ACTIVE PROTECTION SYSTEMS OF MODERN COMBAT VEHICLES

ALIOTH FOUNDATION

TABLE OF CONTENTS

ACTIVE PROTECTION SYSTEMS OF MODERN COMBAT VEHICLES

Poland is intensively modernizing its armed forces, investing billions of zlotys in the purchase of modern armored vehicles. However, the real challenge is not only to purchase a large number of vehicles, but first and foremost to ensure their survivability on the modern battlefield, which is becoming increasingly demanding and saturated with advanced anti-tank means. It is in this context that Active Protection System (APS) appears as a key solution that could revolutionize the way we think about protecting both machines and crews, increasing the chances of mission accomplishment under combat conditions.

Evidence of the effectiveness of APS is hard to dispute. During recent operations in Gaza, Israeli vehicles equipped with these systems repeatedly proved their superiority, intercepting numerous means of destruction that would otherwise have destroyed equipment and endangered the lives of crews. Meanwhile, images from Ukraine, depicting battlefields strewn with the wreckage of tanks and armored personnel carriers, vividly demonstrate the dire consequences that can result from a lack of adequate protective measures. These two conflicts, although so different, clearly demonstrate that vehicle survival and crew survival in a clash with modern means of destruction is one of the most important determinants of combat effectiveness today.

This report is not only a technical and comparative analysis of active protection systems, but is first and foremost a contribution to the debate on building effective ground forces. The implementation of APS in the Polish Army is not only a matter of protecting the lives of our soldiers – which in itself is already a key argument – but also a rational use of public funds because a properly protected smaller number of vehicles can be more combat effective than a larger number, which, however, are relatively easy to destroy.

Alioth Foundation, through this report, wants to be part of the national debate on building a security environment that will become the foundation for Poland's future development.

The key here is not only to understand the challenges we face, but also to recognize that every decision – from the choice of technology to its implementation **– has a real impact on the security of the country, families and society as a whole.**

THE IDEA OF MULTI-LAYERED PROTECTION FOR THE COMBAT VEHICLE

Traditionally, the efficiency of an armored vehicle is considered with reference to the so-called armored triangle, **whose "vertices" are formed by firepower, mobility and armor.** Excessive displacement in any of the directions results in a vehicle that is either successful, but with specific parameters (e.g., a lightly armed and armored fast reconnaissance vehicle or a heavily armored and armed but slow heavy tank) or unsuccessful. In fact, however, the "top" regarding armor has been a bit more elaborate since the dawn of the history of armored vehicles, and the term "protection" or "security" would be more apt for it.

The efficiency of an armored vehicle is considered with reference to the so-called armored triangle, whose "vertices" are formed by **firepower, mobility and armor.**

It is nowadays accepted that an armored vehicle should be protected according to the principle "**don't be detected – don't be hit – don't be penetrated – survive a hit**." This means that in practice, the "armor" or rather "protection" of a vehicle consists of many "layers". The outermost is formed by solutions that reduce the risk of detection of the vehicle. This is primarily camouflage – which also limits the possibility of detection by radar or thermal imaging means – and design solutions that limit vehicle emissions (especially thermal and acoustic).

It is the active protection measures and the possibly small silhouette of the vehicle that reduce the risk of being hit. The former are designed to reduce or even eliminate the risk of hitting the vehicle. Underneath them, protection is provided by the actual armor, nowadays usually modular and multilayered. Reactive elements are often used. In the event of armor penetration, the vehicle can be protected by a variety of solutions to reduce the effects of armor penetration. These include isolated ammunition magazines, automatic fire suppression systems or shrapnel liners. The combination of all the aforementioned solutions is intended to ensure that the chances of survival of both the vehicle itself and the crew are maximized.

An armored vehicle should be protected according to the principle:

