Antoni **KURZEJA**
Wojciech **RAKSZAWSKI**
Zygmunt **REUTER**
Jacek **WIELICKI**
Roman **WANTOCH-REKOWSKI**

APPLICATION OF SK1 PLUTON SIMULATOR IN THE TRAINING OF AMV ROSOMAK CREWS
Part 1.

Abstract: The article discusses the SK-1 Pluton simulator dedicated to train AMV Rosomak crews and designed and manufactured at OBRUM. Design guidelines, with account taken of the requirements and needs of the military services responsible for training, are presented.

Specifications forming the basis for developing the final simulator design, as well as the simulator structure comprising the combat (commander and gunner) and driver modules, are briefly described. The simulator software developed on VBS2, including software for conducting fire and observation and tracking of objectives for the driver module and the combat module, is also described.

Keywords: training, training of troops, training device design, simulators, driving training simulator, shooting simulator

1. METHODS OF ANALYSING, DESIGNING AND IMPLEMENTING SIMULATORS FOR LAND FORCES

Rapid progress in the development of advanced IT techniques and computer hardware has a large impact on the manner of constructing and controlling military equipment. With the increase in the capabilities of the systems being currently implemented, the complexity of human-machine interfaces is growing. Today a military equipment operator must be able to quickly and efficiently handle several control panels responsible for the operation of the various machine subsystems. Moreover, a soldier in a contemporary battlefield must carry out his tasks nearly intuitively, as fast and accurately as possible. Stringent requirements of modern conflicts and the continuous modernisation of the equipment of the Polish land forces, particularly in the field of combat vehicles, make it necessary to implement new, advanced technologies in the process of training. The progress mentioned has had an impact on the efficiency of the simulators and training devices designed for conducting training. Also the cost of manufacturing of this type of equipment has been significantly reduced. Simulators, depending on their sophistication, can replace, or greatly support virtually any kind of training and teaching tasks and exercises.

The complexity of operating the equipment, as well as of the actions undertaken, requires the conducting of advanced training courses and diverse types of exercises at various

Antoni **KURZEJA**, Wojciech **RAKSZAWSKI**, Zygmunt **REUTER**, Jacek **WIELICKI** – Ośrodek Badawczo-Rozwojowy Urządzeń Mechanicznych "OBRUM" sp. z o.o., Gliwice
dr Roman **WANTOCH-REKOWSKI** – Military University of Technology, Warsaw

levels to thoroughly train vehicle crews. When these relationships are taken into account in designing training systems, the equipment developed meets the users' expectations. Prior to designing a training device, it is necessary to carry out an in-depth analysis of:

– the anticipated manner of using the device,
– the range of functions to be fulfilled by the device,
– the planned scope of training,
– current training programmes.

The above can be treated as the initial stage of the design of a training device or system.

The opinions of training personnel and end users is of great importance when defining the areas of application of a training system.

These people have the proper expertise and experience to adequately define the requirements for the new system.

The subsequent step in training system development is the design and setting up of the system's structure that would meet the set tactical and technical specifications.

Despite the divergences in the requirements for various training devices dedicated to a defined type of vehicle, it is desirable to make the adopted solutions uniform.

The system or training device under construction should have a modular structure and be scalable. The structure of the simulator should be of modular design, not only in terms of computer and control system architecture, but also in relation to its mechanical construction.

The device designed in such manner can have several variants dedicated to training on various levels of skills.

The basic requirement when designing land vehicle training devices and simulators is to maintain as far as possible the ergonomics of the real work stations/posts. It is also necessary to reproduce the work space and conditions of the crew as exactly as possible. Accuracy in reproducing the work space of the individual crew members allows to apply various training programmes in future use of the device.

The fidelity of reproduction must be correlated with the cost of that reproduction. A review must be made to indicate items that will not be used and can therefore be omitted in the design. An example of the driver compartment design in shown in Fig. 1.

Properly constructed training system (device) enables its facile modifications and expansion to include new functions or, in some cases, to rectify previous faulty solutions.

Fig. 1. Interior of AMV Rosomak – driver's compartment

Some training systems (devices) can be deliberately stripped of selected internal instrument simulators that will not be necessary during a given type of training. Therefore the system under design should be adapted to fulfil specific functions throughout the entire training cycle. A specific example of an exception to this rule is the construction of a system that can be used on several levels of training. This involves increase of the complexity of the system design, as well as the need to work out a compromise between the quality of the reproduction of the work space of the crew, functions fulfilled by the system and the cost of the solution. High level of uniformisation of the applied solutions is achievable in particular in the area of software, control and diagnostics of training system or device (simulator).

