people. The army investigated these incidents to discover their real causes. The results of the work of the board investigating these cases clearly show that the military helicopters were shot down using the RGP-7 anti-tank grenade launcher and MANPADS Strela-2, Strela-3, and Igla. The results of the research also showed beyond doubt that Iraqis were studying helicopter flight times and routes to prepare an anti-aircraft ambush.

DEVELOPMENT AND PROLIFERATION OF MANPADS IN THE WORLD

Since the development of the American Redeye in the late 1950s, hundreds of thousands of MANPADS have been produced worldwide. The most numerous and best known are the Russian Strela (SA-7 and SA-14), Igla (SA-16 and SA-18)2, and the US-made FIM-92 Stinger.

MANPADS constitute an element of weaponry of many armed forces around the world. It is estimated that from 1950 to the present day 20 developed countries have produced more than 30 different types of portable anti-aircraft missile kits, and their number is around a million.

The analysis of the MANPADS market indicates that they are currently produced in 20 countries that manufacture them or are licensed to produce them, or their components. These include Bulgaria, China, Egypt, France, Germany, Greece, Iran,
Japan, the Netherlands, North Korea, Pakistan, Poland, Romania, Russia, Serbia, South Korea, Sweden, Turkey, the United Kingdom, and the United States. They are in warehouses of many armies around the world. Military experts point out, however, that many of them are outside the control of national governments and have been acquired by terrorist organizations, including Al-Qaeda. It results from the fact that along with the growing number of MANPADS in the arsenals of armies in the world, this weapon system also found itself in the orbit of interest of terrorist groups, which considered it a very interesting and attractive weapon for expanding their current forms and methods of operation. Given the fact that this type of missile has also become widely available on the black market, their purchase by terrorist organizations became possible and depended mainly on the contacts and financial resources of the organization. Currently, the terrorists are estimated to possess from 5 to 150 different types of MANPADS. Experts believe that the majority of this number are the Soviet Strela-2 (SA-7), which is currently possessed by at least 56 countries in the world. The previous analyzes carried out by the authors for the years 2003-2015 indicate that currently MANPADS are owned by 25-30 terrorist groups, or organizations. The table below presents a list of selected terrorist groups that probably have MANPADS.

Table 1
List of terrorist organizations and groups possessing MANPADS. Source: own work

<table>
<thead>
<tr>
<th>Organization</th>
<th>State</th>
<th>MANPADS type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Armed Islamic Group</td>
<td>Algeria</td>
<td>Stinger</td>
</tr>
<tr>
<td>Chechen rebels</td>
<td>Russia</td>
<td>Strela-2 (SA-7), Stinger, Blowpipe</td>
</tr>
<tr>
<td>Democratic Republic of the Congo rebel forces</td>
<td>Democratic Republic of the Congo</td>
<td>SA-16 Iglá</td>
</tr>
<tr>
<td>Harkat ul-Ansar</td>
<td>Kashmir</td>
<td>Strela-2 (SA-7)</td>
</tr>
<tr>
<td>Hezbollah</td>
<td>Lebanon</td>
<td>Strela-2, QW-1, Stinger</td>
</tr>
<tr>
<td>Hizbul Mujahideen</td>
<td>Kashmir</td>
<td>Stinger</td>
</tr>
<tr>
<td>HUTU military forces</td>
<td>Rwanda</td>
<td>Type not known</td>
</tr>
<tr>
<td>Jamiat-e Islami</td>
<td>Afghanistan</td>
<td>Strela-2, Iglá (SA-14)</td>
</tr>
<tr>
<td>Jumbish-i-Milli</td>
<td>Afghanistan</td>
<td>Strela-2 (SA-7)</td>
</tr>
<tr>
<td>Red Khmers</td>
<td>Thailand/Cambodia</td>
<td>Type not known</td>
</tr>
<tr>
<td>Organisation</td>
<td>Country</td>
<td>Missiles</td>
</tr>
<tr>
<td>--------------------------------------</td>
<td>----------------</td>
<td>----------</td>
</tr>
<tr>
<td>Kosovo Liberation Army</td>
<td>Kosovo</td>
<td>Strela-2 (SA-7)</td>
</tr>
<tr>
<td>Kurdistan Workers' Party</td>
<td>Turkey</td>
<td>Strela-2 (S.A.-7), Stinger</td>
</tr>
<tr>
<td>Liberation Tigers of Tamil Eelam</td>
<td>Sri Lanka</td>
<td>Strela-2 (S.A.-7) Igla (S.A.-14), Stinger, HN-5</td>
</tr>
<tr>
<td>Oromo Liberation Front</td>
<td>Ethiopia</td>
<td>Type not known</td>
</tr>
<tr>
<td>Palestinian National Authority</td>
<td>Palestinian National Authority and Lebanon</td>
<td>Strela-2 (SA-7), Stinger</td>
</tr>
<tr>
<td>Popular Front for the Liberation of Palestine</td>
<td>Palestinian National Authority and Lebanon</td>
<td>Type not known</td>
</tr>
<tr>
<td>Provisional Irish Republican Army</td>
<td>Northern Ireland</td>
<td>Strela-2 (SA-7)</td>
</tr>
<tr>
<td>Revolutionary Armed Forces of Colombia</td>
<td>Columbia</td>
<td>Strela-2 (SA-7), Igla (SA-14), SA-16, Redeye, Stinger</td>
</tr>
<tr>
<td>Rwandan Patriotic Front</td>
<td>Rwanda</td>
<td>Sztrzała-2 (SA-7), SA-16</td>
</tr>
<tr>
<td>Somali National Alliance</td>
<td>Somalia</td>
<td>Not known</td>
</tr>
<tr>
<td>AL-Qaeda/Talibs</td>
<td>Afghanistan</td>
<td>All types of Strela and Igla, Stinger, Blowpipe</td>
</tr>
<tr>
<td>National Liberation Army</td>
<td>Columbia</td>
<td>Stinger and other of not known type</td>
</tr>
<tr>
<td>National Liberation Army</td>
<td>Macedonia</td>
<td>Strela-3 SA.-18</td>
</tr>
<tr>
<td>National Union for the Total Independence of Angola</td>
<td>Angola</td>
<td>Strela-2 (SA-7), Igla (SA-14), Strela-3 (SA.-16), Stinger</td>
</tr>
<tr>
<td>United State War Army</td>
<td>Myanmar</td>
<td>Strela-2, HN-5N</td>
</tr>
</tbody>
</table>
There is no doubt that at present MANPADS may already be in the possession of new organizations, or those which did not have them in the analyzed period. The number of the missiles held by terrorists is not known and this is why the data in the table refer only to their types. Additionally, estimating the total number of MANPADS in the world is very difficult as many MANPADS used in war conflicts disappear mysteriously from military warehouses, mainly in post-conflict areas where demilitarization is carried out and part of it is sold illegally on the weapons black market. It is even more complicated to compile a list of the number of functional MANPADS, because their service life is influenced by a whole range of variables – age, storage conditions and quality of maintenance. Even the oldest MANPADS can remain functional, especially if properly stored and maintained.

