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Technical paper

Implemented and Proven Proprietary Technologies Supporting Weapon Training Systems

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Abstract. Zakład Automatyki i Urządzeń Pomiarowych AREX Sp. z o.o. (Gdynia, Poland), part of the WB Group, has many years of experience in the production of weapon training equipment at the highest worldwide level. The article presents the proprietary technologies supporting weapon training systems that provide comprehensive training in weapon operation using the most new generation simulators and training systems so that the use of the delivered equipment is as effective, efficient and safe for the users as possible. Creating a range of comprehensive and complex systems that could compete with the largest global players in the defence industry also means the need to cooperate with recognised partners in Poland. The WB Group continues to introduce technological change within the Polish army and defence industry. Acting in the area of specialised electronics and military IT, the WB Group has helped bring the Polish Armed Forces into the 21st century by setting the applicable standards in key areas for national security. The WB Group is a group of companies in the Polish defence industry and an exporter of technologies and concepts to dozens of countries around the world, including the United States of America. In its activities, it is guided by innovation and the creation of breakthrough technological solutions. The adopted business philosophy of the WB Group is expressed in the range of products, including solutions that are unique on a global scale, and implemented in the most demanding markets. Operation on the global markets has stimulated further development of the WB Group.

Key words: training systems, simulation training systems and weapon simulators, security

1. INTRODUCTION

Zakład Automatyki i Urządzeń Pomiarowych AREX Sp. z o.o. located in Gdynia (hereinafter referred to as “AREX”) has been operating on the market since 1989 and is part of the WB Group, which is the largest private group of companies in the Polish defence industry, offering advanced solutions for armed forces around the world. Currently, more than 1,200 people work in all branches of the WB Group worldwide, of which more than half are engineers and employees of R&D departments [2]. AREX specialises in the design and production of technologies dedicated to three markets:

- a) railways – including power systems for railway and road infrastructure; the flagship product is an electric turnout heating system improving train traffic in winter conditions;
- b) special – including training sets for various types of weapons, components and drive control systems in military equipment;
- c) power electronics – including inverters, engines, energy storage systems, and chargers.

For almost two decades, AREX has been engaged in special production, primarily mechatronics, and its systems can be found in the electromechanical equipment of 155 mm KRAB gun-howitzers, 120 mm RAK self-propelled mortars and the 30 mm ZSSW30 turret system.

The acquired competences have resulted in the company presenting its own final products in 2021 in the form of a family of modular, remotely controlled weapon systems with various weapon elements and control systems.

Thanks to the use of a self-diagnosis and verification system, as well as modularity, it is possible to quickly repair/replace damaged equipment, which greatly facilitates its operation. The intention of the designers is to create functional and intuitive equipment that allows the operator to focus on performance of their tasks rather than on maintenance of equipment. These are entirely domestic solutions, with components manufactured in Poland, which ensures full control over the resulting product [1].

AREX works with leading technical universities, shaping its specialisation in the fields of electric drive control, weapon control and training sets for various types of weapons; and as a technology supplier, it also participates in many military projects, such as the ZUR-23-2KG JODEK-G artillery-missile set, ZSMU-127 KOBUZ remotely controlled weapon station, W-3PL GŁUSZEC combat support helicopter and a company fire module for 120 mm RAK self-propelled mortars.

At AREX we are constantly improving our methods to meet the needs of users of the equipment we supply, based on our long-term experience in the design, production, implementation, training and after-sales service of industrial automation equipment and systems, as well as by building a highly-effective team of specialists who are ready to meet ambitious challenges. The development of training equipment ensuring the most adequate conditions for the realities related to the training of soldiers is currently of great importance. It is crucial not only for teaching, but also for financial and generational reasons. Such possibilities are offered by various types of training systems and simulators. An additional aspect supporting the widespread use of highly computerised equipment that supports training is the fact that the current young generation is brought up in a world filled with virtual reality. Young people expect and boldly accept any technical innovations as something completely normal and natural. They have no problems with operation in such an environment. This is partly the reason why the development trends in every area of military life, including training systems, simulators and modern training support systems, must continue to develop. This article describes selected training systems used by the army – from the simplest models to the more technologically advanced ones [3]. A high number of trained soldiers and high frequency of training make it necessary to properly arrange training, so that they are taught relevant skills and appropriate habits. The use of training systems ensures the safety of the training participants. The courses, therefore, become more attractive; and, for instance, the use of the training systems to teach aiming and to ensure general familiarisation with the weapons ensures that before the first shot is fired, each soldier has precisely developed habits of safe operation of the weapons.