It is desirable to verify the adopted solutions during the so-called supervised operation or by carrying out tests with the participation of representatives of training centres or end users.

2. CONCEPT OF A PLATOON VERSION OF A COMPREHENSIVE SHOOTING SIMULATOR FOR THE CREW OF AMV ROSOMAK

The platoon version of the SK-1 simulator was created as a natural expansion of the SK-1 type Comprehensive Shooting Simulator for AMV Rosomak which was developed and implemented in the years 2007-2012 and manufactured by OBRUM. The SK-1 simulator is used by the Polish Armed Forces in a wide range of training courses for AMV Rosomak crews.

The simulator was put to use at the Land Forces Training Centre in Poznań.

The simulator manufacturer, in order to successfully develop the design further, collected a number of critical observations and recommendations by maintaining a close contact with training instructors who worked with the simulator. These remarks were taken into account when designing the new version of SK-1 Pluton.

OBRUM commenced preparations to implement the new SK- Pluton project in late 2012.

In view of the lack of requirements for a training system (simulator) developed by the client, a decision was taken to develop a new conceptual project [1] and specify tactical and technical requirements for a comprehensive simulator for AMV Rosomak crew platoon.

The most important specifications of the new system:

- increased applicability of the system due to improved functionality of the simulator hardware and software;
- account taken of remarks made by the SK-1 user, that is the Land Forces Training Centre in Poznań, and by the experts from the Military University of Technology and Military Academy of Land Forces in Wrocław;
- improved reliability of the system;
- flexibility and modular design of the system;
- development of inexpensive modular platforms (simulator cabs) enabling the use thereof in basic, specialised and tactical simulation systems;
- modular software;
- Serious Game support enabling training of crews in cooperation with infantry and joint operations;
- implementation of a real time editor along with an editor of artificial intelligence, scenario, weather conditions and the capability of creating combat formations;
- system content complemented with new battlefield objectives, NATO and OPFOR units; introduction of at least 3 new maps covering the minimum area of 10 x 10 km;
- HLA protocol support providing system interoperability at the level of simulator modules and the entire system;
- After Action Review feature.

The design team set up to develop the new simulator consisted of specialist mechatronic, electronic and IT engineers from OBRUM and cybernetic engineers from the Military University of Technology in Warsaw. The team also included experts/officers from the Military Academy of Land Forces in Wrocław. The programming work was also supported by a team of the VBS2 software manufacturer, Bohemia Interactive from Prague.

At the stage of analyses and concepts, and at the subsequent stage of concept design, various software solutions for the simulator were considered. After analysing various environments, simulation engines and after considering prospects in the aspect of foreign markets, decision was taken to use Virtual Battlespace 2 (VBS2) [7] as the engine for simulation, imaging, artificial intelligence and communication interface. The engine used in the simulator allowed to fulfil all requirements, both those related to training device itself - accuracy of reproducing ballistics and operation algorithms, as well as the tactical ones. Examples of screenshots with virtual battlefields generated with VBS2 are shown in Fig. 2. Another example of the capabilities of the software is a generated model of a wheeled armoured carrier shown in Fig. 6.

VBS2 allowed to achieve much more than was initially anticipated. Appropriate design of the system architecture, in both the hardware and software layers, enables the use of any number of Serious Game (SG) stations in the creation of scenarios.

Fig. 2. Training of the soldiers of the 17th Wielkopolska Mechanized Brigade

The developed platoon version of the comprehensive shooting simulator for AMV Rosomak crews [2] consists of 4 training modules (each corresponding to one of the four vehicles in a motorised platoon). As was the case with SK-1, every module comprises a driver module and a combat module.

The following modules within the training system (SK-1 Pluton simulator) can exist separately and independent of each other: Comprehensive Simulator - Driver Module (acronym: SKMK) and Comprehensive Simulator - Combat Module (acronym: SKMB).

The structure of the simulator is shown in Fig. 3.