Analyzing the tactical and technical parameters of MANPADS one may conclude that these weapons are capable of destroying aerial targets at very short distances of about 5-8 km and up to the altitude of 3000-6000 m. These types of missiles are usually 1.5-1.70 m long and weigh an average of 15 to 20 kg.

Table 2
General characteristics of the selected MANPADS. Source: own work.

<table>
<thead>
<tr>
<th>MANPADS type</th>
<th>Total weight of the set (kg)</th>
<th>Weight of the warhead (kg)</th>
<th>Length (m)</th>
<th>Diameter (m)</th>
<th>Max. range (m)</th>
<th>Max. altitude (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strela-3 (SA-14)</td>
<td>9.80</td>
<td>1</td>
<td>1.42</td>
<td>0.072</td>
<td>4000</td>
<td>10,000</td>
</tr>
<tr>
<td>Iglia (SA-18)</td>
<td>10.60</td>
<td>1.15</td>
<td>1.67</td>
<td>0.072</td>
<td>5200</td>
<td>11,500</td>
</tr>
<tr>
<td>Iglia-S</td>
<td>12.60</td>
<td>2.50</td>
<td>1.67</td>
<td>0.072</td>
<td>6000</td>
<td>11,500</td>
</tr>
<tr>
<td>Raytheon Stinger - RMP</td>
<td>10.40</td>
<td>1</td>
<td>1.524</td>
<td>0.07</td>
<td>4500</td>
<td>11,500</td>
</tr>
<tr>
<td>MBDA Mistral</td>
<td>18.70</td>
<td>3</td>
<td>1.86</td>
<td>0.09</td>
<td>6000</td>
<td>-</td>
</tr>
<tr>
<td>Samb Bofors Dynamice RBS 70/90</td>
<td>16.50</td>
<td>-</td>
<td>1.32</td>
<td>0.106</td>
<td>8000</td>
<td>16,500</td>
</tr>
<tr>
<td>Thales Starstreak</td>
<td>13.60</td>
<td>-</td>
<td>1.40</td>
<td>0.127</td>
<td>7000</td>
<td>-</td>
</tr>
</tbody>
</table>
The universally recognized classification divides MANPADS on the basis of the method of guiding the missile at an aerial target. According to this adopted criterion, the following types of missiles have been distinguished:

