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## LEOPARD 2PL – POLISH UPGRADE

**Abstract.** The article describes the currently implemented project of upgrading the LEOPARD 2A4 tanks to the LEOPARD 2PL version. Initial design phases, technical analysis and the final implementation option are presented. The impact of the project on the acquisition of new competencies by the companies of the PGZ S.A. group is shown, especially the unique qualifications of Zakłady Mechaniczne "BUMAR-ŁABĘDY" S.A. Technical and marketing approach to the upgrade and offer preparation process are taken into account.

**Keywords:** upgrade, LEOPARD 2PL, BUMAR - ŁABĘDY S.A.

### 1. INTRODUCTION

The subject of the article is the description and evaluation of the scope of upgrade of LEOPARD 2A4 tanks in service with the Polish Army. The scope of the upgrade is compared with upgrade offers from foreign providers, and the design solutions are confronted with domestic solutions. The LEOPARD 2A4 tanks were sent to the 11th Lubuska Armoured Cavalry Division as part of two deliveries, between August 2002 and June 2003 (first batch of 128 LEOPARD 2A4 tanks) and between May 2014 and November 2015 (second batch of 105 LEOPARD 2A5 tanks and 14 LEOPARD 2A4 tanks). Three years after receiving the first batch of tanks, the domestic industry began analytical and conceptual work on the modernization of LEOPARD tanks. The first user experience, who previously used PT-91 tanks, and then the LEOPARD tanks acquired from the Bundeswehr, forged the soldiers' expectations towards the new tank.

The experience of the Polish armaments sector in the development of tank structures, among them the PT-91 and the PT-91M which originated from the T-72 tank, qualified the Polish industry as a competent integrator of the modernization package. An obstacle to full polonization of the project, however, have become the provisions of the tank transfer agreement, as well as the accession of Poland to the LeOBEN group, obliging to cooperate with the licensed representative of the rights to the tank documentation. There are two large corporations in Germany that possess the rights to design documentation: Rheinmetall Defence and Krauss-Maffei-Wegmann. The article discusses what these corporations offer in the field of modernization, the options and configuration of tanks offered to foreign clients, as well as the Polish upgrade projects. Fig. 1 shows the basic version of the LEOPARD 2A4 tank.



**Fig. 1. LEOPARD 2A4 tank after inspection and repairs**  
(photo by ZM "BUMAR-LABĘDY" S.A.)

## 2. ANALYSIS OF POSSIBILITIES AND PROPOSALS FOR AREAS TO BE MODERNIZED

The authors have analyzed the tactical and technical parameters of the systems of the LEOPARD 2A4 tank in order to indicate areas of potential modernization. The results are listed in Table 1.

**Table 1. LEOPARD 2A4 tank equipment in view of modern generation 3+ tank requirements**

<b>Equipment requirements of 3rd generation (and more recent) combat vehicle standards:</b>	<b>LEOPARD 2A4 equipment in given area:</b>
Composite and/or multi-layered armour [5].	+
Additional armour protecting the sides of the hull and turret, including the drive compartment.	-
No ammunition in crew compartment.	-
Tank gun adapted for firing high-power kinetic energy (muzzle energy > 10MJ) and programmable ammunition.	-
Drive in the form of an integrated system.	+
2-axial gun stabilization, with line of sight follow up system.	+
Independently stabilized 2-axial aiming devices of the gunner and commander.	+
Hunter-Killer operation mode.	+
Automatic gun loading system.	-
Chassis/turret fire suppression system.	+ / -
Chassis/turret explosion protection system.	- / -
Additional power generator / air conditioning.	- / -
Systems: Self-concealment, Soft-Kill and/or Hard-Kill [6].	- / - / -
Passive night vision systems, 3rd generation thermovision systems, imaging cameras for the driver.	+ / - / -

The list in Table 1 helps indicate areas of potential upgrade.. However, considering the construction of the main elements of the tank, such as the chassis and turret, changes in the areas of automatic gun loading and moving ammunition out of the crew compartment are impossible to implement, therefore they will not be considered further in this article.

In areas related to modernization of the gun, fire and explosion protection systems, Polish companies are not able to provide new solutions, which is why the offers of foreign companies are discussed here. In the case of Polish solutions, data from completed projects are presented.