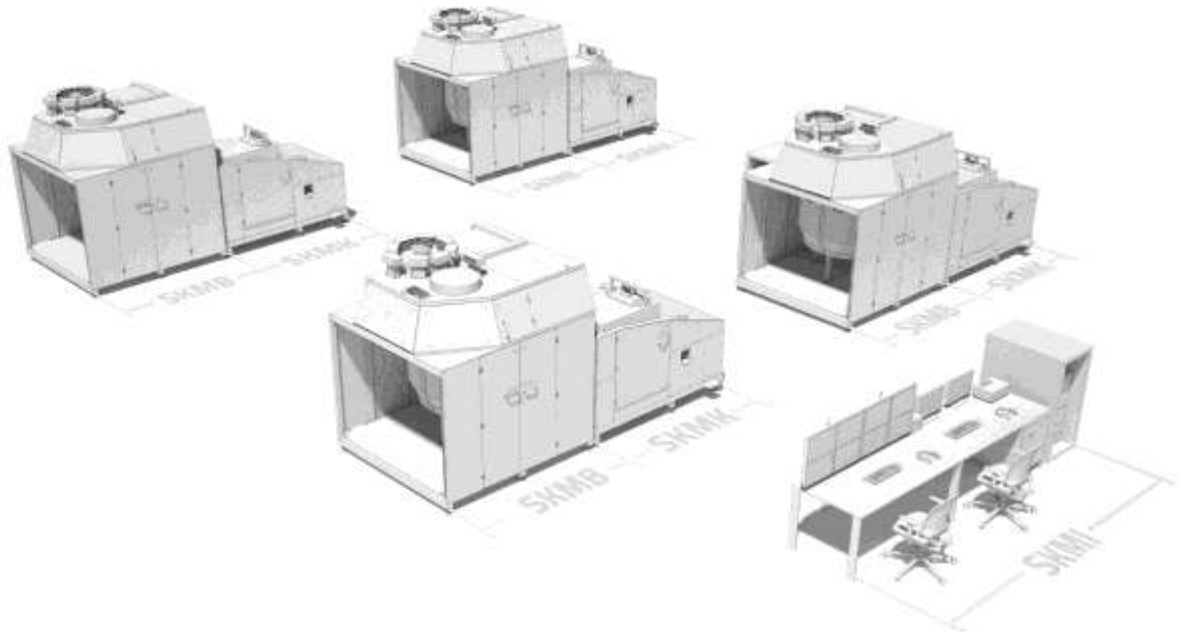

Fig. 3. Structure of SK-1 Pluton

The **SKMK Driver Module** is a self-contained training device designed to train drivers of AMV Rosomak. The SKMK module can be used to implement various training scenarios ranging from basic training to training with the participation of combat compartment crew. The make up of the module depends on the manner of using the device. The module's design enables installing original pieces of equipment of the driver's compartment and additional systems for improving the fidelity of use conditions reproduction. The module reproduces the operation of such systems as the driver's console, vehicle power systems, navigation system, contamination detection system. For the purpose of training AMV Rosomak drivers at an advanced level, the module can be equipped with components for reproducing the operation of suspension and steering systems (motion platform with 6 DOF, vibration generators, steering wheel movement reproducing system). Additionally, the driver module can be fitted with an original hatch and optical instruments connected to imaging system adapted to display image in night vision mode or to simulate driving with the hatch open. The design enables full integration with any combat module, both within a local network or via network interfaces.

The interior of the SKMK module is shown in Fig. 4.

Fig. 4. Interior of the SKMK module

The SKMB gunner and commander module is a self-contained component of the training system for AMV Rosomak designed to train the crews of the HITFIST-30P turret. The combat module is equipped with all simulators of the turret systems necessary to conduct training (fire control system interface, active defence system, power and control systems of the turret, manual fire control). The design of the module includes a number of improvements suggested by instructors from the Land Forces Training Centre in Poznań. The manner of reproducing original devices is adapted to the level defined by the system user. Standard equipment of the module enables operating the module as an independent training device, as well as conducting exercises within any larger training system setup. The combat module may be used for basic training in the operation of the equipment in the turret compartment (turret trainer), for teaching collaboration between the gunner and the commander, and also as a component of a master simulation system, e.g. SK-1 Pluton. A particularly important feature of the SKMB module is the ability to accurately represent the conditions prevailing in the turret, both by fully representing the interior of the turret, as well as by imitating all of its equipment and use of a motion platform.

The interior of the SKMB module is shown in Fig. 5.

