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Remote Controlled Weapon Stations - Development of Thought and Technology

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Abstract. The publication presents the Remote Controlled Weapon Station (RCWS) family, designed, produced and developed at Zakłady Mechaniczne (Mechanical Plant) ‘Tarnów’ S.A. in Tarnów (Poland). The paper describes the functionality, scope and purpose of research and development and the prospective directions of its future development. The publication describes the most important functional elements of RCWS, the most important performance parameters as well as scientific and typically engineering issues encountered during the development of this range of products. Additionally, we have provided examples of the use of RCWS family products in military equipment used by the Polish Armed Forces and proposals for use in equipment that is pending implementation.

The publication presents the RCWS family, from the least to the most advanced and versatile module. It also touches upon the classification of remote controlled military equipment, as well as the methods of its use on the contemporary battlefield.

The publication also illustrates the benefits of using remote controlled equipment on the battlefield - such as providing complete, or at least sufficient isolation of the soldier from the dangers of the battlefield, while supporting correct decision-making and enabling advanced observation, recon and tracking of selected targets.

Keywords: armament, remote controlled, weapon station, RCWS

1. INTRODUCTION

Recently, there has been a huge increase in the number of types of remote controlled equipment on the battlefield. The media repeatedly inform the public about new equipment, no longer presenting it in the form of news about technical novelties. They rather inform about real events, clearly depicting the effects of its actual application. The idea of remote controlled weapons is simple - to ensure the greatest possible safety of your soldiers by completely isolating them from the battlefield.

Remote Controlled Weapon Stations (RCWS) manufactured by Zakłady Mechaniczne 'Tarnów' S.A. in Tarnów (Poland) are designed to fit in the scope of the primary idea behind the remote control - isolating the soldier from the battlefield. Remote Controlled Weapon Stations provide the possibility of observation and fire guidance by the vehicle operator who is protected by the vehicle's armour.

In this paper, Zakłady Mechaniczne 'Tarnów' S.A. (ZMT S.A.), as a manufacturer of Remote Controlled Weapon Station family in the form of tower modules for mounting on vehicles and ships, is presenting the individual items of this family of products. However, the purpose of this publication is not to present a commercial offer, but the scope of research and development works and implemented solutions, developed in response to market expectations, users' comments and technical progress.

2. INTRODUCTION TO THE RCWS GROUP OF PRODUCTS

The Group of Remote Controlled Weapon Stations is a family of products sharing many common features. The modules have a similar purpose - they are adapted to be mounted on carriers such as vehicles, containers and ships. They have a similar operating principle and the degree of integration with the user. At the same time, the creation of each item within this group was favoured by a specific market niche and specific requirements, be it environmental or weapon-related. Hence, there are often significant design differences between individual modules of this family.

The most important common features of the described group are presented below:

1. The module is driven by electric motors with permanent magnets (PMSM type),
2. All RCWS modules are electrically powered with the voltage in the range of 18-32 V DC. This is a range that allows easy integration with the majority of the existing military land vehicles (carriers).
3. Each module is equipped with an optoelectronic head, consisting of the following elements: day camera, thermal imaging camera, laser rangefinder.
4. The user interface always consists of an LCD display, operator control panel and a manipulator in the form of a joystick or a yoke.
5. Each model is designed to be operated by a single person. There is an emergency mode operation option in the event of a power failure or electronic equipment failure. The design of most modules allows for the vehicle commander to take control and/or remote control from outside the vehicle.
6. All models offer the optional installation of 81 mm smoke grenade launchers for self-protection. The modules can therefore cooperate with the warning systems operating in the vehicle, for example with the laser beam radiation detection system or the acoustic detection of the firing direction.

In the following sections of the publication we will describe the characteristic individual elements of the RCWS and accompanying technical solutions worked out during research and development. Three RCWS modules will also be described - as examples of particular segments within the family of products.

3. RCWS DESIGN – SIGNIFICANT TECHNICAL SOLUTIONS

3.1. Drive systems

Electric drives, with particular emphasis on the way they are controlled, are developed by engineers working at ZMT S.A. The drive systems are based on PMSM engines with an unmatched range of stable guidance speeds. The minimum stable guidance speed is 0.1 mrad/s and the maximum speed, depending on the specific solution, is up to 3 rad/s. The provided values are performance parameters, which are always guaranteed; in good conditions, it is possible to achieve an even greater speed range.