- self-guided to a heat source with a single-color (IR) or two-color (IR/UV) head;
- guided from the ground by the operator within the line of sight (Command Line-of-Sight);
- laser guided from the ground (Laser Beam Riders).\(^{13}\)

Kits with infrared (IR) self-guided heads, which direct themselves to a source emitting thermal energy, e.g. aircraft engines, have become the most common in use. Infrared missiles guided by the heat that an aircraft emits, hit it directly, or explode nearby blasting it with hundreds of fragments. Missiles of this type use passive guiding systems. In practice, this is a very big problem for the protection (countermeasures) used in civilian aircraft. Older generations missiles guided by optical sight are the least frequently used. For years, the British *Blowpipe* was such a model, in which the operator, using the optical sight, directed the projectile's flight from the moment it was fired to the moment it hit the target. Using MANPADS of this type required the operators to undergo long training, which made them unattractive for terrorists.\(^{14}\)

Currently produced versions of portable anti-aircraft kits operating more and more often according to the “fire-and-forget” principle (e.g. the British *Javelin* – a portable small-range anti-aircraft missile kit equipped with a television camera and optical sight), are much easier to use even for less prepared users.

The latest group of anti-aircraft missiles are portable kits using a laser data exchange line that occurs between the missile and the guidance system mounted in the kit. The Swedish RBS-70 with the Bolide missile and the British Starstreak are among the most modern kits nowadays. The Swedish RBS-70 is a laser guided missile system in which the operator receives data and information about the aerial target from the local SLT terminal (combat control terminal), which is of the size of a laptop. When an aerial target is detected, the “friend-or-foe” identification system (IFF) is automatically activated. If the target is identified as a foe, the operator launches the missile that destroys the target with a 95% destruction probability.

Missiles of this type are difficult to be disrupted by systems mounted both on military and civilian aircraft. Portable missiles such as the Swedish RBS-70, or the British Starstreak, can attack any cruise aircraft on either an approach, or distance course. Startstreak is effective against maneuvering targets with an overload of up to 9G over a distance of up to 7 km. The probability of hitting the target with the first shell is very high and amounts to 96%).

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\(^{13}\) J. Bury, *Przenośne przeciwlotnicze zestawy rakietowe. Współczesne zagrożenie*, „Przegląd Sił Powietrznych” 2004, nr 10, s. 55

Currently, in military arsenals, in addition to the already mentioned types of portable anti-aircraft missile kits, there are at least a few other models of anti-aircraft missiles such as: the French Mistral (French anti-aircraft short-distance missiles system), the Polish GROM, or the new generation of the British portable anti-aircraft missile kit Starburst that is radio-guided, which makes it difficult to be disrupted by protection systems mounted both on military and civilian aircraft.\textsuperscript{15} The armament of the armed forces also includes numerous modifications to the Soviet MANPADS kits made in Egypt, India, Pakistan,\textsuperscript{16} Iran, and China.

The first MANPADS to be produced in China was the HN-5 (Hong Ying-5) kit, which was based on the Soviet technology. It was withdrawn from operational troops and reserve units, but is still used by police departments. MANPADS QW-1 was the successor of HN-5 in the armed forces, and later its modernized version QW-2. It is the third generation system operating according to the "fire-and-forget" principle. It was developed by Shenyang Hangtian Xinle Ltd. The missile and the launcher are very similar to the Russian 9K310 Igla-1. Compared to the previous version of the Qian Wei-1(QW-1) kit the range of destruction of aerial targets increased from 5 km to 6 km and response time reduced to 5 s. The QW-2 set uses a new two-band passive infrared search head, thus increasing the possibility of using the missile in all weather conditions and at all times of the day (day and night).

Since 2000 the China National Precision Machinery Import & Export Corporation begun the production of a new MANPADS model named FN-6,\textsuperscript{17} which is the first Chinese MANPADS to use an identification device of the “friend-or-foe” type (IFF).

With regard to the costs of purchasing MANPADS on the black market, their price may vary and can range from several hundred dollars to several thousand dollars, depending on the model and its condition. Depending on the type of MANPADS, the price of a single item on the black market ranges from a quarter million dollars for a modern model to 4,000-5,000 USD for older ones e.g. the Soviet Strela-2. According to the report published in “Aviation Week & Space Technology” the black market price of the French Mistral kit on a tripod it is comparable to the price of the Russian Igla set and fluctuates between 60 and 100 thousand USD.

Given the relatively low cost of some of these systems, there is an increased risk of their acquisition by terrorists, or other non-state actors.

Undoubtedly, the acquisition of MANPADS is currently too easy, therefore, in order to limit the proliferation of MANPADS, strict control of the production, storage and transport of MANPADS is crucial. Many countries in this respect exercise due diligence, selling them to other governments, and the whole process is properly monitored, secured, which guarantees that MANPADS will not reach the hands of non-state entities, e.g. terrorists.

