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RAM-TYPE AIR THREATS, OLD – NEW CHALLENGE FOR AIR DEFENCE FORCES. CRAM IN THE MILITARY OPERATIONS

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Abstract

RAM-type air threats represent a new challenge for air defense forces, as these threats have traditionally been classified as ground-based attacks. However, with the increased use of rockets, artillery, and mortar shells in conflicts and stabilization operations, these threats are now being classified as air-based threats. This has created a new set of challenges for air defense forces, who must adapt their defense strategies to combat these new threats.
The study examines the various types and causes of RAM-type air threats, including their origins, capabilities, and modes of operation. It also considers the challenges that these threats pose to air defense forces, such as their low-flying and unpredictable nature. Additionally, the study analyzes anti-aircraft defense systems that have been successfully deployed in other countries to combat these threats, including their advantages and disadvantages.
One of the key findings of the study is the importance of early detection and tracking of RAM-type air threats, which can be accomplished through the use of advanced radar systems and other technologies. Another important factor is the need for flexible defense strategies that can adapt to the evolving nature of these threats. The study concludes that continued research and development of effective defense strategies against RAM-type air threats is crucial for the safety and security of military and civilian populations in conflict and stabilization operations.

Keywords*: air threats, RAM, C-RAM*

ZAGROŻENIA POWIETRZNE TYPU RAM – STARE I NOWE WYZWANIA DLA WOJSK OBRONY PRZECIWLOTNICZEJ. CRAM W OPERACJACH WOJSKOWYCH

Streszczenie

Zagrożenia powietrzne typu RAM stanowią nowe wyzwanie dla wojsk obrony przeciwlotniczej, ponieważ tradycyjnie były one klasyfikowane jako ataki z użyciem uzbrojenia lądowego. Jednak ze względu na rosnące wykorzystanie rakiet, artylerii i moździerzy w konfliktach zbrojnych oraz operacjach stabilizacyjnych, zagrożenia te są obecnie klasyfikowane jako powietrzne. Pociąga to za sobą konieczność dostosowania strategii obronnych do nowych realiów pola walki.
W artykule przeanalizowano różne typy i przyczyny zagrożeń powietrznych typu RAM, w tym ich pochodzenie, możliwości oraz sposoby działania. Uwzględniono również wyzwania, jakie stanowią one dla wojsk OPL, zwłaszcza ze względu na niską trajektorię lotu i trudną do przewidzenia charakterystykę. Przedstawiono także systemy obrony przeciwlotniczej, które zostały skutecznie zastosowane w innych państwach do zwalczania tego typu zagrożeń, omawiając ich zalety i ograniczenia.
Jednym z kluczowych wniosków płynących z analizy jest znaczenie wczesnego wykrywania i śledzenia zagrożeń typu RAM, co można osiągnąć dzięki zastosowaniu zaawansowanych systemów radarowych oraz innych technologii. Istotne jest również opracowanie elastycznych strategii obronnych, które będą mogły się dostosowywać do zmieniającej się natury tych zagrożeń. Autor konkluduje, że dalsze badania i rozwój skutecznych metod przeciwdziałania zagrożeniom typu RAM mają kluczowe znaczenie dla zapewnienia bezpieczeństwa sił zbrojnych oraz ludności cywilnej w trakcie konfliktów i operacji stabilizacyjnych.

Słowa kluczowe*: zagrożenia powietrzne, RAM, C-RAM*

1. Introduction

Classical threats that existed during the Cold War are slowly fading away into the past. The possibility of a clash between equally matched and similarly armed opponents may not have completely disappeared, but it is more unlikely than in the past. Asymmetry of actions creates situations where traditional air defence systems are forced to face new challenges. So far, its adversaries have been manned aircraft (Manned Aircraft – MA), fighter planes (Fixed Wing – FW) and combat helicopters (Rotary Wing – RW), unmanned aerial vehicles (Unmanned Aerial Vehicles – UAVs), maneuvering cruise missiles (Cruise Missiles – CMs), and precision-guided munitions (Precision Guided Munitions – PGM).

A different type of aerial threat compared to technologically advanced constructions mentioned above are cheap and easy-to-engage rockets, artillery projectiles and mortars collectively referred to as

Rockets, Artillery and Mortars – RAM. This represents a new type of threat not due to technical solutions but rather the classification of these hazards as an aerial threat. Although it is not considered the most significant from the perspective of the Polish Air Defence System and maintaining security in its airspace, it directly concerns the forces participating in stabilization operations conducted in areas where armed conflicts have been on-going. The new danger is associated with the widespread use of "primitive" but highly effective weapons by guerrillas or terrorists in asymmetrical conflicts, primarily rocket and mortar artillery. These weapons are easy to transport, simple to operate and ready for immediate and unexpected engagement.