Fig. 5. Interior of the SKMB module

3. DRIVER MODULE SOFTWARE

One of the most important components of the driver module software is the numerical representation of the operation of mechanical elements of the vehicle, including those of the suspension. One of the major elements of proper design of the driver module is the modelling of the dynamic properties of the AMV Rodsomak suspension. A precise mathematical model of motion dynamics is complex and requires immense computing power, therefore simplified models are used. The programmers have to make necessary simplifications in the implemented software. However, the high quality of the driving model must be maintained.

That is not the only mechanism that requires from the programmers an in-depth analysis of operation and careful modelling. Another example is the gearbox. This component has a complex design and, in addition, it has a relatively advanced operation algorithm. The complexity of gearbox operation is compounded by its cooperation with other vehicle subsystems, such as the power transmission system.

These two subsystems must be viewed as critical in the context of tactical training of AMV Rosomak crews, as any errors or shortcomings will create a false image of the vehicle's combat capabilities. It is easy to imagine that better traction, higher engine output and more efficient gearbox than in the real vehicle will provoke the trainees to undertake bolder combat actions. This, however, will cause a real threat for vehicle safety during real battlefield actions.

Fig. 6. 3D model of carrier vehicle developed for SK-1 Pluton simulator

Another issue that required greater creativity of programmers was the setting up of a failure management system. Poor history of the effects of failures occurring in AMV Rosomak was a disadvantage. The existing gaps were filled with information obtained from the vehicle manufacturer and through the analysis of the effects of similar failures in designs and products that were familiar to OBRUM design engineers. Then, after initial implementation, all of the reproduced failures were discussed with vehicle drivers in military units and with training instructors with respect to the effects of these failures on the combat value of the vehicle, and afterwards, corrections and adjustments were introduced into the simulator system. Setting up of a failure database has a significant effect on the training value of the simulator. The trainees learn to respond more promptly to potential failures which are a major threat to their safety during real missions.

An undisputed advantage of the SKMK driver module is the possibility of learning how to operate additional devices, such as the Talin navigation system. Full reproduction of operation algorithms of the system and its connection with the simulated environment enables the trainee to master not only the fundamentals of vehicle operation, but also elementary knowledge of battlefield navigation.

One of the most demanding issues to be solved in the simulator was the implementation and tuning of vehicle failures and conditions resulting from improper operation/actions of the trainee. Initial versions of software for SK-1 Pluton driver module enabled only operations that were accordant with the operating manual. However, in the course of implementing the system and making corrections, subsequent functions were introduced into the software to support trainee operations/actions not compliant with the vehicle use procedures.

The fulfilment of this requirement had diversified and extended in time the development work on the driver module, as some analyses had to be repeated and some software functionalities had to be expanded. This implied the expansion of the initial model of driver module operation. During the implementation of corrections the functionalities of the software were supplemented with responses to incorrect actions, such as applying the hand brake when driving at 100 kph, or engaging the reverse gear when driving forward at a high speed.

Finally, after completing most of the work on the system, first tests were launched with the participation of a group of students from the Military Academy of Land Forces (WSOWL). A few incorrect operations that caused unstable operation of the driver module were detected and eliminated during initial tests. In most cases the deficiencies were eliminated in the periods between the tests or within a few days from obtaining the report describing how the erroneous operation could be caused.

The effects of the work carried out after testing SK-1 Pluton by students and officers of WSOWL could be verified in practice at the 2013 International Defence Industry Exhibition in Kielce.

4. FIRE CONTROL SOFTWARE FOR THE COMBAT MODULE

The main module of the SK-1 Pluton simulator is the module that performs the functions of the Fire Control System (FCS). The diagram of FCS components of the HITFIST 30P turret in AMV Rosomak is shown in Fig. 7. The elements most important for conducting advanced exercises in fire control have been reproduced in the simulator. The following elements were reproduced in the FCS simulation module:

– gunner's display,
– commander's display,
– gunner's console,
– commander's console,
– commander's periscopes,
– gunner's periscope,
– commander's periscopes activation pushbuttons,
– system control panel – PCS,
– day and night sight unit,
– control and power supply unit– DAC,
– gun elevation lock,
– turret rotation lock,
– ammunition link discharge port opening lever,
– manual turret rotation mechanism,
– gun elevation,
– electrical trigger pedal,
– basket shield lock,
– weapon safety switches,
– ammunition selection switches.