\textsuperscript{15} J. O’Hoffman, C Foss, Jane’s Land-Based Air Defence 2003-2004, „Jane’s Intelligence Review “,2003, s. 37.
\textsuperscript{17} Wen Wei Po, Missiles, China Has Them too! Introduction of Finest PLA Missile Series, Hong Kong 1 Jun 99 s. A5.
ATTACKS ON CIVILIAN AIRCRAFT WITH THE USE OF MANPADS AND OTHER ANTI-AIRCRAFT MISSILES

It would be a mistake to believe that the incidents related to the use of MANPADS by terrorists against civilian aircraft are something new, because the first of them took place already in the seventies of the last century. The first confirmed use of MANPADS was registered in November 1975 over Angola. However, the most publicized incidents of shooting down civilian planes using MANPADS were the plane crashes of two Rhodesian airlines (now Zimbabwe) in 1978 and 1979. Cruise planes were shot down using Soviet anti-aircraft missiles Strela-2 (SA-7). Both accidents ended tragically with the deaths of 111 people on board the planes.

The first signs of a threat to civilian aviation posed by MANPADS attacks in Europe appeared in 1973, when Italian police detained five Palestinian terrorists with portable missiles. It was immediately after the incident in which a passenger plane was shot down over Rome.

Looking for yet other cases of the use of portable anti-aircraft missile kits against civilian aircraft, one can note several confirmed incidents of this type in which large turbojet passenger aircraft were attacked by MANPADS. These incidents are presented in Table 3.

Table 3

<table>
<thead>
<tr>
<th>Date</th>
<th>Type of aircraft</th>
<th>Operator</th>
<th>Effects of the attack</th>
</tr>
</thead>
<tbody>
<tr>
<td>November 8, 1983</td>
<td>Angolan Boeing 737</td>
<td>Angolan Airlines (TAAG)</td>
<td>All crew members and passengers died – 130 people</td>
</tr>
<tr>
<td>February 9, 1984</td>
<td>Angolan Boeing 737</td>
<td>Angolan Airlines (TAAG)</td>
<td>The aircraft was hit in the fuselage after take-off at the altitude of 8000 feet. All passengers died – 130 people.</td>
</tr>
<tr>
<td>September 21, 1984</td>
<td>Afghanistan DC-10, Ariana</td>
<td>Afghan Airlines</td>
<td>A missile damaged the aircraft's hydraulic system. The aircraft managed to land safely without any human loss.</td>
</tr>
<tr>
<td>Date</td>
<td>Aircraft Type</td>
<td>Airline</td>
<td>Event Description</td>
</tr>
<tr>
<td>-----------------</td>
<td>-------------------</td>
<td>------------------------------</td>
<td>-------------------</td>
</tr>
<tr>
<td>September 22, 1993</td>
<td>Tu-154 Suchumi in Georgia</td>
<td>TGA (Transair Georgian Airlines)</td>
<td>A missile damaged the aircraft but it was able to land at the airport but then exploded. Before the explosion, 26 people managed to get out of the aircraft.</td>
</tr>
<tr>
<td>October 10, 1998</td>
<td>Democratic Republic of the Congo, Boeing 727</td>
<td>Congo Airlines</td>
<td>In the result of the crush, 41 people died.</td>
</tr>
<tr>
<td>January 2, 1999</td>
<td>Lockheed L-100-30 Hercules over Angola</td>
<td></td>
<td>All people on board the aircraft died.</td>
</tr>
<tr>
<td>November 28, 2002</td>
<td>Kenian Boeing 757</td>
<td>Arkia Israeli Airlines</td>
<td>The aircraft was hit with two Strela-2 missiles at the fuselage during the ascent. There were no human casualties.</td>
</tr>
<tr>
<td>November 22, 2003</td>
<td>Iraq Airbus A300</td>
<td>DHL Cargo Hull</td>
<td>The aircraft was hit by a missile right after taking-off from Baghdad airport. As a result of a missile hit, the hydraulic system was destroyed and the aircraft had to make an emergency landing.</td>
</tr>
<tr>
<td>January 9, 2007</td>
<td>An-26</td>
<td>Aerian Tur-M</td>
<td>In the result, 32 people on board died (one survived).</td>
</tr>
<tr>
<td>March 23, 2007</td>
<td>Il-76</td>
<td>TransAVIAexport Airlines</td>
<td>All 11 people on board the aircraft died.</td>
</tr>
</tbody>
</table>