### 2.1. Modernization supported by the potential of the Polish industry

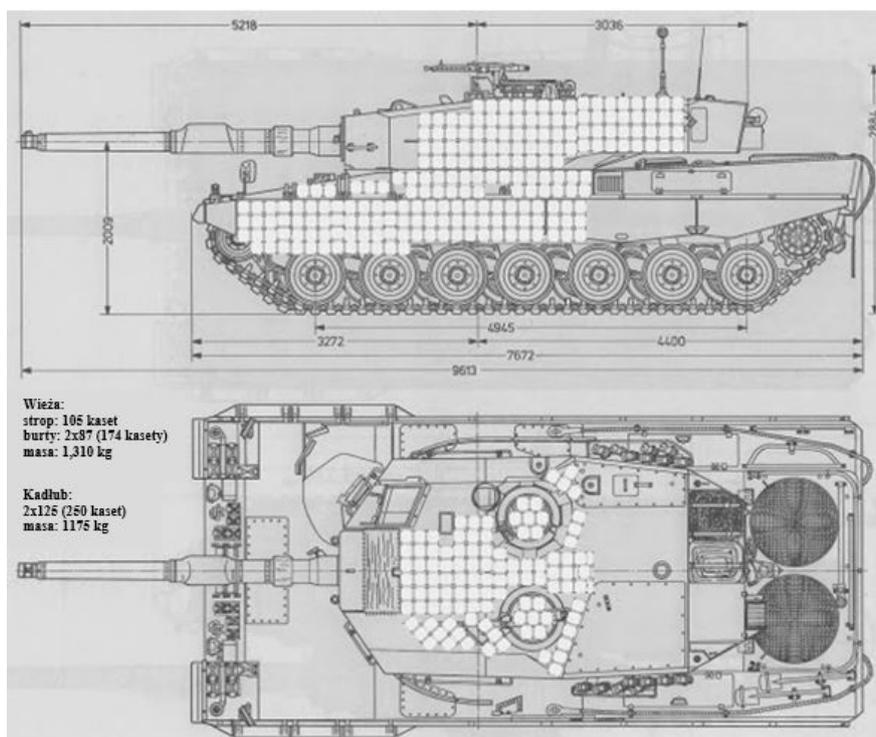
Bearing in mind the achievements of the Polish engineering potential, the first solution that comes to mind with respect to the upgrade process is the use of components of the modern equipment of PT-91 tanks in the modernized LEOPARD 2A4 tank. Solutions that are available in the Polish market are listed in Table 2.

**Table 2. Systems proposed for selected areas of modernization**

Area of modernization	Proposed domestic solution
Additional armour protecting the sides of the hull and turret, including the drive compartment.	ERAWA reactive armour
Additional power generator / air conditioning.	Integrated power unit APU "KOBRA" [7]
Systems: Self-concealment, Soft-Kill and/or Hard-Kill.	SSP-OBRA 3 [8] + system 902A
3rd generation thermovision systems, imaging cameras for the driver.	KLW-1 "ASTERIA camera [9], KDN-1T camera [10]

The ERAWA reactive armour improves significantly the ballistic resistance of the tank. The unique structure of the armour elements enables very tight coverage of protected areas, at a level of > 90% of the area, without any dead zones. In addition, the ERAWA armour proved its high effectiveness against various types of threats (kinetic energy, high-explosive, guided missiles and anti-tank grenades). Of significance is the fact that the level of protection to a lesser degree depends on the angle of inclination of the ERAWA module. This feature is particularly important in view of the squared shape of the LEOPARD 2A4 tank. The suggested arrangement of the ERAWA modules is shown in Fig. 2.

However, when looked at from the perspective of the parameters of the tank's primary armour, testing of the impact of detonation of the ERAWA modules on the primary armour of the tank would be required, as the latter differs from the solutions applied in the modernization of the T-72 tank. According to the "Burlington / Chobham" armour concept [4], the enclosing plates have a thickness of about 50 mm, which may not be enough to keep the structure of the NERA plates stiff.



**Fig. 2. Suggested arrangement of ERAWA-2 armour on a LEOPARD 2A4 tank**

Another important element may be the introduction of the SSP-1 "OBRA-3" radar radiation warning system. The domestic solution, implemented in PT-91 tanks, and in exported tanks (e.g. T-72M4Cz and T-72M2 Moderna) was developed by PCO S.A. A device that increases the awareness of the tank crew of the contact with the enemy, and extends the time to take effective defensive actions. The introduction of four or six detector heads will ensure uniform 360 degrees coverage of the observation sectors. In addition, the integration of launchers provides automatic visual and thermal screening in the threat direction. Providing the LEOPARD 2A4 tank with a digital ballistic computer also gives the possibility of introducing additional functionality in the form of automatic turret rotation towards the threat. Such a rotation could be effected automatically after switching on the "defence" combat mode.