Based on this example, it can be argued that all types of training support equipment can play a key role in learning and maintaining an appropriate level of training intensity. In recent years, training equipment and systems have entered another, higher level of advancement [1].

Their technological level has been constantly evolving and increasing in application possibilities. After using additional accessories (e.g. printers), modern equipment can visualise the achieved results for each soldier, which considerably facilitates the recording and control of results, as well as gives the answer to whether the soldier is ready to shoot with live ammunition. Simulator training saves time, money and equipment. Today, modern simulator and training system equipment is used by soldiers of all the types of armed forces in our army. It is currently a mandatory equipment of almost every training centre, but even several years ago the military had to overcome many obstacles to properly prepare for the performance of these tasks. The lack of modern technology was especially felt after the army became professional and had to face new challenges, including service in foreign missions [2].

2. ESSENCE AND SOURCES OF INNOVATION IN WEAPON TRAINING SYSTEMS

There is no single universally applicable definition of innovation. The concept of innovation comes from Latin – *innovare*, meaning “creating something new”. Innovative advanced technologies are currently the basis for the development of both the largest global economies and individual dynamically growing enterprises. They are often associated with significant capital expenditure and large corporations, but small and medium-sized enterprises play a huge role in their creation and dissemination in the modern economy. Their undoubted advantages are entrepreneurial dynamism, flexibility and commitment to implemented innovative projects, and AREX is a classic example in this regard. It implements its projects based on:

- knowledge related to technological solutions,
- use of technologies introduced in other sectors,
- identification of technical problems and user needs.

The application of innovation may be related to the introduction of new solutions or the improvement of the existing ones [4]. Innovation or innovations are actions aimed at implementing changes leading to the increase in modernity and competitiveness of the company, and as a result increasing its value. For AREX, innovation means:

- introduction of new products,
- implementation of new technologies,
- changes in production and distribution infrastructure,
- actions aimed at better use of the employees’ skills and knowledge,
- development of information networks.

The new AREX products on the market is the extension of a well-known idea, but offering new product and technological quality, so as to meet existing needs in a better and more efficient way than before.

These are also innovations that continue the previously implemented technical solutions. AREX uses previously proven designs and at the same time tries to improve them by proposing new structures or technologies. This group also includes system solutions that adjust known software to specific conditions, requiring appropriate adaptation. This group includes the majority of products and technologies classified by AREX as technological innovations.

3. AREX WEAPON TRAINING SYSTEMS

The main objective of AREX constructing the training equipment for the 23 mm artillery sets is to create its own modern technological solutions for model training conditions of the Polish Armed Forces, reducing training costs and improving the operational safety of the military equipment [6]. In the era of budget cuts, it is important to maintain equipment at the assumed level of combat readiness, and to ensure high quality training. The increasing costs of weapon operation in combat-like conditions (training grounds, exits to the sea, the costs of fuel, provisions and ammunition) result in the need to search for cheaper forms of combat training [1].

The problem of searching for innovative and unique technical solutions for simulators adapted to the needs of the Armed Forces of the Republic of Poland and aimed at reducing the training costs and offering comprehensive development of design documentation for assemblies and elements of military products was noticed by AREX as early as in 2006, when the TR-23 Training System was created for the ZUR-23-2KG Anti-Aircraft Artillery Set. Based on these experiences, a demonstrator for the training system technology (Technological Readiness Level 9) for the ZU-23-2MR WRÓBEL II naval set was developed together with the Polish Naval Academy (PNA) in Gdynia (Poland) as part of the research and development project financed by the Ministry of Science and Higher Education. During the multiple presentations of the training system at the PNA and its supervised use at the PNA, high quality of product manufacture and suitability in the process of education and training at the PNA was confirmed.

3.1. TR-23 training system for ZUR-23-2KG Anti-Aircraft Artillery-Missile Set

The TR-23 training system is designed to train operators of the 23 mm ZUR-23-2KG Anti-Aircraft Artillery-Missile Set. The training system design uses accessories and a base from the ZUR-23-2KG combat cannon, so as to ensure the greatest possible degree of realism.

The TR-23 training system (Fig. 1 and Fig. 2) is mobile and equipped with both the instructor's station and the operator's station, connected to each other via a wireless network. The instructor's station has the ability to connect and work with multiple operator's stations at the same time (an option depending on the user's requirements).