Apart from the cases of anti-aircraft missile firing on civilian aircraft listed in the table, other incidents occurred. One of them was recorded in 1993 over the airspace of Georgia. According to a “Wall Street Journal” reported, a TU-154 aircraft in the former USSR carrying 100 passengers through Georgia was forced to perform emergency landing at the Sukhumi airport. Only 26 passengers managed to escape the aircraft before it exploded killing the rest of the people on board. In the same year, on March 31, a scheduled flight of Boeing 727 departing from Augusto Cesar Sandino international airport carrying diplomats was shot at with MANPADS. After this incident, the airport authorities received information confirming it. The investigation indicated the use of American anti-aircraft Redeye kits, which could have been
intercepted by the Russians during the Vietnam War, and then transported by sea to Cuba, which supported the Nicaraguan communists fighting with the then regime.\textsuperscript{18}

One of the most publicized attempts to shoot down a passenger aircraft by an anti-aircraft missile was the November 28, 2002 incident, where Boeing 757 of the Israeli airlines was shelled. Two Strela-2 missiles were fired at the plane immediately after it took off from the airport in Mombasa (Kenya), but both missed the target. It was this incident that sparked numerous discussions among experts on improving aviation safety and focused the attention of the US Congress and the Bush administration on the need to improve the current state of civil aviation safety. The attack on the plane in Mombasa was assessed as a political attack by Al Qaida terrorists. This incident was also by some experts closely associated with the September 11, 2001 attack in New York.

Another attempt to shoot down planes using MANPADS took place on November 22, 2003 in Iraq, when a DHL transport plane, the moment it was leaving the international airport in the capital of Iraq – Baghdad, was hit in the wing and side.\textsuperscript{19}

The anti-aircraft missile damaged also the hydraulic system. As a result the Aerobus A-300-B4 managed to land, destroying a large fragment of the runway.\textsuperscript{20}

The next of the analyzed incidents took place in December 2003 when an unidentified anti-aircraft missile hit the US air force transport aircraft C-17 Globemaster III. The event happened after passing the international airport in Baghdad. In January 2004 another C-5 Galaxy transport aircraft hit by an anti-aircraft missile had to perform emergency landing in Iraq as well.

On January 9, 2007, an An-26 belonging to Aerian Tur-M (registration markings ER 26068) crashed during a landing attempt at the Balad base in Iraq (80 km north of Baghdad). Although officials blamed the disaster for adverse weather conditions, the witnesses said they saw the plane being shot down. Soon a terrorist group admitted it. As a result of this attack, thirty-four people on board were killed (one survived).

On March 23, 2007 an Il-76 belonging to TransAVIAexport airline crashed on the outskirts of Mogadishu in Somalia during the city's fights between Somali Islamist militants and Ethiopian troops. The witnesses, including a reporter of the Shabelle portal, claimed that they had seen the moment when the aircraft had been shot down. Belarus initiated an investigation into this act of terror, which confirmed initial suspicions.\textsuperscript{21}

One of the most famous air disasters that took place after a civilian aircraft was shot down by a guided anti-aircraft missile took place on July 17, 2014 near the village of Hrabowe (near the city of Torez) in the Donetsk Oblast in Ukraine, about 40

\textsuperscript{18} M. Schroeder, Manpads proliferation in Latin America: an analysis of the threat and the regional response. http://www.comunidadessegura.org/?q=en/node/37647 z dn. 4.01. 2008
\textsuperscript{19} M. Knights, Unfriendly skies: Iraq’s Sunni insurgents focus on air defence, „Jane’s Intelligence Review“, May 2007.
\textsuperscript{20} T. Curtis, Successful Missile Attack on an A300 Jet Airliner, The AirSafe Journal, November 2003, Issue vol. 1 no. 18
kilometers from the border with Russia. This time, the Malaysia Airlines Boeing 777 flying from Amsterdam to Kuala, was not shot with MANPADS, but another guided anti-aircraft missile launched from the BUK anti-aircraft defense system belonging to the 53rd Anti-aircraft Missile Brigade of the Armed Forces of the Russian Federation, which was moved to the area controlled by pro-Russian separatists a few days before the catastrophe. As a result of being hit by the anti-aircraft missile, this aircraft was completely destroyed and its remains fell to the ground. As a result of this disaster, 283 passengers and 15 crew members were killed.

The last of the documented attacks using guided anti-aircraft missiles against a civil aircraft were the events of January 8, 2020. An aircraft belonging to Ukraine International Airlines performing a passenger flight on the route from Tehran to Kiev crashed 15 kilometers from the airport. According to the findings it was shot down by two Iranian 9M331 missiles fired by the Russian TOR-M1 anti-aircraft missile system.22

The list of incidents in which MANPADS and other anti-aircraft missiles were used against civilian aircraft would have been much longer if all the terrorist attacks attempts had been effective.