As a solution developed especially for weaponry modules, the drive systems are fully scalable and universal within these applications.

The control and communication system, regardless of the power of the engine used, remains the same, whereby only the part responsible for power distribution changes depending on the module. It is easy to modify and it can be adapted to a specific solution, not only in terms of transmitted power, but also the method of cooling and the shape of its structure. This means full scalability while maintaining standardization within the product group, and therefore each item within the RCWS family can be reasonably ‘tailor-made’. An example of the PCB board of a single axis drive is shown in Fig. 1.

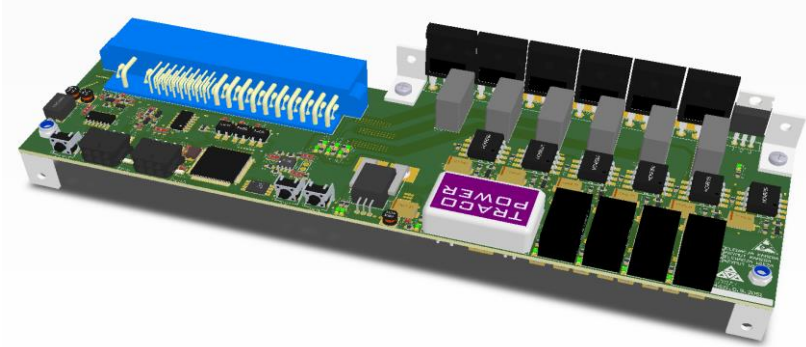


Fig. 1. One axis drive controller for motor power of up to 1 kW

3.2. Operator monitor

The operator monitor plays a very important role in operating the RCWS. It is used in the entire family of Remote Controlled Weapon Stations. It is an original work of ZMT S.A.



Fig. 2. MPO-12 LCD Monitor

In addition to displaying the image from cameras and the current state of the weaponry module, it also plays a role in controlling the module - through a convenient on-screen keyboard. The on-screen keyboard, in addition to the buttons themselves, has the option of informing about events through the backlight colour of the function buttons - in some versions it is also adapted to work in night vision mode. Basic technical parameters of MPO-12 monitor are presented in Table 1.

Table 1. Technical parameters of MPO-12 monitor

Parameter	Value
Voltage	24VDC (18-35 V)
Power consumption	<70 W
Connector type	TVP00WCI17-35PN
Video interfaces	VGA, DVI
Communication interface	RS-422
Video resolution	1024x768
Operating temperature	-40°C to 60°C
Storage temperature	-40°C to 70°C
Keyboard around the screen	20 keys

3.3. Computer – Fire Control System (FCS)

Weaponry modules are advanced weapon systems, whose operation is based on a specialized military computer.

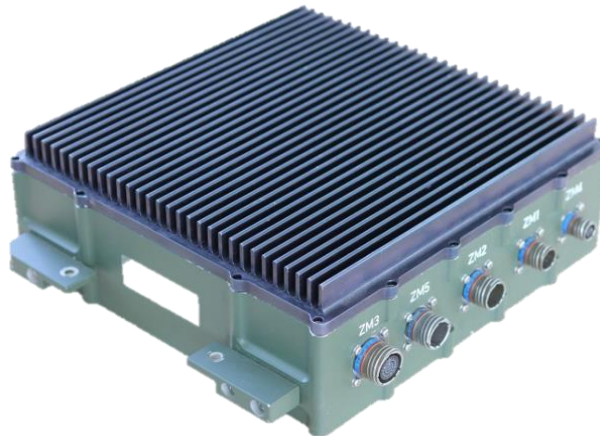


Fig. 3. FCS military computer

In addition to high computing and graphic performance achieved thanks to the use of the latest processors and graphics chips, the computer is also cooled in an innovative way. Entirely passively from the outside and with the heat transport support inside the housing. The cooling system is so innovative that it is protected by the Polish patent number PL 225063. Depending on the specific tower model, the computer also integrates the advanced functions of hardware image processing and energy management for the entire module [1].

3.4. Drive manipulators

Accurate shooting at a distance of up to 2000 m requires more than the precise drive systems and excellent mechanical design of the RCWS. It also needs an ergonomic pointing device, a manipulator that ensures effective transfer of the operator's hand movements to the weapon. In the field of weaponry modules, ZMT S.A. have developed optimal solutions for large and small weapon systems.