It enables training of ZUR-23-2KG staff in conditions similar to the actual conditions in terms of operation, kinematics and dynamics, as well as the procedures related to combat operations. One TR-23 training system for the ZUR-23-2KG Anti-Aircraft Artillery-Missile Set is currently used by the Indonesian Armed Forces and two units are located at the Air Force Training Centre in Koszalin, Poland (Fig. 2).



Fig. 1. ZUR-23-KG training system for the CSSP in Koszalin. (Photo: author's archive)



Fig. 2. ZUR-23-KG training system for the CSSP in Koszalin. (Photo: author's archive)

In 2015, AREX, together with the Military Technical Institute of Armament in Zielonka (Poland) and Autocomp Management Sp. z o.o. from Szczecin (Poland), became the contractor and supplier of ZU-23-2 training equipment (procedure number: IU/42/VI-91/ZO/PO/DOS/SS/2014) for the Air Force Training Centre (CSSP) in Koszalin

The TR-23 training system is based on the actual ZUR-23-2-KG set, maintaining all its functional parameters and kinetic characteristics. The training system consists of the instructor's station and the operator's station, connected to each other via a wireless computer network. The computer simulation of the fire task is displayed on the monitor installed in place of the sight [1].

3.2. TR-23-2MR training system for ZU-23-2MR Naval Artillery Missile Set

The TR-23-2MR training system (Fig. 3 and Fig. 4) is designed to train the operator of the ZU-23-2MR Naval Artillery-Missile Set. In order to achieve the greatest possible degree of realism, the training system is based on the actual ZU-23-2MR set. It retains the full appearance, functions and hydraulic power drives of the ZU-23-2MR. Combat equipment in the form of original guns and barrels were deprived of their functional features [3]. The training system for the ZU-23-2MR Naval Artillery-Missile Set was developed as part of the development project No. 0R 00 0034 09 by the scientific and industrial consortium of the Naval Academy and AREX. It is designed to train operators in combat tasks in the scope of:

- detection and recognition of air, surface and shore targets on a simulated naval battlefield;
- selection of the type of task and weapon/ammunition (artillery – 23 mm, e.g. OFZT, BZT, APDS-T or missile – anti-aircraft missile system) depending on the tactical situation;
- performing fire tasks directed at air, surface and shore targets moving in any directions and at given speeds;
- performing fire tasks during various conditions of the sea (0 to 3 degrees on the Beaufort scale);
- observation and improvement of the effectiveness of the performed fire tasks [7];

as well as

- operation of the electromechanical, electrical and hydraulic equipment of the set;
- checking the functionality of the set to the fullest extent.



Fig. 3. TR ZU-23-2MR training system on a moving platform in the PNA
(Photo: author's archive)

Achievement of the desired degree of realism was possible by faithfully simulating:

- real objects, so that their 3D model presented in the program corresponds to the actual object when it comes to external characteristics (e.g., so that it is possible to identify the object after observing its silhouette);
- atmospheric effects, so that the simulation of weather conditions allows the operator to notice their impact on the course and possibility of performing the task;
- behaviour of objects moving in the simulated world, so as to obtain the correct trajectory of missile flight, proper behaviour of flying objects during manoeuvring, etc.;
- the condition of the sea, so as to avoid the dissonance between the perceived condition of the sea and the condition felt due to platform inclinations;
- sound effects so that their level of realism does not cause a noticeable dissonance between the real sound realism of the actual mechanical components of the set and the sounds played in the program;
- other desirable phenomena, such as missile stall after firing, smoke at the station – depending on the task performed.

The ZU-23-2MR operator's station is located on a moving platform enabling simulation of the ship's inclinations at sea. The moving platform control module (SWP) is responsible for simulating this. The inclination parameters are set at the instructor's station.

The training system consists of the gunner's (operator's) station and the instructor's station connected via a local computer network, whereas the instructor's station can connect and work with multiple gunner's (operator's) stations at the same time (this is an option depending on the user's requirements) [6].