Modernization of the optical systems and the introduction of 3rd generation thermovision cameras is necessary to improve target detection, recognition and identification. WBG thermovision cameras used so far have vector arrays of lower resolution and refresh rates, and are susceptible to interference caused by weather conditions. Therefore, it is proposed to use a modern K LW-1 "Asteria" camera with a cooled MCT (HgCdTe) array with a resolution of 640x512 pixels. The device operates in the 7.7-9.3 $\mu$ m spectral range which is typical for 3rd generation thermovision cameras. For land applications, the wavelength in the range of 8-12  $\mu$ m is more advantageous, (sharper contours of objects), which was confirmed by appropriate field tests. Compact design and the possibility of adapting mechanical and digital interfaces enables installation of the K LW-1 camera in various types of vehicles, including PT-91 (SKO DRAWA-T), LEOPARD 2A4 and 2A5 (EMES-15 and PERI-17). The use of one type of camera in vehicles used by armoured troops improves the logistics and military equipment maintenance system.



**Fig. 3. Optical upgrade kit for the LEOPARD 2A4/2A5 tank – rearview camera KDN-1T "Nyks" (left) and thermovision camera KLV-1 "Asteria" (right)**

## **2.2. Upgrade elements offered by consortium members**

The copyright of the basic documentation of the LEOPARD 2A4 tank is owned by two German companies that have recently been consolidated: Rheinmetall Defence and Krauss-Maffei-Wegmann GmbH. It is obvious that offers of foreign entities are closely related to the variants proposed by the above mentioned German companies. Rheinmetall, as a full upgrade option for the LEOPARD 2A4 tank, presents the MBT Revolution tank. This solution provides improvement of the tactical parameters of the vehicle in all areas except for the traction and driving system, which are not subject to modernization.



**Fig. 4. LEOPARD 2A4 upgrade to MBT Revolution  
(photo Rheinmetall Defence)**

The LEOPARD 2A4 upgrade proposal shown in Fig. 4 is a comprehensive modernization package and includes such components as:

- additional hull and turret all-round armour elements;
- modern optical devices (sights and observation modules);
- modern 120 mm/L55 gun with a programming module for multipurpose projectiles;
- digital crew tank operation management systems;
- explosion and fire protection systems;

- soft-kill (protection/defence systems), hard-kill (active threat destruction systems);
- auxiliary power unit with crew compartment air conditioning system.

An additional advantage of the presented package is its direct integration with the LEOPARD 2A4 tank without the need to bring the tank to the LEOPARD 2A5 or newer standard before its integration.

Despite the technological advancement and the versatility of the package integration, there is a non-compliance with the criterion of price and the weight limit of the tank after its modernization. Failure to meet the 60T weight limit causes a significant increase in costs resulting from changes in the traction system (replacement of gears, suspension arms, torsion bars and shock absorbers).



**Fig. 5. Proposed LEOPARD 2A4 upgrade to LEOPARD 2A7V  
(photo Krauss-Maffei-Wegmann)**

The second package offered was developed by Krauss-Maffei-Wegmann (KMW) and comprises modernization of the tank to the LEOPARD 2A7V version. The basis for the LEOPARD 2A7V shown in Fig. 5 is the 2A5 version of the tank. LEOPARD 2A4 tanks can be adapted to the required version by:

- changing the mounting of the gun mantlet to integrate the "narrow wedge";
- modifying the EMES-15 sight mounting seat to raise it by ca. 30 cm and increasing the ballistic resistance of the right side of the turret;
- relocation of the PERI-R17 commander's panoramic sight. The central placement of the device improves the field of observation, and the change of the commander's observation periscopes enables observation in the 12.00 to 03.00 sector;
- changing the final drives and replacing the suspension system to match the increased weight (over 60T);
- optionally replacing the driver's rotating hatch with a sliding hatch.

The LEOPARD 2A5 upgrade proposal shown in Fig. 5 is a comprehensive modernization package and includes such components as:

- additional hull and turret armour elements in the  $\pm 30^\circ$  sector of the barrel axis;
- elimination and/or improvement of the deficiency of ballistic resistance of vulnerable areas (EMES-15 sight seat, gun mantlet);

- modern optical devices (sights and observation modules);
- modern 120 mm/L55 gun with a programming module for multipurpose projectiles;
- digital crew tank operation management systems;
- explosion and fire protection systems;
- soft-kill (protection/defence systems), hard-kill (active threat destruction systems);
- auxiliary power unit with crew compartment air conditioning system.