DON'T BE **DETECTED**

DON'T BE **HIT**

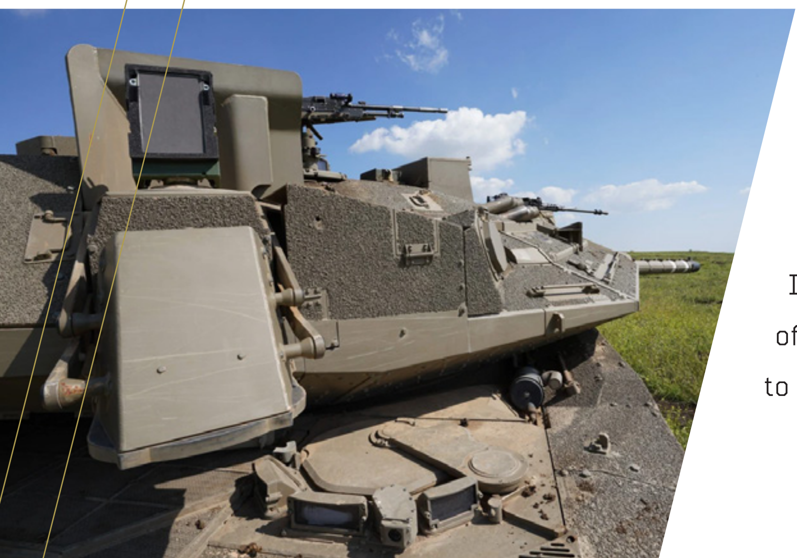
DON'T BE **PENETRATED**

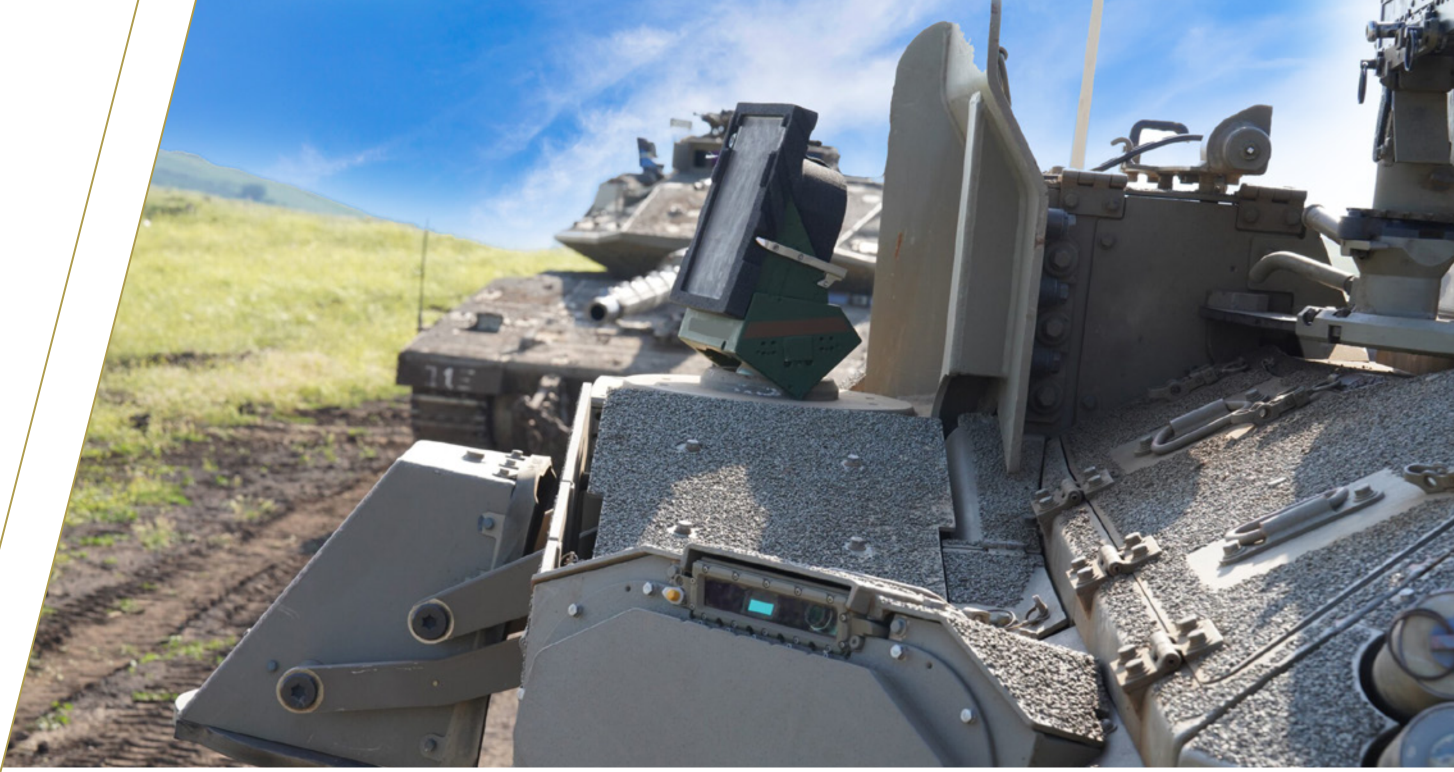
SURVIVE A HIT.

ACTIVE PROTECTION SYSTEM – GENERAL DESIGN

Active protection systems always have the same general scheme of construction. They consist of detectors, a control unit and effectors. Detectors are used to observe the environment and detect the threat. They can be of different types and classes: electro-optical (day and night), radar (including active electronic scanning, AESA), UV, LIDAR, radio or laser detectors.

Sometimes they are used for observation of the vehicle's surroundings by the crew (cooperation with an omnidirectional observation system). Active vehicle protection systems often use several types of detectors, so that one is used to observe the surroundings and detect the threat (missile), while another is used to determine its exact position. Typically, the detectors provide omnidirectional observation. The control unit is the "brain" of the APS. It is a fire control system used to process information from sensors and transmit the obtained information to the crew and effectors. Mostly, it is equipped with a kind of human-machine interface, where the soldier can select the system's mode of operation, while the system informs of the impending threat. In the latest systems, the control unit also communicates with analogous systems mounted on other vehicles via the Battle Management System (BMS), so that two or more vehicles can cover each other with their active protection systems. The final component is the effector. Its purpose is to interact with the enemy's center of gravity or observation and targeting systems so as to minimize the risk of a vehicle being hit.





CLASSIFICATION OF ACTIVE PROTECTION SYSTEMS

Active protection systems are divided into "soft" (soft-kill) and "hard" (hard-kill) systems. The distinguishing factor in this case is the type of effector and the resulting method of impact on the enemy. Soft-kill systems are designed to reduce the risk of hitting a vehicle by affecting the observation and targeting systems of enemy vehicles and launchers, as well as the guidance systems of anti-tank missiles. Their effectors are mostly aerosol and smoke grenade launchers (nowadays usually so-called multispectral, i.e. camouflage in different bands: daylight, thermal imaging, radar band), which are intended to hinder the guidance of armament or guided missile on a protected vehicle. More recently, electromagnetic effectors (in the form of a small electromagnetic grenade fired outside the vehicle in the hope of damaging the chips of guided missiles) and radio-electronic effectors (combat drones on a principle similar to jamming devices) are also emerging. Hard-kill class systems, on the other hand, have effectors capable of damaging or even destroying anti-tank missiles. Mostly they take the form of a grenade fired at a certain distance from the vehicle to intercept and paralyze an anti-tank missile. Less common are effectors in the form of explosive modules attached directly to the vehicle, such as on a frame offset slightly from the chassis or turret.