Fig. 4. TR ZU-23-2MR training system on a moving platform in the PNA (Photo: author's archive)

The operator's station is based on the cannon modernised for training purposes, which retains similar parameters to the ZU-23-2MR set, thanks to which it is possible to carry out complete operator training. The need to use real buttons and switches during missions allows the operator to become familiar with the design and structure of the ZU-23-2MR. During a mission, the operator is subjected to similar overloads as with the actual cannon. The interior of the operator's station resembles the interior of the original set (the panels and boxes present in the ZU-23-2MR have been recreated). The main difference consists in replacing the GP-02MR tachometric sight with an LCD screen to present a virtual image of the mission. The GP-02MR sight model is placed on the screen casing, so that the operator feels as if operating a real sight (certain sight elements are displayed on the screen). The LCD screen is connected to the computer built into the operator's station (OPC – sight-computer of the training system operator). This computer is responsible for generating 3D visualisations and entering appropriate reactions to the virtual theatre of events – corresponding to the states in which the cannon is currently located (such as reaction to cannon movement and operation of switches on the set). Information about the current status of the ZU-23-2MR is sent to the OPC computer from the Control and View (C&V) module built into the set.

In addition, the set includes a training system sound module (GLO) and a module simulating the STRZAŁA-2M missile launches (ORA) [14]. The ZU-23-2MR operator's station is located on a moving platform enabling simulation of ship inclinations corresponding to the ship's rocking at sea. The moving platform control module (SWP) is responsible for the operation of the mechanism simulating the ship's movement at sea. The inclination parameters are set at the instructor's station.

The results of the development work carried out over 10 years ago in the form of the TR ZU-23-2MR training system confirm its usefulness for the training and development process of the Polish Navy personnel. Cooperation between science and industry turned out to be very beneficial for the PNA, raising the profile of the Missile Weapons and Artillery Workshop at the Navigation and Naval Weapons Faculty of the PNA, and especially for the Polish Navy. The PNA thus received financial support for the development of its laboratory and research facilities. Although the main objective of the ZU-23-2MR training system was to create model conditions for training the navy and to lower the training costs, the ZU-23-2MR training system contributed to improving the OHS and environmental protection conditions [13]. The ZU-23-2MR training system was considered innovative and provided the opportunity to obtain knowledge, experience and solid basis for conducting research to develop data for the design of new training systems and modernisation of the older ones [8].

Developing the project from scratch allowed greater freedom in selecting a specific technical solution, but also forced the team to carefully select tools for both the efficient implementation of the project and the possibility of its expansion. Modern technology is able to actually reflect the battlefield through modern multimedia solutions [9]. By participating in the consortium, AREX invested its own funds well in R&D, and thanks to the project and cooperation with the PNA, it gained unique knowledge, also as a partner in the consortium, so that it can compete further on the international market.

All activities carried out as part of the project and referred to as a simulation of the maritime theatre of operations were aimed at ensuring the highest possible realism during exercises. The implementation of this solution brought measurable long-term benefits and a positive impact on the development of individual enterprises (e.g. AREX being consortium member of AMW) and the Polish economy. The applied methods for training ZU-23-2MR operators with the help of the training systems, including the TR ZU-23-2MR, can faithfully recreate the required specificity of the process and conditions of how a ship fights against a surface (shore) and air enemy, making it more real and increasing its effectiveness [4].

3.3. TR-12.7 WKM PS training system for 12.7 mm Heavy Machine Gun on a post base (PS)

The TR-12.7 WKM PS training system (Fig. 5 and Fig. 6) is designed to train the operator of the 12.7 mm Heavy Machine Gun installed on a ship. The design and operation of the training system corresponds to the real 12.7 mm WKM-B Heavy Machine Gun on a post base, which allows the operator to be trained in both the design and combat use of the machine gun. The training set is placed on a platform simulating sea conditions.

The TR-12.7 WKM PS training system is equipped with the instructor's station and the trainee's station, which are connected to each other via a wireless network. The instructor's station has the ability to connect and work with multiple trainee's stations at the same time [4].

The training system is in the form of a multifunctional platform that includes a movement simulator for the carrier – movement of a ship equipped with a 12.7 mm heavy machine gun, including:

- teaching cadets and officers during specialist courses and candidates for (gunners) operators of the practical systems of operations (type, number, sequence and relationships between them) in the field of initial and final preparation for performing reconnaissance and fire tasks, as well as assessing and correcting their effectiveness;
- improving the operation of the 12.7 mm heavy machine gun by cadets and officers during specialist courses;
- developing skills, competence and practical habits [12].



Fig. 5. TR-12.7 WKM PS training system on a moving platform in the PNA (Photo: author's archive)

The functions of the TR-12.7 WKM PS training system correspond to the real system and create conditions for acquiring practical skills necessary to operate real combat sets, including initial and final preparation and assessment of effectiveness, as well as enable the implementation of the training program, while courses can be carried out in the form of exercises divided into individual stages.