The fact that RAM-type threats are a newly defined category of aerial threats and which do not directly threaten the airspace of particular states but are often perceived from the perspective of asymmetrical actions, suggests that there has been insufficient and unsystematic interest in this issue in the literature. The involvement of the Polish Armed Forces in stabilization missions and the real contact with RAM-type threats have contributed to the search for countermeasures against these threats and providing effective protection to troops and infrastructure. The end of stabilization operations in Iraq and Afghanistan, as well as the new armed conflicts in which new-old means of attack, such as unmanned aerial vehicles, were/are extensively used, have resulted in RAM-type threats no longer being a focal point of the Polish Armed Forces' interest. This is evidenced by the assumed distant deadlines for the land-based air defence systems to achieve the capability to counter this category of threat. The material focuses on identifying RAM-type threats, countermeasures employed by other countries' armies as well as a synthetic analysis of the current capabilities of the land-based air defence systems of the Polish Armed Forces.

The present study does not provide proposed solutions to the identified problem. Its main goal is to create a starting point for further considerations in this area, to draw attention to the new-old aerial threats – RAM, and the need for a broad discussion and deliberation aimed at developing concepts of desired capabilities and structures capable of effectively countering these threats.

2. RAM – new type of air threat

RAM are a highly proliferated category of airborne threats, making it likely that they will be increasingly encountered by Land Forces. They pose a significant threat to personnel, installations and vehicles, which classifies them as extremely high risk.

RAM-type threats – rockets, artillery projectiles, and mortars – fall into the category of indirect fire threats, which are defined as fire directed at a target not directly visible to the shooter. Indirect fire, due to the unpredictability of the weapons engaged, can cause significant losses in personnel, military equipment, and disrupt the mobility of forces, as well as have a significant impact on the psychological and physical well-being of soldiers. These systems vary in terms of size (dimensions and calibre) and the effects of their strikes. Rocket and artillery projectiles are usually fired from stationary or portable platforms, while mortars are often operated by mobile crews.[1]

In summary, the following features and properties of indirect fire can be indicated:

- Indirect fire can cause casualties to troops, inhibit mobility, suppress or neutralize weapon systems, damage equipment and installations, and demoralize the enemy.
- Historically, more combat deaths have been caused by indirect fire weapons than by any other means, hence the designation of artillery as the "King of Battle".

[1] Departament of the Army, FM 3-01, US Army and Missile Defence Operations, 2022, 3.8.

- Most casualties to troops in an indirect-fire attack are caused by the initial rounds.
- Best results are achieved by a short engagement at a high rate from as many weapons as possible.[2]

It is worth noting that the main sources of acquiring RAM-type weapons are smuggling, homemade production and the utilization of materials obtained from the military arsenals. Importantly, the analysis of rocket production by rebels shows that the main effort has been focused on increasing the range and the weight of explosive materials in the warheads. In these cases, the precision of the strikes is a secondary aspect.

Rockets are short range unguided motor-propelled munitions with high explosive warheads that are launched from smooth-bore tubes. This inexpensive and simple launching mechanism has made the use of rockets attractive for both regular and irregular warfare (e.g., insurgencies)], as insurgent forces are able to deliver a heavy volume of rockets (though often with limited accuracy) and then quickly retreat before counter-battery fire can be applied. Furthermore, rockets and their associated launchers are highly mobile and easily accessible to both state and non-state actors, making them highly proliferated. Rockets are often used to target assembly areas, air defence locations, defensive positions, and other key spaces.

Rockets have played a pivotal role in a number of recent conflicts. Qassam rockets, short range rockets produced in the Gaza Strip, have been used extensively by Hamas militants during the on-going Israel-Palestinanian conflict. Additionally, in August 2021, the Islamic State Khorasan (ISIS-K) group launched an attack on the Hamid Karzai International Airport in Afghanistan by firing approximately six 107-millimetre artillery rockets.[3]

To sum up rockets have the following characteristics:
- Longer ranges resulting in greater standoff capability.
- Impede critical frequency (CF) in locating the POO due to flatter trajectory.
- Increased time to escape.
- Stockpiles seem readily available.
- Decreased time-of-flight to a target.
- Simplified aiming solution.
- Flight path “deceives” CF sensors.
- Velocity comparison.[4]

Artillery rounds are projectiles, charges or fuzes that are fired from howitzers. They are typically employed in an infantry support role to degrade the opposing forces and often target personnel as well as light and armoured vehicles. Howitzers generally feature a medium-angle trajectory and a longer range when compared to mortar systems.