In a sense, this is an intermediate solution between reactive armor and APS. Some of today's active protection systems have "soft" and "hard" effectors, so they are called "integrated" systems.

ALIOTH FOUNDATION

EFFECTIVENESS OF ACTIVE PROTECTION SYSTEMS

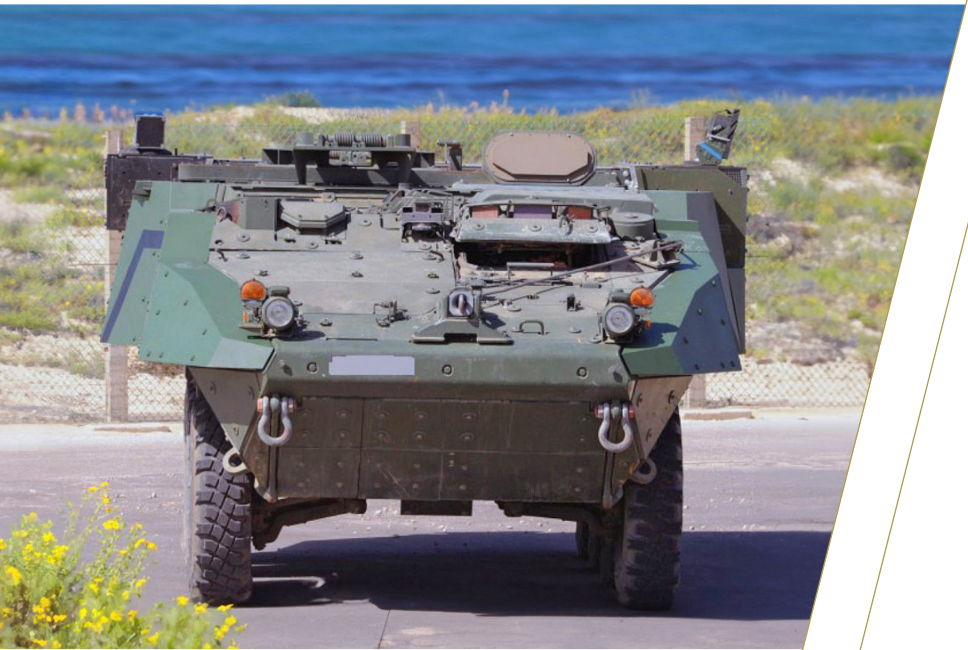
The effectiveness of hard-kill class active protection systems is limited. All systems deployed in service protect targets only against relatively slow (up to a few hundred m/s) projectiles of anti-tank grenade launchers, recoilless guns and anti-tank guided missiles. Tank sub-caliber projectiles (velocity of 1,500 m/s or more) are therefore too fast and can only be countered by some active protection systems and only to a limited extent (e.g., when fired from a long distance, the projectile manages to lose some of its speed). Many also protect the vehicle in a limited range of angles, especially vertically. Details are usually not known, as manufacturers are reluctant to share test information.

However, it is assumed that active vehicle protection systems protect objects with high effectiveness, at least against slower projectiles. In particular, laser beam guided missiles without a top-attack mode (e.g. Russian Kornet) and unguided missiles are vulnerable to countermeasures from APS. The number of effectors (APS munitions) is usually limited and it protects the vehicle only as long as there are enough counter-missiles. Also, only a few APS' can combat drones. The same is true of soft-kill class systems. They have a limited number of smoke grenades, in addition, they can often operate only in a limited spatial range (e.g. rear-facing smoke grenade launchers are usually lacking). Their effectiveness against aerial surveillance means is limited for the same reason. Another limitation is faced by jamming devices acting as effectors. Typically, the length range over which they operate at any given time is limited. Nevertheless, in view of the high price of modern armored vehicles and the need to protect the lives of the crew, it is recognized that an additional layer to protect a valuable and mission-critical vehicle is desirable.

The number of effectors (APS munitions) is usually limited and it protects the vehicle only as long as there are enough counter-missiles.

CRITICISM

Despite their advantages, APSs are subject to criticism due to two reasons. The first argument relates to technical issues. The APS is an additional energy-demanding device that increases vehicle dimensions and requires carefully designed installation, increases vehicle weight by hundreds of kilograms (sometimes more if it is necessary to balance the turret, for example), and facilitates vehicle detection by generating electromagnetic and radar emissions. Each of these problems can be solved, although it requires careful engineering.



OVERVIEW OF SELECTED DESIGNS

Many countries have developed active vehicle protection systems in the past or today. Not all of them have found their way into line service. The following list is incomplete, but allows one to trace trends through selected examples.

The Soviet Union was one of the forerunners in the production of active vehicle protection systems and was the first to deploy such a device in its Armed Forces.