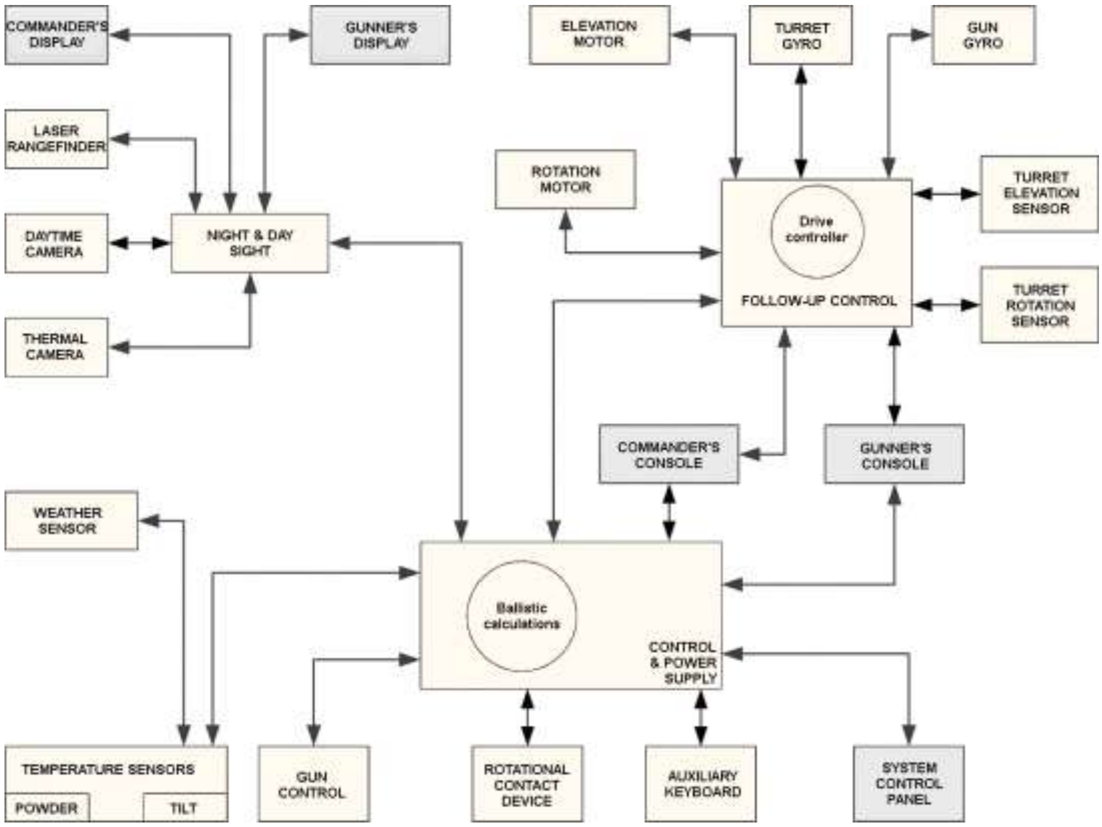

Fig. 7. Diagram of fire control system of HITFIST 30P turret in AMV Rosomak

Basic functions related to fire control are fulfilled using the gunner's (and commander's) display and the gunner's (and commander's) console. View of the display and the console is shown in Fig. 8.

Fig. 8. View of the display and the control console of HITFIST 30P turret in AMV Rosomak

Functions related to the commander's and gunner's display have been implemented in the form of a VBS client inclusive of a dedicated HUD interface [7] (as shown in Fig. 9). The top part of the display provides a picture from a virtual camera which presents the image of a virtual world generated in the VBS2 virtual simulation environment. This means that the trainee sees on the display an image similar to that of the real world which depends on the situation currently occurring. Additionally, physical pushbuttons have labels describing the available functions. The elements of the gunner's and commander's display are elaborate, and the functions of the pushbuttons change depending on the current context of the operations performed. The functions available on the gunner's and commander's displays are supplemented by the gunner's and commander's consoles and by the system control panel (PCS) – Fig. 10.