What is more, many experts warn that the official data may be significantly underestimated in relation to the actual incidents due to the fact that not all disasters were assumed to have been the result of aircraft being fired by anti-aircraft missiles. Therefore, they suggest that they were assigned other causes not in line with the real ones. In other cases, the data confirming the use of MANPADS was insufficient, or the exact weapon was not established. In other situations, it was difficult for the experts to state clearly whether the mission carried out by the given aircraft was of a civilian, or maybe military nature. Therefore, it is difficult for the statistics experts to agree whether a given incident should be included in the files of civil, or military aviation history.23

**ON-BOARD SYSTEMS PROTECTING AIRCRAFT AGAINST LAND-BASED MISSILE ATTACKS**

The increased threat of civilian aircraft being attacked by anti-aircraft missiles has prompted the major air carriers to take it seriously. It has directly influenced the projects implemented by large concerns producing aircraft for the civilian market, who are working on the possibility of installing very modern protective devices in the aircraft in use. The main task of these systems is to minimize the aircraft’s sensitivity to being hit by an infrared missile, as these types of warheads are most often in the hands of terrorist organizations.

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An example of such preventive actions is the United States, where the Congress has already legalized the possibility of introducing anti-missile installations and systems in turbojet aircraft intended for training purposes and transport services. This legislation was adopted under the pressure of considerations of the Homeland Security program which in 2004 received funds amounting to 60 million US dollars and in 2005 even 61 million. This is to finance a program to develop prototypes of ready-to-use anti-missile systems for the commercial civil aviation market. In many cases these solutions will be based on the technologies already being used in military aircraft. The Department of National Security actively joined the work on the defense systems for civil aviation and provided detailed analyses and recommendations of appropriate protection systems that could be used in passenger aircraft. The development works are carried out by special forces among which there are the representatives of the Federal Aviation Agency from defense and intelligence departments, who already in a confidential report issued in 1998 highlighted the threat of civil aircraft by attacks using portable anti-aircraft missiles. This has in many cases led to significant changes in the aircraft designs themselves and has been reflected in operational activities to reduce travelers risk.

A good example of creating protection systems for civil aircraft are devices used in military aviation, which have many systems mitigating the threat of shooting down, or damage an aircraft by anti-aircraft missiles.

Currently only a few civil airlines use similar protection systems. One of the important arguments limiting the widespread introduction of such protection systems to civil aircraft is their high cost, but more and more often for major airlines it will be the only alternative to maintaining the transport market and creating the image of a safe carrier in the minds of the passengers. Estimates of the cost of purchasing such devices and installing them in a transport aircraft range between 1 and 3 million US dollars. Other indirect costs, however, are generated by their installation and logistics of their proper functioning (technical inspections and maintenance).

The electronic warfare specialists use the following division of countermeasures:

- On-board Infrared Countermeasure subsystem;
- Out-board Radar Countermeasure;
- Out-board Infrared Countermeasures;
- Laser Countermeasures sub-system.

Warning and reconnaissance receivers are very popular: laser radiation warning devices LWR (Laser Warning Receiver) and devices warning about firing missiles MWS (Missile Warning System), as well as interference stations and confusing devices operating in the infrared: IRCM (Infrared Countermeasures).24

Laser warning devices (LWR) are designed to detect, process and visualize the hazards associated with illuminating the aircraft with the enemy’s laser system.

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http://www.globalsecurity.org/military/systems/aircraft/systems/ircm.htm
rangefinder, or laser target illuminator. The scope of operation of the device must ensure a sufficiently quick response to the threat, understood as the speed of making decisions about the use of self-defense. It has been confirmed that LWR devices should be able to detect laser illuminators of semi-actively guided missiles, which may pose a threat to helicopters and transport aircraft, laser weapons of different power.

The missile warning device (MWS) is designed to detect and determine the type of threat (type of missile). The MWS system is designed to complement the RWR system, whose main limitation is the ability to detect only electromagnetic radiation present in space.

The MWS system is therefore designed for passive detection of signals in space in the infrared and ultraviolet band. The advantage of the passive detection system is the better detection time (longer period between threat detection and bullet impact). This system provides information about the occurrence of a threat already at the moment of firing the projectile, which in turn gives the possibility of the own shield system to effectively use a DIRCM class device.

In the systems protecting civilian aircraft it is possible to use the Expendable Active Decoy, which are missile missiles (target imitators – bait) of the stand-off class containing transmitter modules. Launched from the carrier’s board, they generate a signal imitating the echo signal from an object with a given RCS. Another type in this class of systems are radiolocation dipoles, fired from on-board launchers in a similar way to thermal flares. It was found that the greatest reflection possibilities of waves occur when dipoles with a length of 0.46 ÷ 0.48 wavelength are used.