Mortars are typically portable, muzzle-loaded weapons that fire shorter-range explosive projectiles at a high-arcing trajectory from a smooth-bore tube. Mortar fires are generally more accurate than rockets, but their successful operation is more complex and the launchers are more expensive, making mortars less accessible to non-state actors when compared to rockets. Mortars have shorter ranges than other indirect fire systems and are typically employed against area targets such as exposed troops or parked aircrafts. Mortars are generally lighter and more portable than howitzers and are often embedded within infantry Units.[5]

[2] *Counter – Rocket, Artillery, Mortar (C – RAM)*, Presentation US Army Air Defence Artillery School.
[3] G. Nikolakakos, M. Amyot-Bourgeois, *A state-of-the-art review and analysis of tactical-level ground-based air defence systems and airborne threats*, Scientific Report, 2022, p. 2.
[4] Headquarters Department of the Army, ATP 3-01.60, Counter-Rocket, Artillery, and Mortar Operations, 2006.
[5] G. Nikolakakos, M. Amyot-Bourgeois, *A state-of-the-art review…*, p. 2–3.

The tactics of groups employing artillery arsenals largely consists in conducting short-term shelling from concealed firing positions, followed by a rapid withdrawal into hilly or urban terrain. Such actions greatly hinder the detection and identification of perpetrators both before and after the attacks. Moreover, the sense of impunity of these acts becomes an additional incentive for other groups employing such tactics. The obvious advantage of these types of weapons is that they are inexpensive and relatively simple to operate, even by poorly trained individuals, which eliminates the need for extensive and costly training.[6]

The analysis of RAM attacks by the coalition forces in Iraq, Afghanistan and Israel indicates that the targets (objects) located within bases were not accidental. The majority of them were directed at helicopter landing zones, command and staff buildings as well as at barracks. The concentration of rocket and mortar attacks on specific objects primarily aimed to intimidate and spread uncertainty among troops stationed in military bases. Firing positions were chosen in locations that allowed the shelling of the entire base area or at least a significant portion of it. In this regard, insurgents fired several mortar or rocket projectiles from well-concealed firing positions. This significantly reduced the time spent by the crew at the firing position. It should be noted that the attacks were preceded by thorough reconnaissance around the base.[7]

Another important aspect of RAM attacks is that the methods of attack are constantly evolving, and the similarities in the methods and tactics used in various conflict zones around the world indicate the exchange of experiences and information between rebel groups and terrorist organizations. Therefore, the methods varied and still vary – from spontaneous and often random engagement of weapons to pre-planned attacks utilizing all available means of warfare.[8] For example, Israel has been the target of more than 10.000 rocket and mortar attacks in recent years. Israeli experience shows that it brings the best effect, best results are achieved by a short engagement at a high rate from as many weapons as possible. This tactic is known as a saturation attack, saturating the entire area with fire, knowing that some of the projectiles must break through anti aircraft cover.

The scheme of carrying out the attack is shown in the figure.

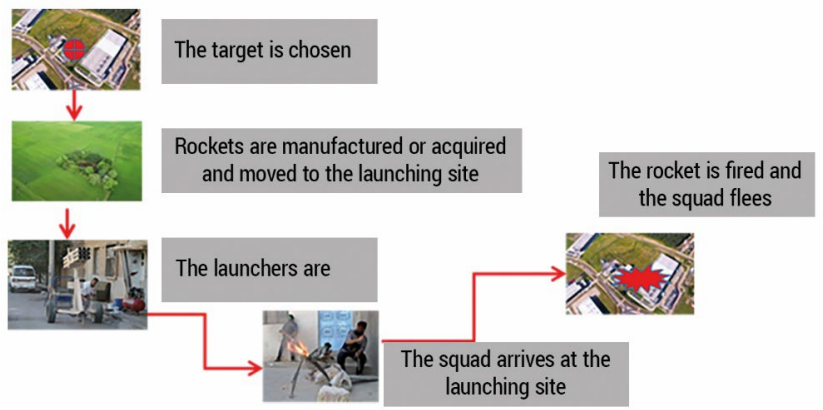

Fig. 1. Diagram of a RAM attack
Source: the author's own study.

[6] K. Dobija, *Uwarunkowania rozwoju Systemu Obrony Powietrznej Polski*, ASzWoj, Warszawa 2019, p. 85.
[7] A. Radomyski, *Obrona przeciwlotnicza w działaniach stabilizacyjnych*, LAW, Dęblin 2019, p. 32–34.
[8] Ibidem, p. 44–45.