The software components in the Multifunctional Training Platform for the 12.7 mm heavy machine gun, and especially the software at the instructor's station, provide the following features:

- preparation of exercise scenarios, including exercises repeatable in terms of tasks (resulting from the training methodology) and non-standard

- exercise scenarios, e.g. combating asymmetric threats (not provided for in the training methodology);
- automatic assessment of performed exercises with the option for making the instructor's comments;
 - documenting the course of exercises by recording and archiving the training and achieved results in the properly configured databases; recording and archiving done with the use of typical IT data carriers.



Fig. 6. TR-12.7 WKM PS training system on a moving platform in the PNA
(Photo: author's archive)

Proper implementation of the methodical functionality of the training station in the form of a multifunctional platform of the carrier movement simulator – movement of the ship equipped with a 12.7 mm heavy machine gun is ensured by the technical equipment of the training system, including:

1. Operator's/gunner's station, which includes:
 - 12.7 mm heavy machine gun training system adapted to educational needs;
 - combat situation simulator (using aiming instruments);
 - communication system between the operator and the instructor (ship radio module);
 - sea condition simulator (moving platform module for 12.7 mm heavy machine gun reflecting the movement of the ship due to the waves).
2. Instructor's station, which includes:
 - combat situation programmer;
 - module for setting tasks and assessing their performance;
 - ship's radio station;
 - database of participants and training results.

3. Visualisation system, including:
 - system for displaying the course and the results of the exercise;
 - system for displaying the Fire Control process.
4. Training station (modules) enabling the execution of exercises in terms of:
 - operation, including learning the design, maintenance, assembly and disassembly of the machine gun and barrel;
 - preparation of ammunition, including ammunition belt filling;
 - search and tracking (guidance).

The main training station for operators of the Mobile Training Station in the form of a multifunctional platform of the carrier movement simulator – movement of a ship equipped with a 12.7 mm heavy machine gun was built on the basis of a model of the real military equipment reconstructed for training and deprived of combat features and additionally equipped with:

- receiver for the carrier movement simulator – movement of a ship equipped with a 12.7 mm heavy machine gun and the GROM Man-Portable Air-Defense Missile System due to waves;
- receiver for the simulator of the characteristics of the fire control instruments and image of the maritime (shore and air) enemy;
- ammunition belts and training cartridges (dummy or training ammunition).

Kinematic characteristics of training equipment correspond to the actual characteristics of a 12.7 mm heavy machine gun. The operator’s training station corresponds to the actual station. For training purposes, additional elements were installed to view the operator’s activities.

3.4. TR-PPZR training system for the GROM Man-Portable Air-Defense Missile System

The TR-PPZR GROM training system designed to train soldiers operating the GROM Man-Portable Air-Defense Missile System (Fig. 7 and Fig. 8) is a stationary item of training equipment that includes the instructor’s and trainee’s station (for anti-aircraft gunner). These stations are connected to each other via LAN. The TR-PPZR GROM visualization system is based on VBS (*Virtual Battlespace Systems*) software, which generates three-dimensional, moving and stationary air objects (airplanes, helicopters, UAVs) [15].

The TR-PPZR GROM training system is a modern equipment enabling training of operators of the GROM Man-Portable Air-Defense Missile System without the use of ammunition. A simulator is a piece of equipment for reproducing actual conditions in artificial conditions. Currently, most simulators use computer simulation.

Another approach to the simulator (Latin: simulator – “imitator”) treats it as a piece of technical equipment that imitates the operation of another piece of equipment and is used during tests and training.

A training system is a piece of training equipment for training individual soldiers and teams in the use of combat equipment (machines, equipment and instruments).



Fig. 7. TR-PPZR GROM training system (Photo: author’s archive)



Fig. 8. TR-PPZR GROM training system (Photo: author’s archive)

The TR-PPZR GROM training system replaces combat equipment and significantly reduces the training costs [10]. Its mechanisms and equipment are the models that are similar to the original, and hence they allow training under conditions similar to the real ones. This allows soldiers to acquire practical skills or to practice them.

The training system consists of a launch module replica adapted to work with the system and a real size mock-up of the launcher with a missile. The scope of its use in the training process is virtually unlimited; however, the main areas are:

- learning, control and evaluation of target aiming;
- preparation (to the necessary extent) for shooting with live ammunition;
- training in detecting and destroying targets under diverse environments and conditions;
- reacting in unusual situations.