On-board systems are another group of protective IRCM (Infrared Countermeasure) devices. They are interfering devices (e.g. AN/ALQ 144) which emit modulated energy in the selected infrared range. This modulated energy (light pulses) causes errors and, as a result, the infrared guided missile crosses over the head of the infrared-guided missile. Directional sources of DIRCM infrared interference can dazzle, or damage due to high intensity concentric light radiation. A typical DIRCM solution is to use a laser, or a special flash. The simplest and cheapest way of interfering with infrared are still flares.

There can be many more solutions in this respect. One of them may be the proposal of one American concern producing aircraft – Gulfstream Aviation, which offers protection measures to protect the aircraft from infrared. Another solution may be pulsating lights, or installing special nozzles on aircraft that reduce the thermal footprint of gases escaping the engines.

Emerging ideas for the use of techniques to reduce the spectrum of the aircraft are very interesting, but do not lead to such a state in which the aircraft would become invisible to terrorists. However, one should be fully aware of the fact that the proposed technical solutions can only reduce the aircraft susceptibility to infrared missiles without totally eliminating the threat. In this situation, according to many experts, the main task is first to equip civil aircraft with means, protective devices that strengthen their immunity after being hit by an anti-aircraft missile.
An interesting example in this regard may be the program known as the FAA’s Commercial Aircraft Hardening Program. As part of these works, the experts focus on the research aimed to find a method of improving the resistance of the aircraft to internal gusts caused by bomb, or missile explosion. In this context, the strength of the aircraft’s structure (its fuselage and sheathing) is tested against the explosion of an anti-aircraft missile detonating already after hitting the aircraft, or exploding in its vicinity. The results of these studies so far indicate that some elements of the aircraft structure, such as wings, will have to be strengthened.

In 2002, work on protective systems for cruise liners in Israel was initiated. As a result El AL, Arkia and Israir are the only commercial airlines which equipped their aircraft with anti-missile systems. The effect of the work of the Israeli company Elbit Systems was the C-MUSIC aircraft defense system, which is considered the most advanced of its kind in the world. The system localizes the shoulder-launched missiles aimed at the aircraft. After identifying the threat it generates a laser IR beam (DIRCM) which interrupts the missile and causes its self-destruction at a safe distance from the aircraft. Another protection system used by EL AL is the Flight Guard device developed by an Israeli company Elta and the Israel Military Industries. The system has been designed as a protection both for the military aircraft and civilian aircraft flying through dangerous areas. It has been tested under real threat conditions of MANPADS attacks. The Flight Guard system is capable of detecting missiles approaching the aircraft and alerting the crew of the imminent danger. After performing these actions the system automatically launches the active countermeasures whose aim is to change the flightpath of the missile so that is does not hit the flying aircraft. The system is based on six miniaturized impulse Doppler sensors that can be easily placed on any aircraft.

The Israeli manufacturer states that this system guarantees a 99% probability of detecting the missile, and has a very low false alarm rate.

Especially intensive work on the civil aircraft security system was undertaken by the Rafael company, whose representatives reported that within 10 years they will be able to prevent such terrorist attacks. After receiving the final approval of the aviation authorities, Rafael began installing the technology, called Britening, on board civilian passenger aircraft. As one of the representatives of Rafael, Yediot Aharonot, emphasized, the anti-missile system proposed by the company contains electronic sensors that search and detect the launched missiles on the basis of changes in heat. The system then sends out strong rays of light that guides the missile away from the plane. Britening protects the aircraft against MANPADS attacks and anti-tank guided missiles mainly during take-off and landing.

Interesting solutions in the field of protections systems against MANPADS attacks have been proposed by American companies. On December 21, 2008, the US Department of Defense signed a 29 million US dollars contract with BAE Systems for measures to protect commercial civil aircraft. Under the contract, the first three American Airlines passenger aircraft that run on the route between New York and California are to be equipped with the missile protection system. The idea of this
Another company, Northrop Grumman, also developed an on-board system to protect civilian aircraft from MANPADS attacks and named it Guardian. It was created as a result of the civilian implementation of the MANPADS military countermeasure system AN/AAQ-24 (V) NEMESIS. It uses the latest solutions based on laser technology. The Northrop Grumman Guardian™ Missile Defense protection system, unlike older missile defense systems that only protect against older generation missiles, provides protection with 360 degrees range around the aircraft against the most modern MANPADS that could be in the hands of terrorists. It has been in normal operation since January 2007. After 14 months of operation of the Guardian system, in which it worked for over 22,000 hours and made 4500 flights, an 3-4% increase in fuel consumption was found. The Guardian system can be placed anywhere in the fuselage at 51 domestic and international airports (Pledger, 2006: 4).

The Guardian system can be quickly mounted on any aircraft flying over an area of increased MANPADS attack risk.