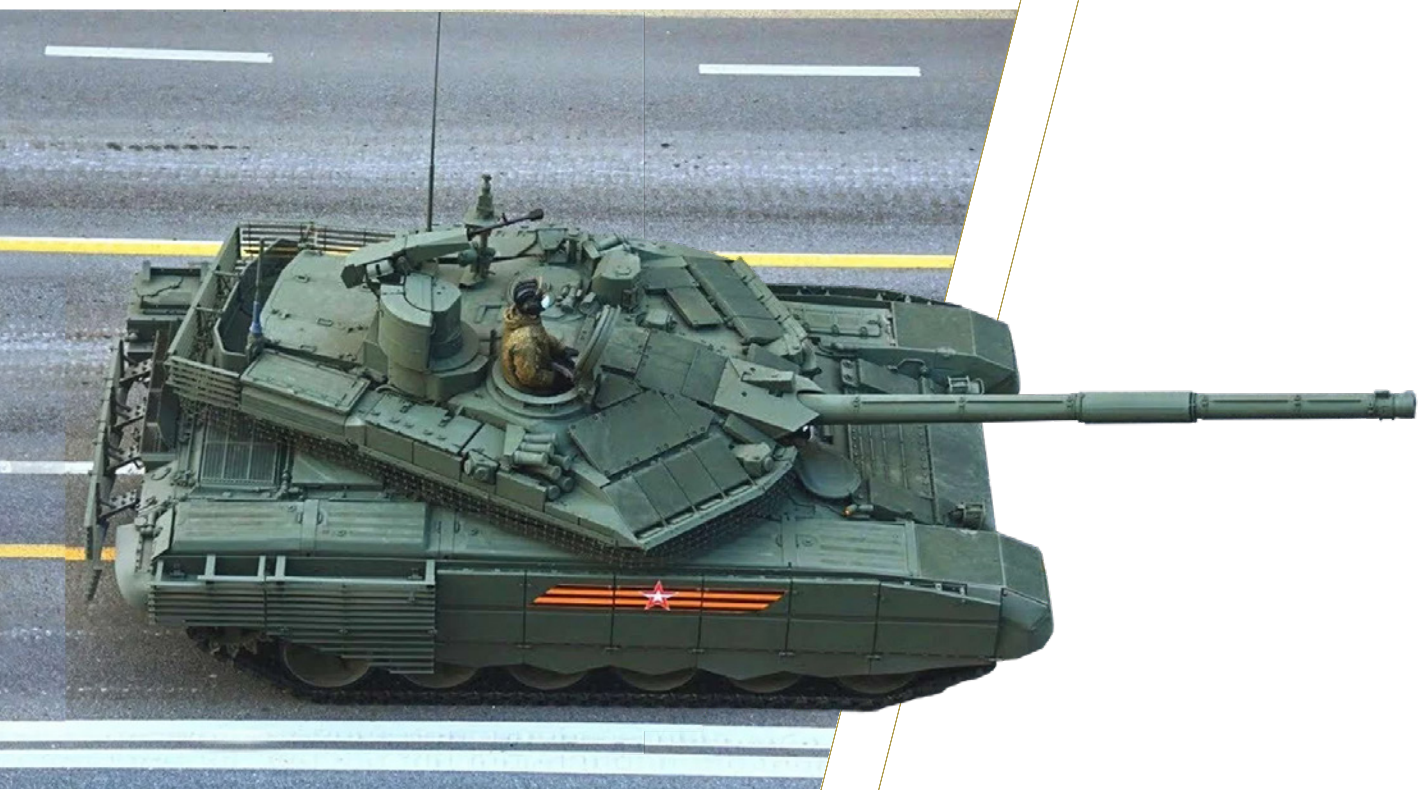
RUSSIAN FEDERATION

The Soviet Union was one of the forerunners in the production of active vehicle protection systems and was the first to deploy such a device in its Armed Forces. This was the 1030M-01 Drozd Complex, mounted in the 1980s on T-55A tanks (new designation: T-55AD). The system was considered successful, but was withdrawn from service along with the T-55 under the CFE Treaty. It was never used in combat. It is known that it was also integrated into the T-80U tank (T-80UM-2).

A much more important system was the Arena, also originating from the Soviet era. The system was accepted into service in 1993, but was never serialized. The role of the detector was played by radar stations, while the effectors were fragmentation charges, fired from single launchers (a set of 22-26 pieces was enough to protect the basic tank in the 270-360° range). The system's design makes it turret-mounted, though so far only for testing. The fire control system responds only to targets up to 50 m from the tank, and does not respond to specific disturbances identified as birds, small-caliber shells, etc. The system's zone of fire does not exceed 30 m. The Arena is capable of countering projectiles with a velocity not exceeding 700 m/s. The weight of the system, depending on the configuration, reaches 1100-1300 kg. Over time, newer variants were developed: the export Arena-E and Arena-M. The system has been integrated into tanks of the T-72 (probably only T-72B3 and newer), T-80 (U, BWM), T-90A, T-90M families, as well as the BMPT Terminator support vehicle and the BMP-3 infantry fighting vehicle. From time to time there are announcements of the introduction of Arena into large-scale service, but so far this has not happened.

Afghanit is Russia's latest active vehicle protection system. It is mounted on armored vehicles of the Armata, Bumierang, and Kurganets types. Due to delays in the production of these, it has not entered large-scale service.

The Arena is capable of countering projectiles with a velocity not exceeding 700 m/s.



ISRAEL

Two main types of active vehicle protection systems have been developed in Israel – Rafael's Trophy and Elbit's Iron Fist. The former was developed in response to the experience of the Israel Defense Forces (IDF) from the Second Lebanon War (2006; although it must be said that the first work was carried out back in the 1990s), when Israeli troops suffered quite severe losses. Merkava tanks were hit with anti-tank guided missiles 55 times, including 25 armor penetrations, and five tanks were destroyed. The bad mood was compounded by the fact that effective hits were obtained by the enemy using old 9M131 Metys-M and 9M111 Fagot missiles. Thus, a device was expected to emerge that would intercept the most popular missiles used by a potential adversary (Hamas, Hezbollah), i.e. guided anti-tank missiles and anti-tank grenade launchers. The target version of the Trophy was certified in 2010, and the first tanks adapted to its assembly – the Merkava Mk IVM – began production back in 2009. Trophy's design is typical of systems in this class. Four radar sensors with AESA IAI-EltaELM-2133 antennas serve as detectors (according to some sources, newer variants also use optoelectronic sensors, possibly with data from an omnidirectional observation system).