The training system has a modular design, thanks to which it is possible to create many different training stations on its basis. In the basic configuration, the system consists of:

1. Master computer with a monitor (instructor's station) ensuring control of the entire system, access to the operator's graphic interface and collection and processing of the exercise results;
2. Any number of individual computer training stations connected to the instructor's station via LAN, including:
 - a) 3D visualization computer ensuring generation of realistic imaging of the virtual world, objectives and the GROM system,
 - b) visualisation system ensuring the display of the generated 3D image in stereoscopic VR goggles,
 - c) audio subsystem ensuring realistic reproduction of the acoustic environment in the headphones or using a loudspeaker set,
 - d) GROM MPADS mock-up ensuring proper dimensions and weight when using the set,
 - e) measurement and control system with motion sensor and trigger press sensor built into the launch module replica for the GROM MPADS, ensuring fully interactive work between the system and the computer.
 - f) helmet and special 3D (VR) goggles, reflecting virtual reality [10].

The system software provides the following:

- possibility of simultaneously starting and conducting many exercises, each of which can have its own course and its own set of objectives intended for a single training station;
- user-friendly graphical interface for very easy and intuitive operation of all functions;
- editor ensuring fully interactive creation of exercise scenarios based on a graphical situation map;
- ability to save and read exercise scenarios;
- recording of all exercises and their results in the database for further analysis;
- viewing and analysing recorded exercise results.

The operator's training set consists of two elements:

- replica of the launch module – with an electronics block responsible for correct work with the simulator system;

- launcher mock-up – this is a passive element constituting only the launcher equivalent in terms of dimensions and weight.

The use of modern training methods using virtual reality, i.e. the implementation of the training system project in the form of the TR-PPZR GROM training system enabled the construction of a unique research base. It is considered an innovative development, which stands out thanks to the originality of the technical solutions and high-performance parameters, and its use contributes to the development of military technology and to improvement of the efficiency of the training system production and military training [2]. In addition, it also contributed to the improvement of OHS and environmental protection conditions.

The result of the TR-PPZR GROM project ensured the opportunity to obtain knowledge, experience and solid base for conducting research to develop data for the design of new training system and modernisation of the above-mentioned training system.

The advantages of the TR-PPZR GROM training system manufactured by AREX are mainly as follows:

- relatively low cost of purchase and maintenance,
- full scope of gunner training,
- ability to generate any scenarios,
- interaction between multiple gunners,
- virtual integrated training using various types of equipment.

The TR-PPZR GROM training system allows the operator of the GROM MPADS to acquire practical skills or practice them. Its functions refer to the actual system and create conditions for acquiring practical skills necessary to handle actual combat systems in terms of initial and final preparation and assessment of effectiveness in the training centre [11].

3.5. TRAK-01 training system for the RAK 120 mm Self-Propelled Gun-Mortar

Development of the TRAK-01 training system for the M120K RAK Self-Propelled Gun-Mortar (Fig. 9 and Fig. 10) provided additional training facilities for users of RAK Self-Propelled Gun-Mortars in terms of execution of simulated fire tasks (virtual battlefield), operation and service of electromechanical equipment, damage location through a built-in mortar equipment damage simulator, and multimedia diagnostic system (augmented reality). It is also possible to make an open version training system, i.e. equipment installed on the stand or a turret-mounted version, e.g. KTO.



Fig. 9. TRAK-01 training system (Photo: author's archive)

The functionality of the AREX TRAK-01 training system was ensured by the use of the latest multimedia technologies – VBS (*Virtual Battle Space*), i.e. execution of fire tasks on a virtual battlefield, and through the exercises in the field of the straight-ahead aiming system.

VBS is an interactive, three-dimensional synthetic environment generating a virtual training ground adapted to conduct a wide range of tactical training, variance analyses and scientific experiments. VBS is a ready-made solution for the simulation of a wide range of tactical situations, providing a flexible and networked training environment [10]. The VBS virtual battlefield simulation environment system was designed to simulate tactical exercises at the battalion level. VBS is an advanced battlefield simulator environment, a far-reaching development of the graphic engine of the commercial computer game “Operation Flashpoint” developed since 2001 for comprehensive simulation of tactical formations in the modern battlefield.

It now constitutes a standard tactical simulator of many NATO countries and is used by the US Marine Corps, US Army, British Armed Forces, Swedish Armed Forces, Australian (and New Zealand) Armed Forces, Canadian Armed Forces, Finnish Armed Forces, and others. The latest users of the VBS3 Enterprise license are the Bundeswehr and the French army. Advanced negotiations are underway with Ukraine, where the system is to be delivered as part of the American FMS (*Foreign Military Sales*) system for supporting allies, a mechanism also used by Poland. In NATO, VBS3 is available to member countries under the NATO Allied Command Transformation (ACT) agreement [7]. It enables real-time simulation of various situations encountered on the battlefield (both in full-scale and asymmetric conflicts), including attacks with the use of improvised explosive devices (IEDs), using maps and vehicles from the database, which can be expanded to include further necessary items.