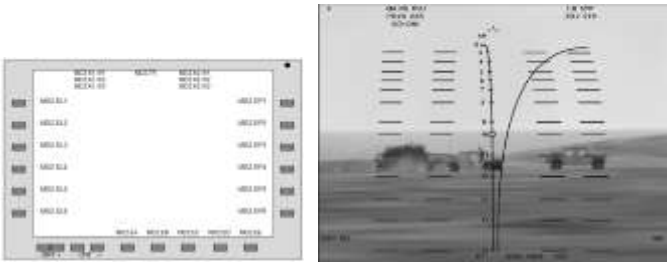

Fig. 9. Design and an embodiment of the gunner's display interface

Fig. 10. View of the system control panel (PCS) of HITFIST 30P turret in AMV Rosomak

The functions of the displays, consoles and PCS are reproduced in the simulator and operate closely together. Software for reproducing the various FCS functions was created using SQF scripts and the Fusion module [7].

The FCS module has been provided with all available grids (ballistic and sight) to enable fire control in various modes (see Figs. 12, 13, 14, 15 and 16).

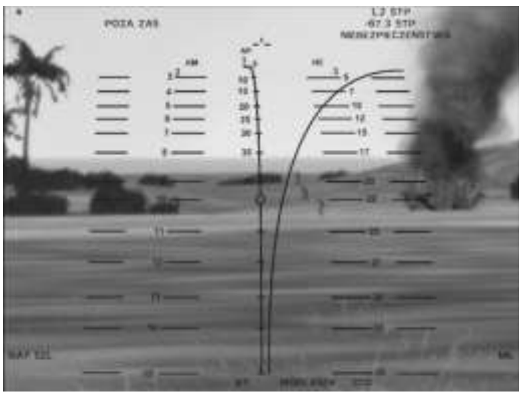

Fig. 11. Universal ballistic grid of the FCS module

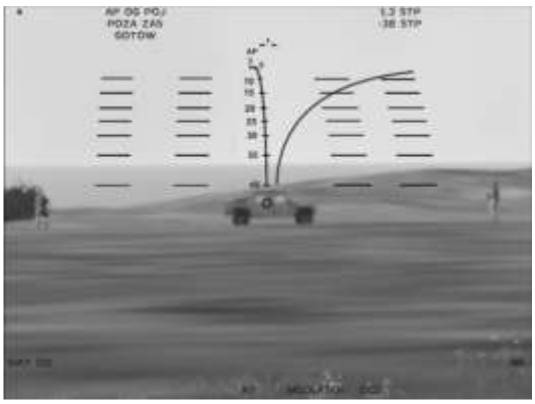

Fig. 12. Ballistic grid of the FCS module for AP shells

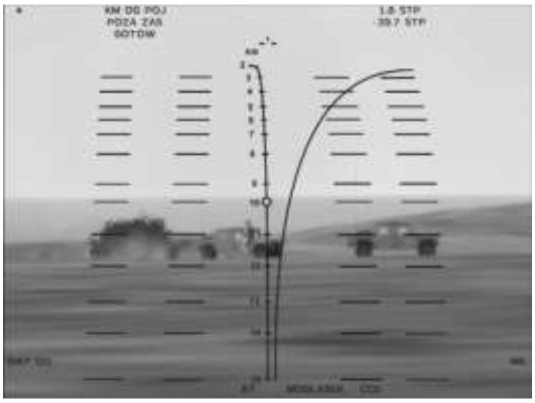

Fig. 13. Ballistic grid of the FCS module for KM shells

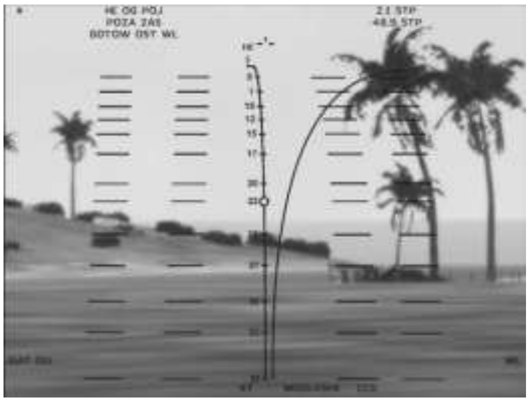

Fig. 14. Ballistic grid of the FCS module for HE shells

Fig. 15. Sight grid of the FCS module

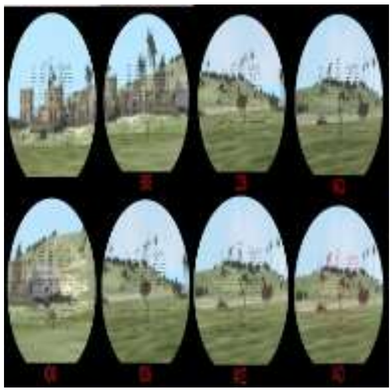

Fig. 16. Sight grid of optical sight

The FCS module simulator enables calibration of selected elements (e.g. position and brightness of sight grids) and use of image from thermal and night vision cameras (Fig. 17).