Accordingly, in the case of small weapon systems, a joystick type manipulator is used, which harmonizes well with the small interior of the vehicle, does not take up much space, and provides basic functionality. At the same time, it provides incredibly precise and natural control. The joystick type manipulator is shown in Fig. 4.



Fig. 4. Joystick and yoke type manipulators

For larger weapon systems, with more module functions, ZMT S.A. offers a yoke type manipulator. In addition to a more stable grip, it features two handles, each with a set of buttons, including a drive lock and trigger. It also includes a backlit front keyboard constituting an additional control interface - without the need for taking your hands off the manipulator.

The manipulator is designed to be controlled by either one or both hands. This feature described above necessitates a larger size of the manipulator, but due to its intended use - in larger systems - it is not a problem as vehicles equipped with more extensive systems usually also have a more spacious interior. The yoke type manipulator is shown in Fig. 4.

The following part of the paper presents exemplary design solutions of the RCWS family. The Polish designation ZSMU was used.

4. ZSMU – 1276 A3



Fig. 5. Remote Controlled Weapon Station ZSMU - 1276 A3 with the UKM 2000C machine gun

The Remote Controlled Weapon Station ZSMU - 1276 A3 is the smallest and the simplest module available from the ZMT S.A., both in terms of its design and operation. By default, it is intended for technical vehicles - Rosomak WRT/WPT. It is a module typically designed to combat infantry at distances up to 800 m, which makes the UKM 2000C Universal Machine Gun used as the module armament perfectly fitted for this purpose. UKM 2000C is also manufactured by the ZMT S.A. [2]. The great advantage of the module is its low weight (180 kg) and small dimensions, both the tower part and the operator's station. Due to the above, it is used in vehicles where the location of a larger or heavier module would not be possible, including small, unmanned land platforms.

From a research and development point of view, it is entirely an offspring of Tarnów engineers, ranging from electronic design, through mechanical construction, to software and research.

Currently, it is a weapon module produced in the largest number of items, thus its design already takes into account the conclusions stemming from its practical use. For the purposes of discussing further development, it should be assumed to be the basic product.

Table 2. Technical parameters of module ZSMU-1276 A3

Parameter	Value
Armament	1x UKM 7.62 mm
Smoke grenades	Yes, optional
Maximum module weight	180 kg
Voltage	24V DC (20 – 32 V DC)
Ammo box capacity	400 7.62 mm bullets
Armament stabilisation	none
Optoelectronic head	- day camera: wide viewing angle 17° x 12.5°, narrow viewing angle 4° x 3° - thermal imaging camera: wide viewing angle 14.3° x 10.7°, narrow viewing angle 4.5° x 3.5° - laser rangefinder: measurement range 5 km, accuracy 1 m, band 1.55 μm
Video tracker	none

5. ZSMU A3B

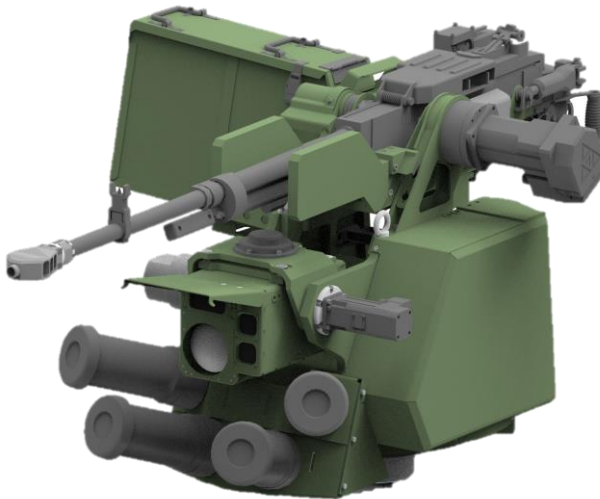


Fig. 6. Remote Controlled Weapon Station ZSMU A3B with the WKM 12.7 mm machine gun