3. The C-RAM systems – response to a new type of air threat

During the Iraq Freedom Operations the US Forces and their coalition were facing serious damage due to insurgents firing. The number of losses both from military personnel and civilian was increasing. There were some methods of countering those firings prior to their launch such as aggressive patrolling, establishing ambushes, and counter firings on suspected or confirmed enemy locations, but each of these method posed risks to soldiers and civilians. Iraq Freedom Operations revealed the need for the development of a system with quick reaction ability, effectiveness and precision. The system which would be able to protect both ground forces and forward operating bases from insurgents' firings. Counter – Rocket Artillery Mortar (C-RAM) weapons fill a capability need that has evolved since the end of the Cold War. These weapons are intended to shoot down incoming rocket, artillery and mortar rounds. Technologies proposed and developed for this purpose include rapid-fire guns, short range missiles and Directed Energy Weapons (DEW).[9]

The C-RAM, as a capability, refers to a system of systems, like sensors, interceptors and warning systes and not only a weapon. It is used to detect and/or destroy incoming rockets, artillery and mortar rounds in the air before they hit their ground targets or simply provide early warning. The system uses sensors like radars and UAVs, and computing systems to update itself with information about the location of friendly air platforms. This information is updated almost continuously. At the same time the system detects incoming RAM and calculates the optimal time to engage the target and the needed duration of firing with extended use of Artificial Intelligence. Although the system cannot prevent all casualties, having C-RAM is certainly more effective that the status quo prior to it. The C-RAM is a multitool. It can operate as a standalone system offering protection from incoming RAM, nut also it can be a part of a greater system, contributing to the development of a more effective AD umbrella, offering mission – tailored defence.[10]

To sum up, the C-RAM system should have the following characteristics:

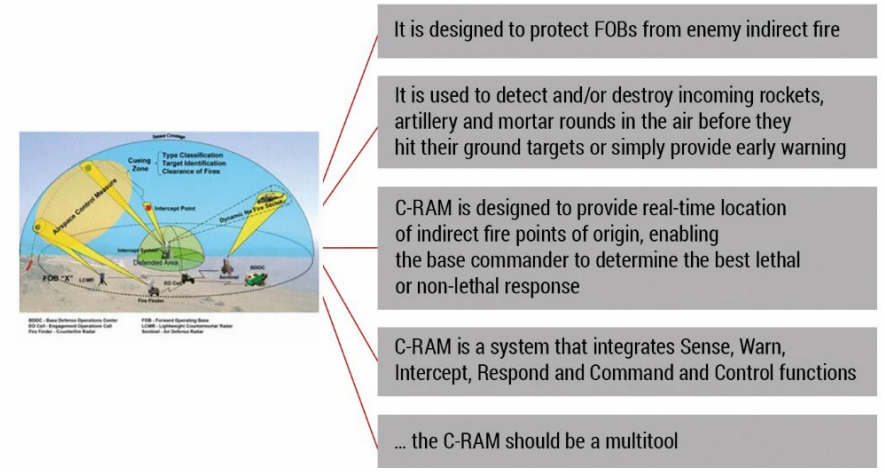

Fig. 2. Requirements for C-RAM systems
Source: the author's own study.

[9] C. Kopp, *Counter – Rocket Artillery Mortar futures*, "Defence Today" 2010, no. 26.
[10] M. Katsamakas, *C – RAM systems beyond conventional ways of employment – utilizing the highly reactive capability in a Multi – Dimensional environment*, IAMD, 2022, p. 44–45.

A combination of active sensors – radar systems as well as the passive optoelectronic sensors can be used for target detection and tracking. These sensors scan the controlled area and track the appearing targets in the infrared spectrum. The difficulty consists in the fact that new attack means are very small, and therefore they exhibit minimal signals in all spectra. The figure below illustrates that the signatures of such targets have decreased thousands of times compared to classical ones.

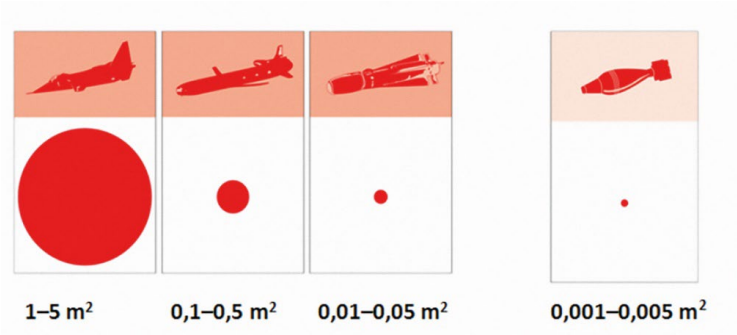

Fig. 3. Radar signatures of modern air attack means
Source: Armed Forces General Command.