The detection and control unit can be integrated with soft-kill effectors, but the Trophy's primary function is hard-kill.

The control unit is capable of classifying the type of projectile. The detection and control unit can be integrated with soft-kill effectors, but the Trophy's primary function is hard-kill. In the hard--kill version, effectors are fired from ejector-equipped automated anti-missile magazines (each launcher is a separate fire channel, so the number of launchers determines the maximum number of anti-missiles to be fought). The anti-missile fights the target with 30-45 explosively formed MEFP penetrators with an initial velocity of almost 2000 m/s. The reloading time is 2-3 s and the range of fire is 2-25 m, while the stock of effectors is 3-5 pcs. The anti-missiles can effectively combat lower velocity anti-tank munitions. In 2023, the ability to combat drones was confirmed with the example of a relatively large apparent target attacking from the upper hemisphere.

Trophy is capable of homing a tank's armament automatically to a threat. In newer varieties, Trophy can transmit information via the BMS to Trophy systems mounted on other vehicles, so that the vehicles can cover each other. There are other versions of the Trophy: the medium MV with its weight reduced by almost half and smaller dimensions), the medium VPS, which is slightly heavier than the MV of up to 95%, and the light LV, which is actually a completely different curtain-class system, i.e. with a frame-based design mounted around the vehicle and with effectors in the form of explosive panels.

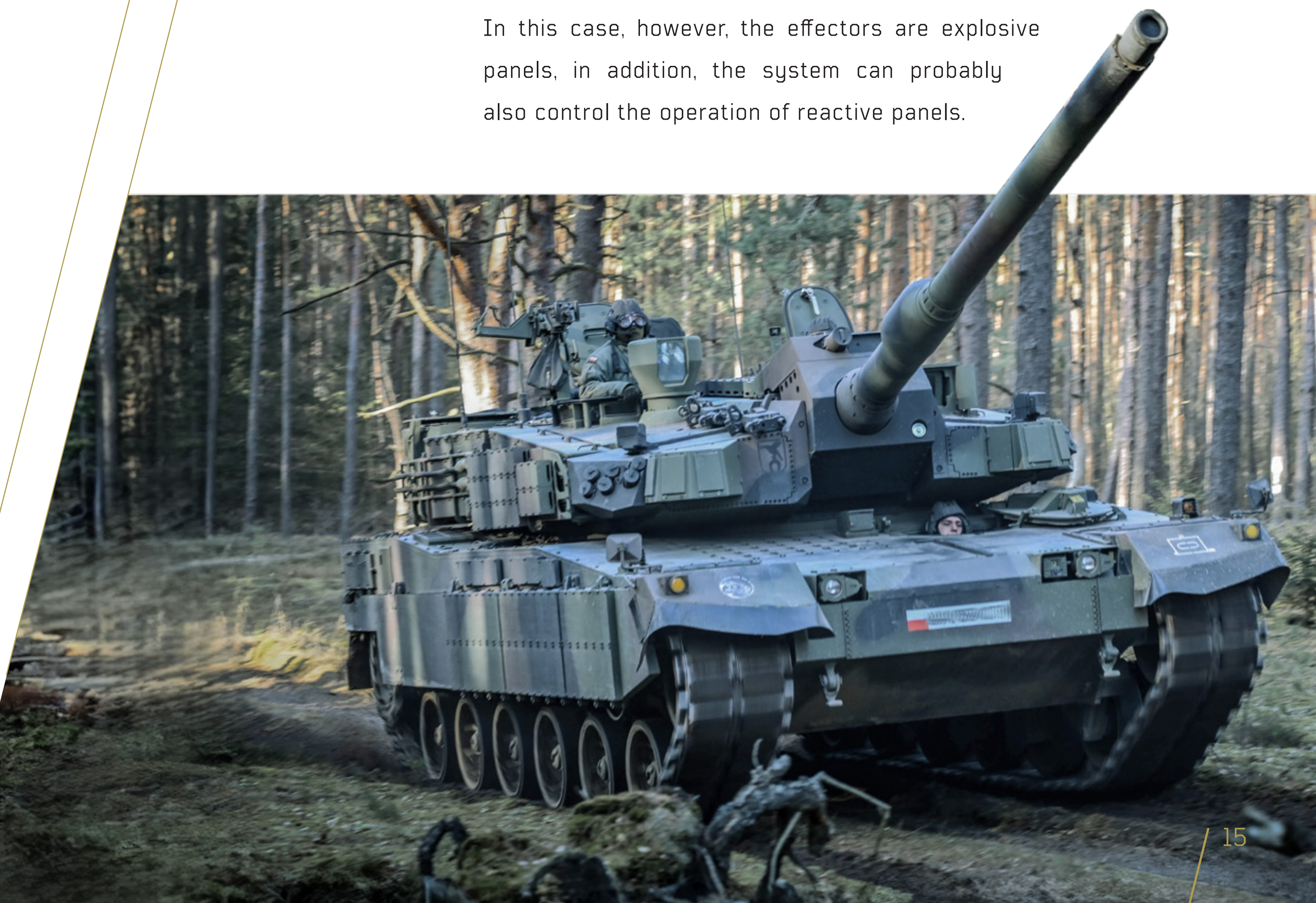
The second Israeli system is the Elbit Iron Fist. Only slightly younger than Trophy, it did not enter service in the Israel Defense Forces – contrary to plans. It was supposed to provide protection for the Namer heavy armored personnel carrier, but the IDF abandoned it. The overall design of the system is typical. AESA radar sensors (optionally supplemented by optoelectronic sensors or infrared detectors) provide situational awareness to the system. The control unit can classify an incoming target. Effectors are missiles fired by two mobile launchers, holding two anti-missiles each. There is no way to reload the anti-missiles other than manually after leaving the vehicle. Iron Fist is supposed to be able to combat slow (up to 1,400 m/s at the time of interception) sub-caliber missiles.