The requirement to integrate the modernization package with the LEOPARD 2A4 tank is, as mentioned above, bringing the tank to the LEOPARD 2A5 or newer standard before its integration. This solution is expensive and, like in the Rheinmetall Defence solution, the weight of the modernized tank exceeds 60T. Table 3 shows, in a simplified way, areas of modernization, presenting the proposed solution with its integrator, which are available on foreign markets.

**Table 3. Some of the systems proposed for selected areas of modernization**

<b>Area of modernization</b>	<b>Proposed foreign solution</b>
Additional armour protecting the sides of the hull and turret, including the drive compartment.	<ol style="list-style-type: none"> <li>1. NERA – IBD Deisenroth armour plates</li> <li>2. AMAP modular armour – Rheinmetall Chempro</li> <li>3. AMAP-ADS active defence system (Hard-Kill) – Rheinmetall Defence</li> </ol>
Additional power generator.	Jenoptik Defence & Civil Systems ESW
Vehicle self concealment system.	ROSY-L - Rheinmetall Defence
3rd generation thermovision systems, imaging cameras for the driver.	<ol style="list-style-type: none"> <li>1. 3rd generation thermovision cameras "Saphir" – Rheinmetall Defence</li> <li>All-around observation system</li> <li>SAS – Situational Awareness System - Rheinmetall</li> </ol>
Modernized ballistic computer and modernized observation and sight instruments.	<ol style="list-style-type: none"> <li>1. Gunner's sight EMES-15A2 with 3rd generation camera - Jenoptik Defence &amp; Civil Systems ESW</li> <li>2. Commander's panoramic instrument SEOSS - Jenoptik Defence &amp; Civil Systems ESW</li> </ol>

### 2.3. Final upgrade option – LEOPARD 2PL

According to the agreement concluded between the Inspectorate of Armament and the consortium headed by ZM "BUMAR-ŁABĘDY" S.A., the main areas of modernization of the LEOPARD 2A4 tanks to the LEOPARD 2PL version include:

- improving the ballistic resistance of the turret, while maintaining the weight of 60T;
- replacement of the hydraulic gun stabilization system (WNA) with fully electric system used in LEOPARD 2A5 and newer tanks;
- modernization of the gunner's sight and commander's panoramic observation instrument by installing 3rd generation thermovision cameras;
- increase of the firepower by adapting the gun to be able to fire programmable DM-11 ammunition and subcalibre DM-53 and DM-63 ammunition;
- explosion and fire protection systems using an agent harmless for the crew;
- integration of auxiliary power units;
- improved crew safety;
- driver's rearview camera.



**Fig. 6. Areas proposed for modernization during the dialogue on LEOPARD 2A4 upgrade (photo Dziennik Zbrojny)**

1) electric stabilization; 2) new gunner's thermovision camera; 2a) new commander's night sight and observation instrument; 3) driver's rearview camera; 4) additional power unit (APU); 5) driver's seat; 5a) additional hull bottom plates – handles; 6) explosion protection system cylinders and sensors



**Fig. 7. Modernized LEOPARD 2PL tank  
(photo ZM "BUMAR-ŁABĘDY" S.A.)**

The final scope of upgrade is a 'compromise' between the solutions described in sections 2.1 and 2.2. The selection of the modernization areas depended on 3 major factors: unit cost, tank weight, combat value.

The entity responsible for making changes in the modernized areas, including the repairs of non-upgraded systems, is a consortium of the PGZ group companies, with the integrator being Zakłady Mechaniczne "BUMAR-ŁABĘDY" S.A. The consortium includes, among others, Wojskowe Zakłady Motoryzacyjne S.A., PCO S.A., ROSOMAK S.A., Zakłady Mechaniczne Tarnów S.A. and OBRUM sp. o.o. Table 4 presents the technical aspects of modernization and consortium members responsible for the implementation of a given area.