Thanks to this, it is possible to prepare for combat missions and become familiar with the terrain, conduct tactical training from the level of the individual soldier to combat teams, combined training of tactical units, movement of convoys, training of observers, provision of fire support, etc.

Also, the simulator of damage to mortar equipment elements, such as the repair procedure using augmented reality, will have a very positive impact on the mortar functionality.

Currently there is a mobile version of the AREX TRAK-01 training system in HSW S.A. in Stalowa Wola – in a transport and training container. The autonomy of the TRAK-01 training system is ensured by its entire equipment enabling its use in field conditions. The mobility of the training system is ensured thanks to the actuator system and a standard 20-foot container.

The RAK TRAK-01 mortar training system provides a full range of training, including execution of fire tasks, as well as diagnostics and service of equipment through the latest training technologies (virtual reality, augmented reality) and work on real equipment. The development of the project TRAK-01 Mobile Trainer for the RAK 120 mm Self-Propelled Gun-Mortar from scratch allowed a flexible approach in choosing a specific technical solution. There is no need to adapt it to a specific platform.



Fig. 10. TRAK-01 training system (Photo: author's archive)

4. AREX TRAINING SYSTEMS AT EXHIBITIONS AND CONFERENCES

On May 30, 2012, during the Poznań International Fair (in Poland), the Innovation-Technology-Machine Fair, the results of the National Competition of the Association of Polish Mechanical Engineers and Technicians were announced, under the Honorary Patronage of the Vice-President of the Council of Ministers – Minister of Economy, and the project awarded in the 5th edition

of the Competition for the “Best technical achievement of 2011” and taking the first place in the scientific and research project category was the *Training System for the ZU-23-2MR Naval Anti-Aircraft Artillery-Missile Set* developed by the Scientific and Industrial Consortium Team: PNA in Gdynia and AREX (Fig. 11) [4].



Fig. 11. Diplomas and achievement awards for AREX (Photo: author’s archive)

On September 6-9, 2012, during the 20th International Defence Industry Exhibition in Kielce (Poland), the following demonstrator was presented: TR-12.7 WKM PS training system for a 12.7 mm heavy machine gun on a post base, mounted on warships, as well as the TR-PPZR GROM training system.

On June 27-29, 2012, in Gdańsk (Poland), as part of the 12th Baltic Military Fair, BALT-MILITARY-EXPO 2012, under the honorary patronage of the Polish Minister of National Defence, Tomasz Siemoniak, Zakład Automatyki i Urządzeń Pomiarowych AREX Sp. z o.o. exhibited some of its products, including the TR-12.7 WKM PS training system and the latest product – the TR-PPZR GROM training system for training operators of the GROM Man-Portable Air-Defense Missile System [1].

In 2012, as part of the 8th edition of the TECHNICON - INNOVATIONS - Industrial Technology, Science and Innovation Fair, in the competition for the “Mercurius Gedanensis Medal”, the TR-12.7 WKM PS and TR-PPZR GROM training systems received honourable recognitions.

On June 25, 2013, the 2nd symposium *Modern technologies in military training* was held at the Military Academy of Land Forces in Wrocław (Poland). During the demonstration, the TR-PPZR Grom training system was coupled with a SK-1 PLUTON. The simulator based on VBS created by Bohemia Interactive allowed the interaction with different training systems based on VBS, as well as software from other manufacturers.

On June 24-26, 2014, at the AMBEREXPO Exhibition and Congress Centre of the Gdańsk International Fair, as part of the 6th International Scientific and Technical Conference, “Maritime technologies for defence and security” – NATCON 2014, held together with the 13th BALT MILITARY EXPO 2014, during the 10th Session – Exploration of Maritime Technology regarding *Simulation and training system*, the following paper was presented: *Innovative solutions of the training system for the naval missile and artillery set for the Polish Navy*. A multimedia presentation of the ZU-23-2MR training system was presented at the fair stand of the Naval Academy during BALT MILITARY EXPO 2014. The presented innovative solutions for the ZU-23-2MR Naval Anti-Aircraft Artillery-Missile Set aroused great interest among both official domestic delegations and foreign guests visiting the fair stand.