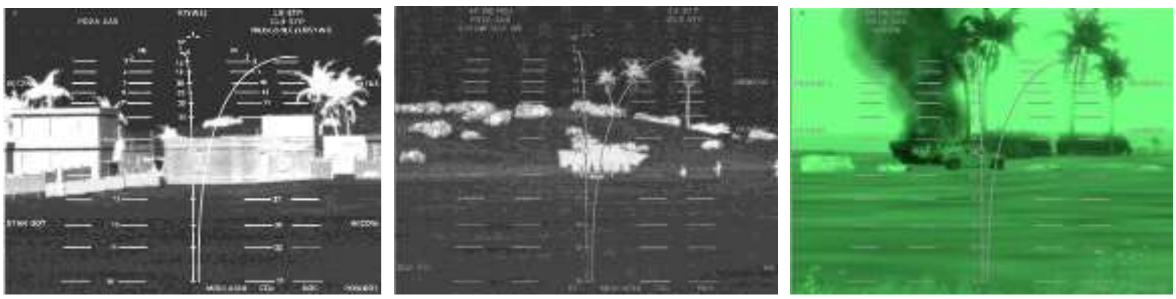

Fig. 17. Views using various modes of the thermal and night vision cameras

During firing the simulator reproduces the ballistics and the parameters of the missile, such as muzzle velocity, air resistance, ballistic curve and view of missile flight and effects of destruction.

5. COMBAT MODULE SOFTWARE FOR OBSERVATION AND TRACKING OF OBJECTIVES

The turret crew in AMV Rosomak observes the battlefield by means of optoelectronic instruments:

– two fire control system displays (coupled with daytime and thermal cameras) which enable observation of targets both during day, night and using a thermovision camera;

– nine commander's periscopes enabling all-round observation and one gunner's periscope, orientation of which follows the firing direction. The commander's periscopes are arranged around the commander's station and enable observation of action field in all directions, including the blind areas existing in the original AMV configuration;

– direct optical viewfinder is used for conducting fire when other imaging devices fail.

In SK-1 Pluton the terrain imaging components have been reproduced with the use of mechanism included in AMV Rosomak model (fabricated for the needs of the simulator) and, to a high degree, by means of VBS 2 Fusion programming interface. It enables to use C++ programming language to expand the functionalities of the VBS2 environment.

Fig. 18. Gunner's display views with ballistic grids

All functions of the gunner's and commander's displays, inclusive of graphical elements, such as ballistic computer menu and ballistic grids (examples of which are shown in Fig. 18) have been fully reproduced in the vehicle model scripts. This approach enabled the inclusion of basic functionalities in the model, and thereby to utilise the vehicle model (used in the simulator) to train crews in tactics and behaviour in the battlefield, with the use of computer stations of the Serious Games type with VBS2 software installed.

As the functionalities of the other imaging components are not as elaborate as in the case of fire control system displays, and their efficiency is important for the smooth operation of the IT system of the simulator, they were created with the use of VBS2 View Client applications which were created for the VBS2 environment to expand observation capabilities. These objects can readily be linked to player objects, and the created View Client linked to the game does not require any interference during a mission to update position or direction. All these operations are supported by the mechanisms of the VBS2 engine. It is only necessary to set proper parameter values, such as the apertures of observation cones.

In addition to passive observation of battlefield, the crew of the combat compartment has at its disposal systems that support active tracking of objects. These include the gun stabilisation system which enables maintaining the selected target in the field of view when driving, and angle of advance mechanism which enables imposing constant turret rotating speed. By imposing an angle of advance of the turret, it becomes possible to track targets moving at an angular velocity in relation to the turret. Both systems, as was the case with periscopes, have been reproduced in the VBS2 Fusion environment.

6. SUMMARY

The SK-1 Pluton simulator presented in the article is an example of the application of technologically advanced solutions to develop a system for use in conducting specialised training courses.

The solution enables on the station training for the various members of AMV Rosomak crews and carrying out exercises in the action tactics of the entire platoon of AMV Rosomak, as well as cooperation of this platoon with other units.

This article constitutes part 1 of the work. In part 2 of the article under the same title, other authors discuss practical remarks and observations collected during the training of officer candidates and professional soldiers.