**Table 4. Upgrades conducted by Polish and foreign entities**

Area of modernization	Implementing entities
New CCMS commander's display and modernization of RPP control unit. Image streaming from sight devices, turret systems management, turret systems testing.	Rheinmetall Landsysteme, Rheinmetall Waffe Munition, Rheinmetall Defence Electronics, Airbus DS Optronics
New data bus (CAN BUS interface).	Rheinmetall Landsysteme, Rheinmetall Defence Electronics
Modernization of observation and sight devices (gunner's EMES-15A1 and commander's PERI-R17A3L4CP), installation of 3rd generation thermovision camera (KLW-1 "Asteria").	PCO S.A., Rheinmetall Defence Electronics, Airbus DS Optronics
Installation of a driver's day and night rearview camera KDN-1T "Nyks".	PCO S.A.

Area of modernization	Implementing entities
Replacement of the WNA-22H electro-hydraulic weapon stabilization system for the fully electric EWNA system, similar to that used in LEOPARD 2A5 and newer tanks. <b>Manufacture under licence of EWNA stabilization system by ZM Tarnów S.A.</b>	ZM Tarnów S.A., Jenoptik Defence & Civil Systems ESW
Installation of additional external turret armour and installation of internal anti-spall lining in crew compartment. <b>Manufacture under licence of armour modules and anti-spall linings by ROSOMAK S.A.</b>	ROSOMAK S.A., IBD Deisenroth Engineering
Modernization of the Rh120L44 gun, programming device for multi-purpose projectiles (e.g. DM11) and redesign to enable use of DM-53 and DM-63 ammunition or their equivalents. <b>Licence for maintenance and modernization of Rh120L44 guns by ZM "BUMAR - ŁABĘDY" S.A.</b>	ZM "BUMAR-ŁABĘDY" S.A., Rheinmetall Waffe Munition
Installation of auxiliary 17 kVA power unit. <b>Licence for installation and maintenance of auxiliary power units by ZM "BUMAR-ŁABĘDY" S.A.</b>	Jenoptik Defence & Civil Systems ESW
Modernization of fire protection system, new explosion protection system in crew compartment. New agent harmless for the crew (DeuGEN-N).	Kidde-Deugra Brandschutzsysteme
Modification of towing devices, adapted to increased tank weight.	ZM "BUMAR-ŁABĘDY" S.A.
Installation of additional transport cages.	ZM "BUMAR-ŁABĘDY" S.A.
Reconstruction of hull and turret.	ZM "BUMAR-ŁABĘDY" S.A.

All other LEOPARD 2A4 tank systems not upgraded will be exchanged or repaired in accordance with the TDv 2350 / 033-22 TDV operating and service instructions and subject to the F6 service level (equivalent to major overhaul). In the area of repairs, one of the key aspects is the repair of integrated drive systems (Power-Pack) by WZM S.A. in Poznań.

### 3. TACTICAL AND TECHNICAL SPECIFICATIONS OF LEOPARD 2PL TANK IN COMPARISON TO 3RD GENERATION TANKS

To provide a closer look into the scope of upgrade, which depends on the completion time, design constraints and financial resources earmarked for this purpose, Table 5 presents a comparison of the LEOPARD 2PL tank with equivalent vehicles.

**Table 5. LEOPARD 2PL tank equipment in view of modern generation 3+ tanks**

<b>Equipment requirements of 3rd generation (and more recent) combat vehicle standards:</b>	<b>LEOPARD 2PL</b>	<b>T-90MS</b>	<b>M1A2 ABRAMS</b>	<b>LEOPARD 2A7V</b>
Composite and/or multi-layered armour.	+	+	+	+
Additional armour protecting the sides of the hull and turret, including the drive compartment.	+	+	+	+
No ammunition in crew compartment.	-	-	-	-
Tank gun adapted for firing high-power kinetic energy (muzzle energy > 10MJ) and programmable ammunition.	+	+	+	+
Drive in the form of an integrated system.	+	-	+	+
2-axial gun stabilization, with line of sight follow up system.	+	+	+	+
Independently stabilized 2-axial aiming devices of the gunner and commander.	+	+	+	+
Hunter-Killer operation mode.	+	+	+	+
Automatic gun loading system.	-	+	-	-
Chassis/turret fire suppression system.	+ / +	+ / +	+ / +	+ / +
Chassis/turret explosion protection system.	+ / +	+ / +	+ / +	+ / +
Additional power generator / air conditioning.	+ / -	+ / +	+ / +	+ / +
Systems: Self-concealment, Soft-Kill and/or Hard-Kill.	- / - / -	+ / + / +	+ / + / +	+ / + / +
Passive night vision systems, 3rd generation thermovision systems, imaging cameras for the driver.	+ / + / +	+ / + / +	+ / + / +	+ / + / +

The above comparison shows that it was possible to significantly raise the combat value of the vehicle with a relatively small financial effort and limited interference in the design of the tank. Self-concealment, soft-kill and hard-kill systems were the areas that have not been dealt with. In this case, however, there is a proven solution available on the domestic market that can be easily installed in the tank. Other areas correspond to the level of generation 3+ tanks, which justifies the validity of the upgrade programme of LEOPARD 2A4 tanks.