In 2023, the ability to combat drones was confirmed with the example of a relatively large apparent target attacking from the upper hemisphere.

ALIOTH FOUNDATION

EXAMPLES OF APSS FROM OTHER COUNTRIES

Various active hard-kill vehicle protection systems have been developed in many countries in the 20th and 21st centuries. These trials mostly ended with the development of demonstration devices or prototypes that did not enter service. Among the best known are the Ukrainian Curtain system, the German StrtikeShield system or the Chinese GL5. The former is a development version of the still Soviet-era Drozd system, developed by Mikrotek. It consists of autonomous modules, each of which is a separate active protection system with 1 or 2 effectors in the form of explosive tubes. An interesting capability is the optional use of a drone combat module, it must then be mounted on the vehicle's ceiling. The Rheinmetall StrikeShield is similarly designed. As for autonomy, again, each module can operate independently, as it houses the entire APS. In this case, however, the effectors are explosive panels, in addition, the system can probably also control the operation of reactive panels.



The NORINCO GL5, on the other hand, is a system built in a more classical way, with several radar detectors operating together and two turrets with fragmentation missile launchers. In Poland, work on the hard-kill class APS was also carried out, but despite some successes (successful demonstrations of the device Integrated Vehicle Active Protection System – "Aktywna" and the development of the so-called "smart anti-missile"), further work on already tested solutions was abandoned. The reason was the publication in 2020 of new requirements for systems of this class, which, however, none of the existing APSs met at the time (in terms of protection against tank missiles).

> Thus, the only Polish APS is the soft-kill SSP-1 Obra-3 class device and its development versions, manufactured by PGZ S.A.

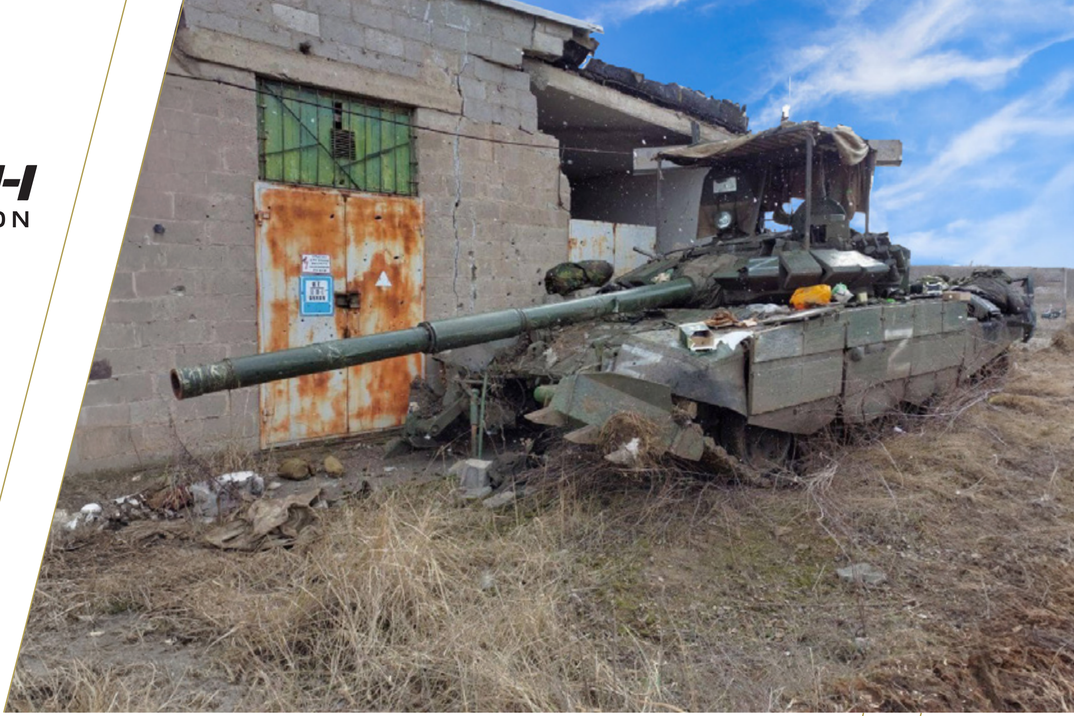
DISSEMINATION

Relatively few hard-kill APS systems remain in service. Few have also been procured. Many more systems have been integrated with various platforms for testing purposes (e.g., the Rafael Trophy LV has been integrated with the MRAP M-ATV or the Stryker, but has not been ordered for those platforms). Israel's Rafael Trophy system is the most widespread. In its HV version, it equips several types of basic tanks. In addition to two versions of the Merkava tank and Namer family vehicles, it is or will be used on several types of basic tanks. The US Army has already bought several hundred sets of the system for M1A2 SEPv3 tanks (integration with the SEPv2 version has also been carried out), Germany recently received the first Leopard 2A7A1 tank retrofitted with the Trophy system (a dozen units have been ordered; in addition, all A8 version Leopards 2 will be equipped with the Trophy HV system), and the UK has ordered 148 upgraded Challenger 3 tanks with Trophy HV. It is also integrated with the K2 tank – so it is integrated with the three types of basic tanks that the Polish Land Forces use or are expected to use – and in view of the failure of work on the indigenous K-APS system, the Republic of Korea is working on a correlated version of Trophy, the K-APS 2 system. In the Korean version, it additionally works with a jammer to combat drones. Trophy is also being offered for several "tanks of the future."