The Remote Controlled Weapon Station ZSMU A3B was developed on the basis of the already produced ZSMU - 1276 A3 module. The driving force behind the research and development work was the vehicle integrators interest in such a module. The module is equipped with a standard 12.7 mm WKM machine gun and four smoke grenade launchers on a movable base. Looking at the previously discussed ZSMU - 1276 A3 module, one could get the impression that it would be enough to replace the 7.62 mm rifle with 12.7 mm for its proper operation. However, as it turned out in the course of research and development, this task was not so trivial. In the A3 module, the camera was rigidly attached to the machine gun mount known as the weapon cradle. This means that to ensure the appropriate ballistic corrections for the distance, it was necessary to move the reticle on the screen. The ballistic correction was achieved by changing the reticle drawing point. This variant works perfectly well and simplifies the design for the 7.62 mm machine gun. In the case of larger calibres with effective firing at a distance of up to 2000 m, this solution effectively limits the possibility of shooting at long distances. In the case of high magnification of the targeting camera (narrow angle) – and this is the only one useful when shooting at long distances – there is a situation when the bullet drop, along the shooting distance, is so large that the reticle is out of the screen. This makes effective aiming impossible. For the ZSMU A3B, it became necessary to introduce an additional (third) drive. It is the drive of the camera elevation. In the current solution, the ballistic correction for the bullet drop is achieved by changing the angle of elevation of the weapon relative to the elevation of the camera, whereby the reticle permanently remains in the centre of the screen. The lateral correction is implemented as before, by moving the reticle on the screen. It should be noted that in the case of the 7.62 mm and 12.7 mm machine guns, these corrections can be described as negligible.

The above illustrates how careful one should be in declaring the ease of changes in highly specialized equipment. It often turns out that a small change from the user's point of view causes a number of changes in the design of the product itself. It seems that it is inevitable in the face of the flaws that can be noticed when possibly designing the most universal products. It always comes at the expense of reduced specialization of the product for a specific task, often also with an increase in weight and many other compromises.

Another requirement, previously unencountered by us in weaponry modules, was a portable control unit coexisting with the operator's position inside the vehicle.

The portable control module has been designed as a comfortable suitcase housing the required control elements - monitor, control panel and manipulator. The design allows the starting of operation right after unfolding the unit. The unit can be located 20 m away from the vehicle, thanks to the wired data and image transmission medium. The requirement as to the distance and the medium was imposed by the vehicle integrator.

In the case of two operator positions, the most important issue is to reconcile competences and authorizations between the two positions. Developing a standard of conduct and defining shared functions (observation) with simultaneous determination of functions assigned to one specific position at a time (shooting, reloading, drive control) and ensuring the safety of operation, became the most important points in the development of the portable control unit of the ZSMU A3B module.



Fig. 7. ZSMU A3B portable control unit module

Table 3. Technical parameters of module ZSMU A3B

Parameter	Value
Armament	1x WKM 12.7 mm
Smoke grenades	Yes, 4 pieces
Maximum module weight	220 kg
Voltage	24V DC (20 – 32V DC)
Ammo box capacity	150 12.7 mm bullets
Armament stabilisation	optional / on request
Optoelectronic head	- day camera: wide viewing angle 17° x 12.5°, narrow viewing angle 4° x 3° - thermal imaging camera: wide viewing angle 14.3° x 10.7°, narrow viewing angle 4.5° x 3.5° - laser rangefinder: measurement range 5 km, accuracy 1 m, band 1.55 μm
Video tracker	optional / on request
Portable control unit module	weight 25 kg

6. ZSMU A5



Fig. 8. Remote Controlled Weapon Station ZSMU A5 armed with WKM 12.7 mm and UKM 2000C 7.62 mm machine guns

The ZSMU A5 module is the most advanced remote controlled weapon station offered by ZMT S.A. The ZSMU A5 offers extraordinary freedom of firing from two machine guns, UKM 2000C 7.62 mm and WKM 12.7 mm. The latter machine gun can be replaced with a 40 mm automatic grenade launcher. In addition, the module is equipped with a video tracker system - automatic target tracking and an effective aiming point stabilization system. The above functions make it possible to fire effectively from a moving vehicle, both at infantry and vehicles. An additional advantage is a modern optoelectronic module with a cooled thermal imaging camera.

Remote Controlled Weapon Station equipped with two types of weapons is a global standard, hence it was only a matter of time when such a module would appear in the offer of ZMT S.A. The undoubted advantages of dual modules include greater firepower and the ability to fire in the event of failure of one weapon. From the design perspective, this poses a number of challenges, such as the appropriate stiffness of the structure, weapon switching arrangement, developing methods of shooting the module, implementation of at least two ballistic models, appropriate azimuth and elevation control of the camera. The dual module should be defined as an advanced structure, intended for a demanding user. The same user, however, has to accept some disadvantages of such a module, which are mainly greater weight and dimensions, and a slightly smaller stock of available ammunition.