Looking from the perspective of logistic security of armoured troops, and of the increase in tactical and technical specifications, the LEOPARD 2A5 tank, which is in service in the First Warsaw Armoured Brigade and the 34th Armoured Cavalry Brigade, is also worth being modernized and polonized.

#### 4. MARKETING ACTIONS RELATED TO CONTRACT EXECUTION

Promotional and advertising activities of entities involved in the upgrade process are oriented both on delivering a coherent message and regularly providing information on the progress in project implementation, as well as on creating a positive company image and identity. Due to the sensitivity of data concerning individual stages of programme implementation, the external communication process seems to be more complex and difficult, especially at the prototype stage. On the other hand, however, marketing activities in this case may be focused on the presentation of competencies and capabilities. ZM "BUMAR-ŁABĘDY" S.A. take advantage of the development opportunities offered by the programme, presenting in their promotional activities their participation as the main contractor for the modernization of Leopard 2A4 tanks to the Leopard 2PL version. The company also announces its competencies and experience in maintaining and servicing Leopard 2A4 tanks, where technical inspections of the F6 level of the chassis as well as of the turret and weapons are carried out. The communication process is effected through publications in the press and on specialized websites, on national and international fairs, industry conferences, as well as equipment demonstrations and commercial presentations.

#### 5. REFERENCES

- [1] Armour and Artillery, Jane's, 1993 ÷ 1994.
- [2] Jackson R.: „CZOLGI I POJAZDY BOJOWE”, Wydawnictwo Vesper, Edition I, May 2010, ISBN 978-83-61524-74-8.
- [3] Holota M., Tybińkowski D.: „Podniesienie własności bojowych czołgu leopard 2A4 poprzez jego modernizacje i modyfikacje – analiza zakresu możliwości”, Szybkobieżne Pojazdy Gąsienicowe, (22) No. 1, 2007. (pp. 61-72) OBRUM sp. z o.o. Gliwice, May 2007.
- [4] Przeździecki P.: „Zarys historii brytyjskich czołgowych pancerzy specjalnych: opracowanie i rozwój pancerza Chobham w latach 1964-1976”, Przegląd Historyczno-Wojskowy 12(63)/4 (237) (pp. 105-130), 2011,
- [5] Wiśniewski A.: „Pancerze, budowa, projektowanie i badanie. Wydawnictwa Naukowo-Techniczne, Warszawa 2001.
- [6] Dąbrowski M., Komański Z.: „Aktywne systemy obrony pojazdów (ASOP) cz. I”, Szybkobieżne Pojazdy Gąsienicowe, (29) No. 1, 2012 (pp. 19-28). OBRUM sp. z o.o. Gliwice, March 2012.
- [7] Chodkiewicz K., Szulborski A.: „Pomocnicze agregaty prądowórcze a czołgi Wojska Polskiego”, Nowa Technika Wojskowa, No. 12 (pp. 38-42), WSOWL 2009.
- [8] „SSP-1 OBRA-3 System Samoosłony Pojazdu”, PCO S.A. publication, [https://pcosa.com.pl/wp-content/uploads/2018/07/PCO\\_a4\\_mala\\_SSP-1-OBRA-3\\_pop\\_03.pdf](https://pcosa.com.pl/wp-content/uploads/2018/07/PCO_a4_mala_SSP-1-OBRA-3_pop_03.pdf) [Retrieved: 20.03.2019].
- [9] „KLW-1 ASTERIA Kamera termowizyjna”, PCO S.A. publication, [https://pcosa.com.pl/wp-content/uploads/2018/07/PCO\\_a4\\_mala\\_KLW-1-ASTERIA\\_pop\\_03.pdf](https://pcosa.com.pl/wp-content/uploads/2018/07/PCO_a4_mala_KLW-1-ASTERIA_pop_03.pdf) [Retrieved: 20.03.2019].
- [10] „KDN-1T Kamera cofania”, PCO S.A. publication, <https://pcosa.com.pl/wp-content/uploads/2018/09/ulotka-KDN-1T-pl-web.pdf> [Retrieved: 20.03.2019].