The thermal or kinetic energy is used to destroy the attack means. Attempts to utilize kinetic energy – laser systems – have not been successful so far and require further development and work. Therefore, today, only means based on explosive or kinetic actions can be offered. Ammunition or rockets that have explosive effects on the target must be used in the required quantity to achieve effective hits. Equipping the attack means with guidance functions would be technically complex since they would need their own sensors and guidance systems to hit the target directly. Both methods can achieve the desired result – target destruction. However, considering the need to apply them on a large scale or utilize highly advanced technologies, they are not cheap.[11]

The simplest way to effectively engage a RAM-type target is to use ammunition that releases a specific number of sub-projectiles in front of the target. Due to their high kinetic energy, these sub-projectiles are capable of destroying the target with a single hit. To increase the probability of hitting the target, the number of sub-projectiles is multiplied either by increasing their quantity in a single warhead or by increasing the rate of fire at which these projectiles are launched by an automatic gun. Considering these new threats it should be noted that significant improvements in precision of impact are vital and necessary to implement in such systems.[12] The conditions and features of C-RAM systems presented above have been implemented in anti-aircraft systems successfully operating in the armies of other countries. Below I will present the characteristics of the C-RAM systems, two artillery systems and one missile system.

4. Skyshield

Skyshield air-defence system is a modular, light weight, short range air defense (SHORAD) system developed by the Swiss corporation Oerlikon Contraves (now a subsidiary of Rheinmetall of Germany). The successor to the Skyguard defense system, Skyshield is intended to rapidly acquire and destroy threatening aircraft and missiles, as well as to fulfill a C-RAM role. The complex is equipped with the

[11] Rheinmetall Defence, *Obrona bezpośrednia C – RAM Direct defence - CRAM*, "Nowa Technika Wojskowa" 2008, no. 7, p. 37.
[12] Ibidem, p. 37.

fire control system “Skyshield”, which is an upgraded version of JMS “Skyguard”, which is widely used in the armies of many countries. As a means of destruction are used remotely controlled paired 35 mm anti-aircraft guns GDF-005 company “Oerlikon Contraves” and anti-aircraft guided missiles ADATS which can use up to two surface-to-air missile 8-cell modules for an expanded air defense capability. The radar and optoelectronic equipment is placed separately from the control point, and this, according to the developers, significantly increases the survivability. The control station can be placed at a distance of up to 500 m from other elements of the complex. In the event of failure of the fire control system detection facilities, targets may be searched independently with the help of the opto-electronic modules available on each launcher.[13]

Skyshield C-RAM has an open interface and can be integrated into existing command systems. The operation of the Skyshield C-RAM system is highly automated, which means that it does not require the user's constant focus on operation to defend against classical threats and sudden sporadic RAM attacks, even when operating 24/7.[14]

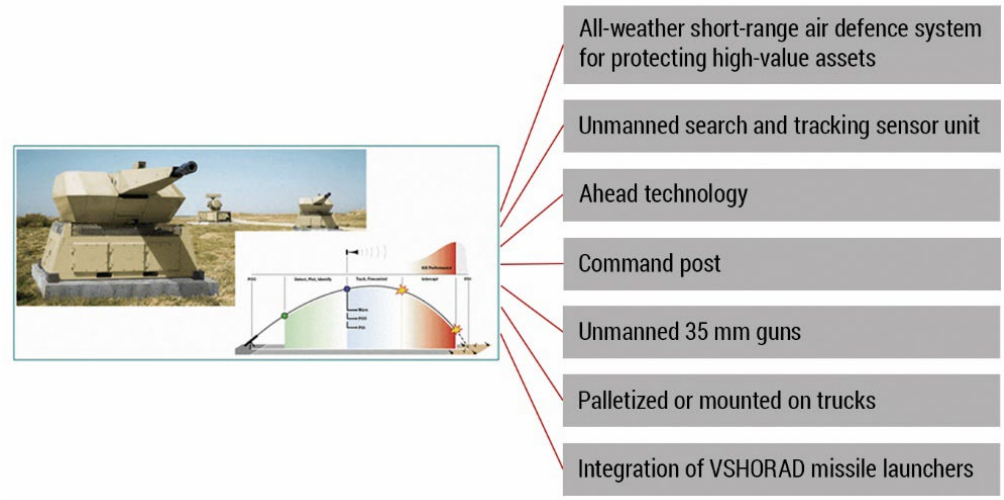

Fig. 4. Skysield C-RAM system
Source: the author's own study.