As a result of cooperation of two companies Raytheon and BEA System the first comprehensive system protecting civilian aircraft against terrorist attacks using MANPADS has been created. This is the “Quiet Eyes” system whose first tests in flight conducted by Raytheon finished in 2008. The way this system works is based on a laser indicator of searching and tracking the flight path of the missile and disrupting it by blocking the proper trajectory of the missile to the target. The Quiet Eyes system has been integrated with the BEA System of UH-60 Blackhawk infrared countermeasure system. According to experts, the Quiet Eyes system represents a significant breakthrough in the field of infrared countermeasures technology. It is currently the smallest and lightest, as well as the most attractive and reliable laser pointer available on the market. During the ATRCIM tests it detected threats during the flight, then went into the phase of tracking the missile, and then automatically activated protective devices (countermeasures). The system was reliable both when flying at high and low speeds and during acceleration and braking. The system consists of an anti-aircraft missile warning subsystem and a laser route tracking indicator. The missile threat warning system, identifies the threat in fractions of a second in relation to the route and direction of flight of the aircraft. In the event of a hazard being identified, a laser countermeasure system is automatically activated and destroys the missile flying towards the aircraft.

In turn, the effect of cooperation between Saab Avitronics (alarm and warning systems), Saab Aerotech (certification, security installations) and Chemring in the United Kingdom is the CAMPS-100 and CIDAS aircraft security system.

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27 P. La Franchi, Raytheon i BAE Systems complete first Eyes Quiet Laser Pointer-Trader Flight Test, Flightglobal.com z dn. 28.03. 2007.
A typical version of the CAMPS-100 system consists of four MAW-300 sensors detecting missiles and warning about their detection and two BOA thermal trap distributors with a total weight of about 35 kg.28 Within seven seconds of the missile being detected, the thermal trap launcher is activated, which is determined by a special modem control system located in the cockpit of the aircraft cabin. It operates fully automatically without human intervention. The system can simultaneously counteract up to eight missiles. At the optimal moment, the control modem issues the command to release thermal traps from the containers (launchers), which include a special chemical compound. The electro-mechanical tank (BOA Dispenser System) with a special self-igniting substance is an effective protection against infrared missiles. These types of electro-mechanical distributors have been produced by Saab Avitronics since the mid-1950s. They are characterized by high reliability, easy integration with other elements and excellent performance.

The chemical material used in the flares developed by the Chemring Group does not explode and does not burn at a relatively low temperature. In addition, the material is safe and its loading and unloading does not require any special training, or additional protective measures. This means that the material can be used in sensitive areas such as civil airports. The tests of the system began in March 2007 at the South African Air Company in Embraer EMB-120 aircraft of Brazilian production, which were equipped with four MAW-300s sensors and one container with thermal traps. Tests carried out in South Africa have demonstrated the effectiveness of the CAMPS system against the Strela-2M (SA-7) missiles.

CONCLUSIONS

The results of the conducted research clearly indicate that terrorist attacks on civil aircraft using MANPADS have already been a serious threat, and now and in the near future they can become a weapon that terrorists will increasingly use.

The first factor conducive to the spread of MANPADS is the relatively easy access of this type of weapon, whether through legal, or illegal purchase.

Secondly, this type of weapon, especially the older types, is relatively cheap. Most MANPADS are relatively easy to use, which means that training the shooter does not require special conditions and a long preparation process.

Another and very important factor affecting the use of MANPADS by terrorists is that these systems are characterized by small dimensions, which means that they can be secretly transported by ordinary passenger cars, or SUVs.

Another factor contributing to the intensification of the threat of MANPADS and other anti-aircraft missiles is their high effectiveness of destruction, which has become a very important marketing factor. Increasing the effectiveness and accuracy of destruction is widely regarded by MANPADS producers as the main incentive to buy a specific product that is to be more effective than the products of other competing

companies. In this situation, one often observes the appearance of increasingly deadly MANPADS export versions on the market.

In order to reduce the threat to civilian aircraft posed by anti-aircraft missile attacks it is necessary to undertake legislative and administrative activities, not only by the governments of individual countries, but also intensified efforts of international organizations, such as the UN and ICAO to increase the safety of cruise aircraft against the possibility of an attack from the ground using portable anti-aircraft missiles.

However, efforts to tighten MANPADS export controls to limit their acquisition by terrorist organizations must be consolidated and respected by all weapons market participants. In this regard, as Western experts emphasize, these activities must be comprehensive and consistent in the implementation of the agreements and resolutions by all signatories.

In addition to legal regulations, efforts must also be continued to develop specific equipment, or entire defense systems for civil and military aircraft that will give passengers and crews a sense of safety in the air. Here, mutual and close cooperation of all aviation companies seems necessary in order to develop a common strategy to fight terrorism. The seriousness of these preventive actions is fully justified, since this type of terrorist acts directed against civilian aircraft is particularly dangerous and threatening not only for passengers and aircraft crews themselves, but also for other people present at plane crash sites.

REFERENCES