7. REFERENCES

[1] Antoni KURZEJAKurzeja A.: Conceptual design "Comprehensive Shooting Simulator for AMV Rosomak crew - platoon version" (unpublished) OBRUM sp. z o.o., Gliwice, January 2012.

[2] SK-1 Pluton. Platoon version of a comprehensive shooting simulator for the crew of AMV Rosomak. Specification Sheet. OBRUM sp. z o.o. Gliwice, 2013.

[3] Stefaniak J.: Interfejs instruktora w symulatorach wojskowych [*Instructor's interface in military simulators*]. Szybkobieżne Pojazdy Gąsienicowe (33) No. 2, September 2013, pp. 63-74. ISSN 0860-8369.

[4] Platoon version of the comprehensive shooting simulator for AMV Rosomak crew, covername SK-1 P.
- Operating instructions. Electrical and mechanical.
- Software manual.

OBRUM sp. z o.o. Gliwice, June 2013, (unpublished).

[5] Koźlak M., Kurzeja A., Nawrat A.: Virtual Reality Technology for Military and Industry Training Programs, Vision Based Systems for UAV Applications http://link.springer.com/chapter/10.1007/978-3-319-00369-6_21. February 2014.

[6] Kurzeja A., Wielicki J.: SK-1 Pluton dla załóg Rosomaka [*SK-1 Pluton for Rosomak crews*]. Nowa Technika Wojskowa. Warszawa, No. 2, 2014, pp. 46-48. ISSN 1230-1655.

[7] Roman WANTOCH-REKOWSKI (editor): Programowalne środowisko symulacji wirtualnej VBS2 [*Programmable environment of virtual simulation VBS2*], PWN 2013 Warszawa.

[8] Roguski J., Wantoch-Rekowski R., Koszela J., Majka A.: Koncepcja symulatora do szkolenia kierowców wozów bojowych PSP w zakresie zadań realizowanych w ramach krajowego systemu ratowniczo-gaśniczego [*A concept of a simulator for*

training fire truck drivers in the area of tasks performed within the framework of the national emergency system]. Bezpieczeństwo i Technika Pożarnicza, No. 4, 2012, pp. 71-81. ISSN 1895-8443.

[9] Koszela J., Drozdowski T., Wantoch-Rekowski R.: Przygotowanie danych terenowych na potrzeby symulacji wielorozdzielczej [*Terrain data preparation for multiresolution simulation needs*]. Szybkobieżne Pojazdy Gąsienicowe (31) No. 3, 2012, pp. 109-118. ISSN 0860-8369.

[10] Koszela J., Drozdowski T., Wantoch-Rekowski R.: Zaawansowane metody przygotowania danych terenowych do symulatora szczebla taktycznego VBS2 [*Advanced methods of terrain data preparation for VBS2 tactical level simulator*]. Biuletyn Instytutu Systemów Informatycznych, (11) 2013, pp. 1508-4183.

[11] Koszela J., Wróblewski P., Szymańska A., Wantoch-Rekowski R.: Projekt i implementacja mechanizmów sztucznej inteligencji w środowisku symulacyjnym VBS2 [*Design and implementation of artificial intelligence mechanisms in VBS simulation environment*]. Szybkobieżne Pojazdy Gąsienicowe (31) No. 3, 2012, pp. 119-132. ISSN 0860-8369.

[12] Koszela J., Wantoch-Rekowski R.: Zastosowania symulatorów do szkolenia w zakresie sytuacji kryzysowych [*Application of simulators in training in managing critical emergency situations*]. Bezpieczeństwo i Technika Pożarnicza, No. 1, 2013, pp. 113-120. ISSN 1895-8443.

[13] M. Stopniak: VBS2 - Nowoczesne środowisko trójwymiarowego zobrazowania. [*VBS2 - Modern three-dimensional imaging environment*] Szybkobieżne Pojazdy Gąsienicowe (31) No. 3, 2012, pp. 119-132. ISSN 0860-8369.

[14] Instrukcja eksploatacji wieży HITFIST 30 mm - IEW-001 [*HITFIST 30 mm turret operating instructions*]. KTO/2006. Wojskowe Zakłady Mechaniczne S.A. Siemianowice Śląskie 2006.

Use was made of the results of work carried out under a contract between Bumar and OBRUM Gliwice on the development and fabrication of SK-1 Pluton simulator.