The purpose of the AREX participation in the Conferences and Fairs is to build an international platform for the exchange of knowledge between future users, industry and scientific and research institutions of the Baltic countries, while the priority topics of the Conference were solutions in the area of military maritime technology and maritime safety [6].

Both the TR-12.7WKM PS training system and the TR-PPZR GROM training system were presented and tested in 2012-2013 at the Missile Weapons and Artillery Workshop, the Navigation and Naval Weapons Faculty of the Polish Naval Academy in Gdynia.

During multiple presentations of the training systems at the PNA and its supervised use, their high quality and suitability in the training were confirmed. The suitability of the TR ZU-23-2MR training system, the TR-12.7 WKM PS training system or the GROM MPADS gunner’s station consisting of autonomous modules, i.e., the ship’s movement simulator due to waves and the combat simulator, was confirmed during the tests in the aspect of the indicated factors [3]. The application of modern training methods using a naval weapon training platform, including the TR ZU-23-2MR or the TR-12.7 WKM PS training systems, faithfully reflects the specificity of the ship’s fight against air, surface and shore enemies.

5. CONCLUSIONS

The main purpose of AREX training systems is to improve the training of troops and to reduce the costs of training. Thanks to the rapid development of information technology and the exchange of experience as part of international cooperation, AREX allows the enhancement of the teaching methods used in military training, especially the method of practical operation, enriched by the use of weapon simulators and training systems.

Currently, training with the use of virtual reality is becoming a necessity: there is no turning back from this path. However, the balance between what is virtual and real is important. Even the best trained soldier in simulated conditions must ultimately experience the real conditions and learn to cope with them on the battlefield. Investing their own funds and bearing the business risk, the industrial partners are able to determine well and relatively objectively the future benefits of implementing the research results.

Nowadays, in an era of rapid technological development, the issue of cooperation between science and industry and the future users of training systems are an extremely important factor in the competitiveness and attractiveness of the manufactured products, and thus their economic success.

The experience of AREX, who has undertaken technological cooperation with industrial partners, the AMW and other universities, research and development centres and the future user of training systems, allows the representatives of the scientific community and the cooperating entities to achieve significant benefits.

Partnerships between the world of science and industry are built in a difficult and long-term process, which requires overcoming many various barriers; however, they are still possible and can create opportunities for increasing the innovativeness of the Polish economy.

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Wdrożone i sprawdzone autorskie technologie, wspierające systemy szkoleniowe i treningowe uzbrojenia

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Streszczenie. Zakład Automatyki i Urządzeń Pomiarowych AREX Sp. z o.o. wchodzący w skład Grupy WB posiada wieloletnie doświadczenia w dziedzinie produkcji urządzeń szkolno-treningowych uzbrojenia na najwyższym światowym poziomie. Przedstawione w artykule autorskie technologie, wspierające systemy szkoleniowe i treningowe uzbrojenia zapewniają kompleksowe szkolenie z obsługi uzbrojenia za pomocą najnowszej generacji symulatorów i trenażerów tak, aby użytkowanie dostarczanych urządzeń było maksymalnie efektywne, skuteczne i bezpieczne dla użytkowników. Stworzenie oferty idącej w kierunku kompleksowych, złożonych systemów, które mogłyby konkurować z największymi światowymi graczami przemysłu obronnego, oznacza też potrzebę kooperacji z uznanymi partnerami w Polsce. Grupa WB to kontynuator zmiany technologicznej w polskiej armii i przemyśle obronnym. Działając w obszarze specjalistycznej elektroniki i informatyki wojskowej wprowadziła Siły Zbrojne RP w XXI w. wyznaczając obowiązujące standardy w kluczowych obszarach dla narodowego bezpieczeństwa. Grupa WB jest polską grupą kapitałową przemysłu obronnego w Polsce i jest eksporterem technologii i koncepcji do kilkudziesięciu państw na całym świecie, w tym Stanów Zjednoczonych Ameryki. W swojej działalności kieruje się innowacyjnością i tworzeniem przełomowych rozwiązań technologicznych. Przyjęta filozofia biznesowa Grupy WB wyraża się w ofercie produktowej obejmującej rozwiązania unikatowe w skali świata, implementowane na najbardziej wymagających rynkach. Operowanie na światowych rynkach dało impuls do dalszego rozwoju Grupy WB.

Słowa kluczowe: bezpieczeństwo, systemy szkoleniowe, trenażery i symulatory uzbrojenia