LESSONS LEARNED

Information on the combat use of active vehicle protection systems is emerging in the discourse of conflicts in the Middle East. The reason is mundane: only the Israel Defense Forces have so far used vehicles with active vehicle protection systems in large-scale combat. So far, only the use of vehicles equipped with the Trophy system has been confirmed, especially since from the Israeli-Palestinian conflict in 2014 and beyond, until the Palestinian attack on civilian targets in October 2023, the Israel Defense Forces command sought to have only or almost only vehicles equipped with the system take part in combat actions. According to information provided by the manufacturer in September 2023, 1,900 sets of Trophy had been handed over to users (mainly IDF and US Army) by that date. At that time, the total operational time exceeded 1,900 hours (presumably, this refers to use in combat conditions only; as early as late 2018 and early 2019, the system's total operating hours were expected to exceed 0.5 million hours, during which 4,000 interceptions were to occur during testing and combat). For the first time, Trophy protected the crew of a Merkava Mk IVM tank under combat conditions on March 1, 2011, intercepting a missile from an RPG-7. 19 days later, the ability to determine the trajectory of a missile was confirmed in practice (a missile that was expected to fly nearby was detected and missed). During the fighting in Gaza in 2014, the Trophy system intercepted no less than 15 means of destruction (that much was confirmed with photographic and video footage). There is also known footage from operations in Gaza in 2023-24, confirming Trophy's effectiveness (including for countering missiles fired from a distance of less than 30 meters). Some tanks equipped with the Trophy system were lost during the fighting, including the Merkava Mk IV Barak (on a heavy improvised explosive charge, so the armor could not protect it) and several Mk IVM vehicles. The latter were equipped with an older version of the system, which did not protect the ceiling of the vehicle, so the enemy managed to drop improvised bombs built with PG-7W warheads and mortar grenades on the tanks. According to the online edition of the Haaretz

During the fighting in Gaza in 2014, the Trophy system intercepted no less than 15 means of destruction.



newspaper, Trophies were said to have intercepted up to "thousands" of missiles during the fighting in the Gaza Strip, although this may be an exaggerated figure. Nonetheless, the system has demonstrated a high level of effectiveness in battles, and the information gathered will be used to modernize it (such as introducing drone combat capabilities) and to develop other Israeli army systems.

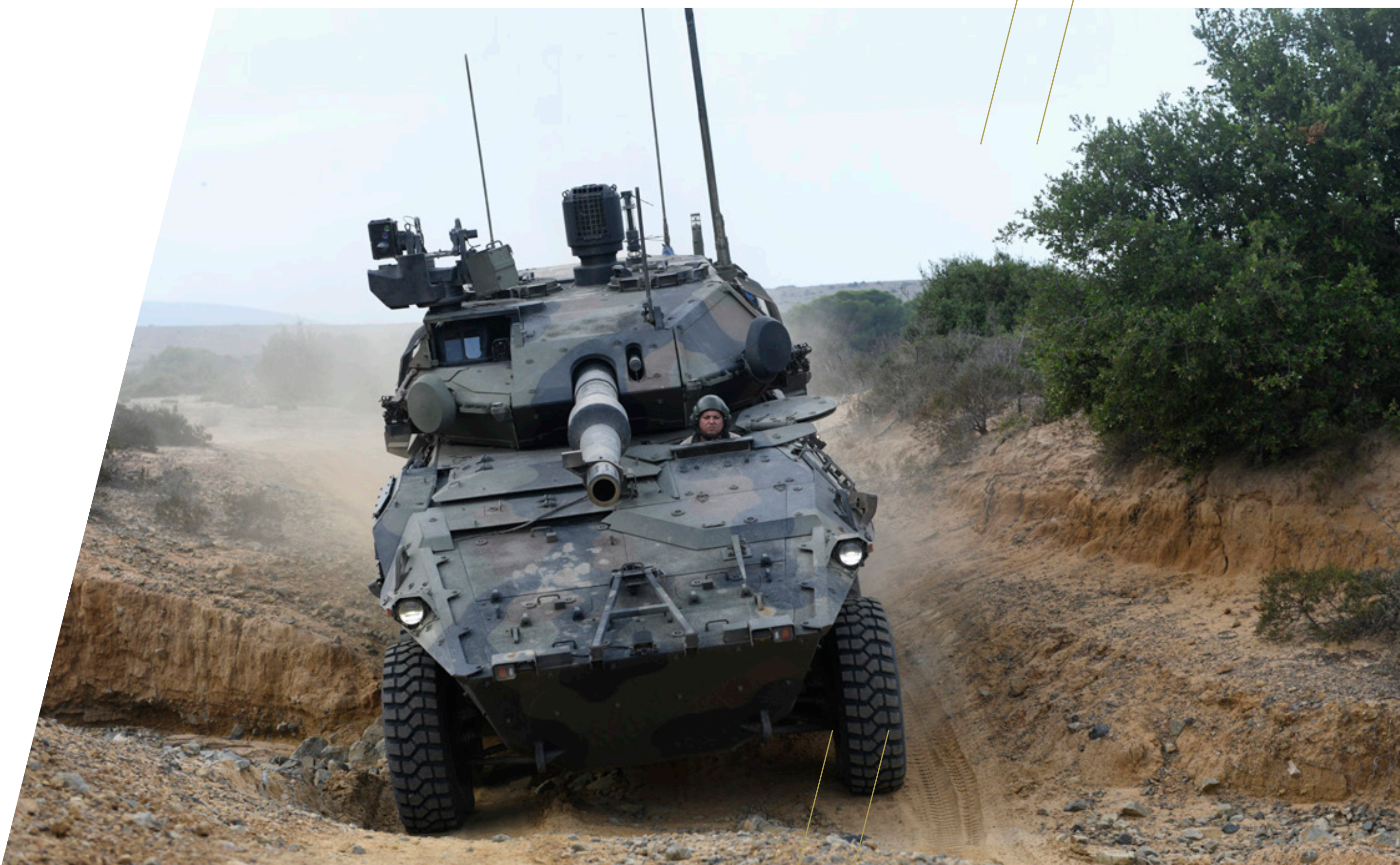
There is no information on the use of active protection systems on the front lines of the Russian-Ukrainian war. The Ukrainian side apparently does not use the Zasłon systems (although they were supposed to be mounted on some T-64BWs before 2014), while the Russians do not use the Arena and Afganit systems. The only reports, as mentioned above, are very vague and singular. Given the massive losses in armored vehicles by modern standards (so-called "white intelligence" data confirms the loss of several thousand armored vehicles, including several thousand tanks, on both sides), surely the massive use of active vehicle protection systems would lead to reduced losses inflicted by infantry anti-tank weapons or vehicle-mounted anti-tank guided missiles. The Ukrainian Curtain could also be effective against drones (if a vertically placed module is installed on the ceiling), against which both sides currently use various forms of secondary armor (similar ones, by the way, appeared in 2023/24 on IDF vehicles not equipped with an active protection system and equipped with older versions of the Trophy).