5. Phalanx LPWS (Land-Based Phalanx Weapon System)

Another C-RAM system is PHALANX. The basis of the system is the 20 mm M61 Vulcan Gatling gun autocannon, used by the United States military on various tactical aircraft since 1959, linked to fire control radar system for acquiring and tracking targets. The system enables automatic search, detection, tracking, engage, and confirmation of destruction using a computer-controlled radar system. Effective firing range 1.486 m Maximum firing range 5.500 m. Emplacement time for the complete system is approximately 45 minutes with a 6-man crew.[15]

As mentioned above, the basis of the system is an anti-aircraft six-barrel Gatling 20 mm gun coupled with two cooperating intercepting radars. The first radar provides the computer with data about the

[13] https://en.wikipedia.org/wiki/Skyshield [access: 10.02.2025].
[14] Rheinmetall Defence, *Obrona bezpośrednia…*, p. 38.
[15] https://en.wikipedia.org/wiki/Phalanx CIWS [access: 10.02.2025].

course, range, speed, and altitude of the targets. This information is analysed and verified to determine which of the tracked objects poses the greatest threat and should be engaged for destruction. Once the appropriate target is identified, the gun rotates towards it, passing the target tracking task to the second guidance radar. Depending on the system configuration, the gun is then automatically or manually fired. During firing, the CIWS radar system also tracks its own projectiles, adjusting the barrel position if necessary.[16]

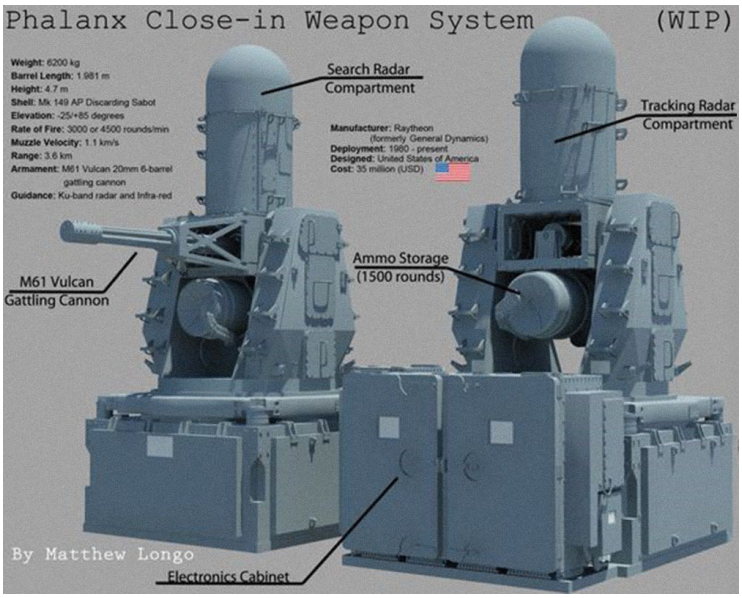

Fig. 5. Phalanx system
Source: ar.pinterest.com [access: 10.02.2025].

6. Iron Dome

It's the world's most-used system, intercepting more than 1.500 incoming targets with a success rate exceeding 90 percent since being fielded in 2011.[17]

The system is designed to counter short-range rockets and 155 mm artillery shells with a range of up to 70 kilometers (43 mi). According to its manufacturer, Iron Dome will operate day and night, under adverse weather conditions, and can respond to multiple threats simultaneously. Iron Dome detects, assesses and intercepts a variety of shorter-range targets such as rockets, artillery and mortars. Iron Dome has three central components:

- Detection & Tracking Radar.
- Battle Management & Weapon Control (BMC).

[16] A. Radomyski, *Obrona przeciwlotnicza…*, p. 98.
[17] Analysing the combat actions conducted by the Israeli forces since the beginning of 2006 in terms of casualties and infrastructure damage caused by the RAM usage, significant numerical disparities can be observed in this regard. In the case of the Second Lebanon War in 2006, when Israel did not yet have the Iron Dome system, approximately 3.600 RAM engagements resulted in 53 fatalities. However, eight years later, when Israel was already using the Iron Dome system, Hamas forces using 4.500 RAM means caused only six casualties; S. Maślanka, *Środki napadu powietrznego – doświadczenia z konfliktów zbrojnych ostatniej dekady*, LAW, Dęblin 2018.

- Missile Firing Unit: the unit launches the Tamir interceptor missile, A typical Iron Dome battery has 3–4 launchers (20 missiles per launcher).

The ability to protect an area of approximately 150 km^2.