Table 4. Technical parameters of module ZSMU A5

Parameter	Value
Armament	1x WKM 12.7 mm 1x UKM 2000C 7.62 mm Grenade launcher AGL 40 mm (instead of WKM)
Smoke grenades	Yes, optional, controlled from the system
Maximum module weight	360 kg
Voltage	24 V DC (20 – 32 V DC)
Ammo box capacity	150 12.7 mm bullets 250 7.62 mm bullets
Armament stabilisation	standard, full
Optoelectronic head	- day camera: wide viewing angle 10° x 8°, narrow viewing angle 3° x 2° - thermal imaging camera: wide viewing angle 10° x 8°, narrow viewing angle 3° x 2°, operating band 3-5 μm - laser rangefinder: measurement range 10 km, accuracy 1 m, band 1.55 μm
Video tracker	standard, full

7. CONCLUSIONS

On the basis of the described versions of the RCWS modules, it is possible to demonstrate the development of thought and technology, as well as the variety of applications and customer expectations. There are tremendous advances in ergonomics, performance, reliability and operator integration. Taking into account many environmental factors, speed of movement, tilts, target movement, bullet ballistics and wind, brings amazing results in terms of firing effectiveness. Together with the ergonomics and intuitive operation, it reduces the time needed to fully train the RCWS operator. Currently, it is possible to train RCWS staff to the basic level of skills within a few hours of theoretical and practical classes. Training to use the weapon at a similar level of expertise will certainly take more time. At the same time, the RCWSs provide an invaluable advantage - staying inside the vehicle while firing.

It seems that the further development of remotely controlled battlefield elements is inevitable as it results directly from the desire to protect one's own soldiers from harm, and the effectiveness of such solutions.

Objectives set by Zakłady Mechaniczne 'Tarnów' S.A. for the coming years are primarily to improve the operator's situational awareness through the use of wide-angle cameras, full integration with vehicle cover systems and threat information systems, development of advanced imaging techniques for better visualization of the situation on the battlefield, development of effective methods of crew training and assessment of their predispositions and training progress.

The above certainly do not meet all of the expectations of future customers and users of the modules themselves, which is why we are listening to their opinions and observations, believing that successively bringing the modules to perfection will result in gaining recognition among users.

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Zdalnie Sterowane Moduły Uzbrojenia – rozwój myśli i techniki

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Streszczenie. Publikacja przedstawia rodzinę Zdalnie Sterowanych Modułów Uzbrojenia ZSMU, opracowanych, produkowanych i rozwijanych w Zakładach Mechanicznych „Tarnów” S.A. Opisana została funkcjonalność, zakres i cel przeprowadzanych prac badawczo-rozwojowych oraz dalsze potencjalne kierunki rozwoju. Publikacja opisuje najważniejsze elementy funkcjonalne ZSMU, najważniejsze parametry użytkowe oraz problemy naukowe i typowo inżynierskie napotkane na drodze rozwoju tej gamy produktów. Jako uzupełnienie, podano przykłady wykorzystania produktów z rodziny ZSMU w sprzęcie wojskowym, będącym na wyposażeniu Sił Zbrojnych RP oraz propozycje wykorzystania w sprzęcie, który dopiero ma zostać wdrożony. Publikacja prezentuje rodzinę ZSMU od modelu najmniej zaawansowanego po moduł najbardziej zaawansowany i wszechstronny. Dotyka również klasyfikacji wojskowego sprzętu zdalnie sterowanego, a także sposobów jego wykorzystania na obecnym polu walki. Publikacja ukazuje również korzyści płynące z wykorzystania sprzętu zdalnie sterowanego na polu walki - jako dające pełną lub wystarczającą izolację żołnierza od niebezpieczeństw pola walki, wspierając równocześnie podejmowanie prawidłowych decyzji oraz umożliwiając zaawansowaną obserwację, rozpoznanie i śledzenie obranych celów.

Słowa kluczowe: uzbrojenie, zdalne sterowanie, moduły uzbrojenia, ZSMU