ALIOTH FOUNDATION

SUMMARY

Active vehicle protection systems are still considered an expensive solution, hence some armies are dragging their feet on acquiring them. However, the price of an APS cannot be considered in isolation from the overall cost of purchases and combat vehicle survivability. After all, battlefield survivability is of key importance – and this is definitely higher for vehicles using APS. In practice, this means that fewer vehicles (e.g., tanks) can be purchased that, by being equipped with the appropriate APS, will be able to replace a much larger number of vehicles without these systems, which will be eliminated from combat much more quickly.

In fact, in view of the prevalence of dedicated and improvised anti-tank means on the battlefield (FPV drones, circulating ammunition, artillery ammunition and sub-munition, anti-tank guided missiles,



anti-tank grenade launchers, tank shells), despite the limitation of the effectiveness of most types of APSs to combat targets with velocities in the hundreds of m/s, the use of such devices brilliantly increases vehicle and crew survival.

In direct terms, APS costing several hundred thousand USD protects a vehicle worth even a dozen or so million USD, its 3-5-person crew and (in the case of IFVs, etc.) up to 10 troops. In indirect terms, introducing another device to increase the survivability of a combat vehicle on an increasingly complex battlefield radically increases the chances of carrying out the mission, because the combat group carrying it out will suffer losses more slowly than one that does not have vehicles with APS. It is therefore not surprising that the armed forces of more and more countries are ordering such systems for their vehicles, not only for main battle tanks, but also for cheaper and simpler infantry fighting vehicles or wheeled armoured personnel carriers. The Armed Forces of the Republic of Poland currently do not have any active hard-kill vehicle protection system. In the past, Polish industry made more or less successful attempts to develop this class of system, which was not met with understanding by decision-makers. A similar fate befell the offers of several foreign manufacturers. Meanwhile, the requirements for new generation armoured vehicles (IFV Borsuk, wheeled APC with ZSSW-30 turret, the would-be light tank Gepard, the Wilk MBT) included the requirement to integrate APS. More than a decade has passed since the publication of the requirements, some new generation vehicles have managed to be created, and in the meantime two new types of main battle tanks have entered service, both optionally equipped with APS. Meanwhile, protection against modern threats still does not differ in general from the idea that guided the creators of the first tank. There is still nothing in front of the armour that would limit the risk of hitting a combat vehicle, and even a seemingly ineffective hit can lead to damage to some equipment elements (e.g. communication means, optoelectronics) and to limit the vehicle's efficiency to such an extent that it is unable to complete the task.

How this can affect the combat efficiency of the Land Forces on a wider scale, and thus the entire national defence system – this does not need to be explained. APS solutions appear to provide vehicles with better protection while at the same time making public money more efficient.

PHOTOGRAPHS

Page	Source
1	Polish MOD
2	CIO
7	Rafael Advanced Defense Systems
8	Rafael Advanced Defense Systems
10 (left)	Leonardo DRS
10 (right)	Wikipedia
12	Sputnik
13	Wikipedia
15	Polish MOD (w wersji PL: MON)
18	Leonardo DRS
19	Wikipedia

Publication was financed with funds from the National Freedom Institute - Center for Civil Society Development.

PUBLIC BENEFIT COMMITTEE

Financed by the National Institute of Freedom – Center for Civil Society Development as part of The Government Programme for Civil Society Organisations Development for 2018-2030 CSODev

Government Programme for Civil Society Organisations Development for 2018-2030 CSODev

ALIOTH FOUNDATION

foundation.alioth.group