The system's radar is referred to as EL/M-2084. It detects the rocket's launch and tracks its trajectory. The BMC calculates the impact point according to the reported data, and uses this information to determine whether the target constitutes a threat to a designated area. Only when that threat is determined, an interceptor missile is fired to destroy the incoming rocket before it reaches the predicted impact area.[18]

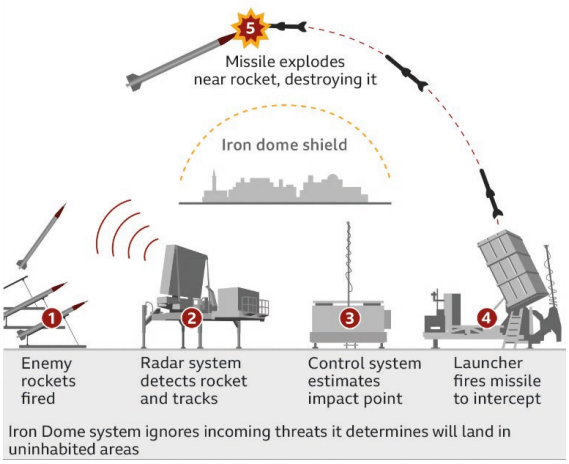

Fig. 6. How Israel Iron Dome defence system works
Source: https://www.bbc.com/news/world-middle-east-20385306 [access: 10.02.2025].

7. The Polish programs – C-RAM

Poland's air defence system is undergoing revolutionary changes through the successful implementation of the WISŁA and NAREW programs. The lowest layer of air defence, very short-range (SHORAD) defence, is being transformed by the introduction of the PIORUN short-range anti-aircraft missile system and the PILICA system. Efforts are also being made to achieve the capability to counter RAM means. However, compared to the examples mentioned above, there have not been such spectacular achievements in the field of C-RAM. By introducing the SOŁA Transportable Radar Surveillance Station (ZDPSR SOŁA) into the inventory of the Air Defence Forces, the station's capability to detect not only typical aerial objects but also unmanned aerial vehicles and mortar projectiles has been implemented.

The radar scans the searched space with several beams which are steered electronically in elevation plane and with a rotating antenna in the azimuth plane. The radar applies numerous ECCM techniques. Due to the requirement of operation within automated anti-aircraft systems, the radar provides very short time of information refreshment (1 sec). The radar operation is controlled from a local console or remotely at the distance up to 400 m.[19] The table below presents the capabilities of the ZDPSR SOŁA in detecting various means of attack depending on the effective detection surface.

[18] https://en.wikipedia.org/wiki/Iron_Dome [access: 10.02.2025].
[19] SOŁA Redeployable Radar, https://pitradwar.com [access: 10.02.2025].

Tab. 1. Detection range at various RCS targets

Detection range at various RCS targets	Range	Height
Fighters with RCS as this of F-16/MiG-29 class	1.5 km to 40 km	50 m to 8 km
Range Targets of RCS = 0.05 m^2	1.5 km to 16 km	50 m to 4 km
Helicopters	1.5 km to 8 km	50 m to 2 km
98 mm mortar rounds	1.5 km to 8 km	50 m to 5 km

Source: Own study based on materials PIT-RADWAR.

As a comprehensive response to the need for a very short-range air defence system (VSHORAD) capable of protecting troops against a wide range of air threats, including RAM-type threats, the SONA program is being implemented. The SONA programme covers a multitude of different domains, as it is to result in the development of a comprehensive, mobile air defence system for the land component, protecting the land forces from a myriad of air threats, including rocket, artillery, and mortar munitions in the C-RAM domain. The SONA programme, offering to base its proposal on the existing systems, such as the Poprad self-propelled SAM solution, OSU-35 warship armament system, the ZSU-23-4 MP Biała modernization package, and "Grom" and "Piorun" MANPADS (and a new missile derived from Piorun), deployable Soła and Bystra radars, and IFF suite. Know-how that had been gathered previously during the Loara and Pilica programmes would also be usable.

To meet these requirements, the SONA system has the following combat characteristics:

- High mobility.
- Combat survivability on the battlefield.
- Full autonomy and interoperability within the brigade air defence system.
- Very short reaction time to threats.
- Operational effectiveness in all atmospheric, environmental, and temporal conditions (day/night).
- Full automation of command and fire control functions.
- Capability to select the appropriate effector depending on the nature of the air target.

The SONA program includes the following subunit configuration:

- Command and Control Vehicles for data exchange, weapon management, and sensor utilization, as well as data processing and analysis.
- Mobile Early Warning Radars (MEWR) as the primary detectors of incoming threats.
- Self-Propelled Air Defence Artillery and Missile Systems (SPADAMS) providing air defense capabilities against aircraft, manoeuvring missiles, helicopters, airplanes, and including C-RAM functionalities.
- Self-Propelled Air Defence Laser Systems (SPADLS) and Self-Propelled Electromagnetic Weapon Systems (SPEWS) providing air defense through the use of non-kinetic means of neutralizing air attack means, particularly unmanned aerial objects.

The number of these elements in a battery module depends on the user's requirements and the assigned task. This flexible selection is possible thanks to the open architecture of the command and control system, the design of the proposed effector systems (SPADAMS, SPADLS and SPEWS), the sensors, and the applied communication and data transmission systems. This open architecture also ensures interoperability with other VSHORAD and SHORAD systems in the inventory or under development by the Polish Armed Forces. The PGZ's proposal also features an entirely new solution – self-propelled laser – and directed energy anti-aircraft systems, that would ensure air defence by using non-kinetic measures to act against air threats – primarily the unmanned platforms. The SONA system, in the proposed configuration by the Polish Armaments Group – PAG, is intended to be a specialized subunit for the protection of armoured and mechanized forces, capable of engaging air targets on the move or during short stops using three independently operating classes of effectors: missile-based,

artillery-based, and non-kinetic. This allows for the use of different types of ammunition in a single firing cycle, such as programmable and sub-calibre ammunition, with the simultaneous use of missiles. For the gun-based armament, PAG proposes equipping individual SPADAMS with 35 mm calibre artillery and multi-barrel Gatling gun systems, using 20 mm calibre ammunition. The missile effector will consist of various types of VSHORAD rockets. Apart from kinetic armaments the PGZ's proposal also features an entirely new solution – self-propelled laser – and directed energy anti-aircraft systems, that would ensure air defence by using non-kinetic measures to act against air threats – primarily the unmanned platforms.

The SONA system concept assumes continuous development and modification of the proposed solution, including the addition of additional effectors and technical observation systems. In practice, this means the gradual increase in the system's potential. The initiation of technical dialogue by the Armament Inspectorate (AI) indicates that the current Long-Term Modernization Plan (LTMP) until 2035 includes the necessary financial resources, and the implementation of this task is planned. The SONA system is expected to bring entirely new capabilities to the Polish Armed Forces.[20]

Fig. 7. Model of the anti-aircraft and artillery set on the K9 chassis
Source: PAG.

8. Summary

Developing the concept of achieving effective defense against RAM-type air threats requires analyzing and evaluating various factors to propose rational operational, organizational, and technical solutions. Achieving this capability is not an end in itself but makes up a part of broader efforts to enhance the military security of the state and strengthen military deterrence. The war experiences from the Russian-Ukrainian conflict indicate that the RAM can be a crucial means to gain the advantage by inflicting tangible losses on the enemy in personnel and the military equipment.[21] The intangible aspect of the RAM usage should not be overlooked as it wields a confirmed impact on the morale and psycho-physical state of the military and civilian personnel. The RAM threats, such as the rocket and mortar artillery, are constantly present in conflict zones where the use of "primitive" but highly effective means of attack, easy to transport and relatively simple to operate, allows for immediate and unexpected deployment, neutralizing quantitative and qualitative disparities. The RAM threats are current and still standing and are perceived as a new type of air threat, which, due to their "simplicity," are highly dangerous means of attack. This is confirmed by the mentioned C-RAM solutions applied in the armies of other countries.

[20] https_defence24.pl [access: 10.02.2025].
[21] D. Michalski, P. Bernat, *Air security of NATO's eastern flank: threats and challenges*, "Scientific Journal of the Military University of Land Forces" 2020, p. 52.

At the NATO level, in the face of the aforementioned threats, their increase and implications in various theaters of operation, a working group called DAMA (Defense Against Mortar Attacks) was established at the end of 2004. It consists of representatives from the NATO member states with the aim of developing effective and cost-efficient systems that provide a sense of security for troops and civilians through the development of C-RAM systems. Proper initiatives are also being taken in the development of the C-RAM system in the Polish Army. The SONA program, in its proposed architecture, emulates capabilities already implemented in other existing C-RAM systems while introducing new solutions, such as non-kinetic effectors. Today, these may still be perceived as futuristic, but in the near future they will become essential components of the anti-aircraft/air defence systems.

The assertion that the RAM threats constitute either old or new challenges for the Air Defense Forces remains relevant. Regardless of how the thesis is presented, it continues to pose a challenge for the Air Defense. The development of C-RAM systems is a response to the technological advancements of the RAM. We should not be "reassured" by the fact that the RAM threats may not be considered the most significant from the perspective of the Polish Air Defense system. This threat is entirely real and has been proven in various combat operations. The war experiences gained from them, along with the results achieved by the teams at the NATO level, should serve as fuel for intensive work by specialists from the Polish Army and the defense industry in finding a solution that would meet the NATO Forces' required capabilities.

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