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MODERN INFORMATION TECHNOLOGIES AS BASIS FOR FUTURE DEVELOPMENT WORK

Abstract. One of the basic areas of research and development conducted at OBRUM were and are instruction and training devices used in the instruction processes. IT technologies used by OBRUM specialists, combined with a new look at instruction methodology, enabled the development of an innovative training mode offered to the client. The tools used are based on the latest IT multimedia technologies (image, sound, animation, film), virtual reality, augmented reality or advanced, three-dimensional real-time computer graphics. The article describes the proposed solutions that create a comprehensive instruction system. A step-by-step instruction mode is proposed in the area of use and maintenance for users of complex equipment. The scopes of individual and team (e.g. vehicle crew) instruction are discussed. The summary refers to the possibility of using the developed methodology and tools for both military and civilian clients. The possibilities of including additional stages or new instruction materials in the instruction stages proposed in the system are shown.

Keywords: use of equipment, equipment maintenance, user instruction, trainer device, simulator, instruction system, instruction materials.

1. INTRODUCTION

In recent years, OBRUM carried out research and development projects that pertained to training devices [1], [2]. Solutions were sought to reduce the cost of training, especially that type of training where modern military equipment was used (tank, recovery vehicle, radar station, etc.), and at the same time warrant a high level of training. The technologies available allowed to construct training devices using original components built into simplified mechanical structures that represented real equipment. During further work simulators were created, e.g. BESKID - 3 [3], [4], in which mathematical models of vehicle motion dynamics and of fire control system as well as virtual terrain databases were applied. Programmable controllers were used in the simulation of the operation of equipment component units. Attempts were also made to conduct instruction on real equipment by injecting interfering external signals to real systems, aimed at producing the necessary reaction of the vehicle crew or of equipment operators [5].

In the 21st century the rapid technological development of the equipment used by the Polish Army and the introduction of voluntary military service forced the necessity of having a very high level of training in the tactics of use, operation and handling, including maintenance, as well as continuous improvement of military equipment and materiel.

In order to meet new requirements, in 2012 an independent organizational unit was established at OBRUM, the Simulators Department, which was based on the former section of Simulators and Training Devices [6]. One of the first tasks was to develop a simulator for the wheeled armoured personnel carrier AMV ROSOMAK. Initially the simulator was in the form of a one man station, subsequently expanded to an infantry platoon unit [7], [8], [9], [10].

The further development work carried out at OBRUM, frequent contacts with users of armaments, military equipment and devices, consultations and discussions on the mode of

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conducted training, allowed to develop elements of a comprehensive instruction system that could be built based on materials and systems provided by OBRUM.

The components of the comprehensive instruction process proposed by OBRUM, based on instruction and training devices, IT systems and instruction materials, allow to significantly increase the effectiveness of the instruction, reduce its cost and ensure the necessary development of military personnel. The main advantage of the proposed system is the comprehensive approach to the issues of instruction, allowing the use of systems with different levels of representation, different training tasks using modern IT technologies.

Enabling the Polish Armed Forces to provide comprehensive instruction to troops and enabling the companies of Polska Grupa Zbrojeniowa SA (PGZ - Polish Armaments Group) to provide a complete support package for the products offered was and is the most important objective of OBRUM's Simulators Department. To accomplish these tasks, the possibilities of extensive use of civilian and military technologies, specialized software and an appropriate team of specialists are combined [11], [12], [13], [14], [23]. The instruction methods applied, based on the latest simulation and visualization technologies, allow providing the customer with a solution that enables efficient and safe preparation of the operator, mechanic, driver and vehicle commander to future combat operations.

The purpose of the article is to present the concept of instructing military specialists based on the methodology and devices, training aids, that have been developed at OBRUM.

2. STAGES OF MILITARY SPECIALIST TRAINING

In our opinion, in order to educate and prepare a soldier of any specialty, it is necessary to supplement field training with additional instructions with the use of modern instruction and training systems that simulate real operations. These methods are applied in many armies as a mandatory component of training necessary for the proper use of military equipment during combat operations.

Based on modern technologies, OBRUM offers a comprehensive instruction system for selected specialties, such as: driver, gunner, crew commander or vehicle mechanic (Fig. 1). This proposal applies to general instruction and instruction in specific type of military equipment.

Depending on the prior preparation of the trainee, diverse variants of the first stage of instruction are proposed. In the case of specialists already trained on similar type of equipment, instruction materials using e-learning are proposed. As part of this stage, initial instruction is given, including familiarization with the purpose, components, design and the most important characteristics of military equipment.

After the initial stage of instruction with the use of an e-learning platform, the first stage of training in a Military Unit (MU) using procedural simulators is proposed. Procedural simulators, being an interactive military equipment instruction manual, allow familiarization with the operation algorithms and methods of using the equipment.

The second stage of instruction should include specialized simulators for specific specialties of vehicle crew members (e.g. gunner, commander, driver, loader). In the second stage of the instruction, harmonization of the crew is also improved using complex simulators for vehicle crews. As part of this stage, tactical training is also carried out in military units - harmonization is attained at the level of a platoon or company. For this training, solutions designed for the SK-1 Pluton simulator have been successfully applied, expanded in this case with additional infantry stations.

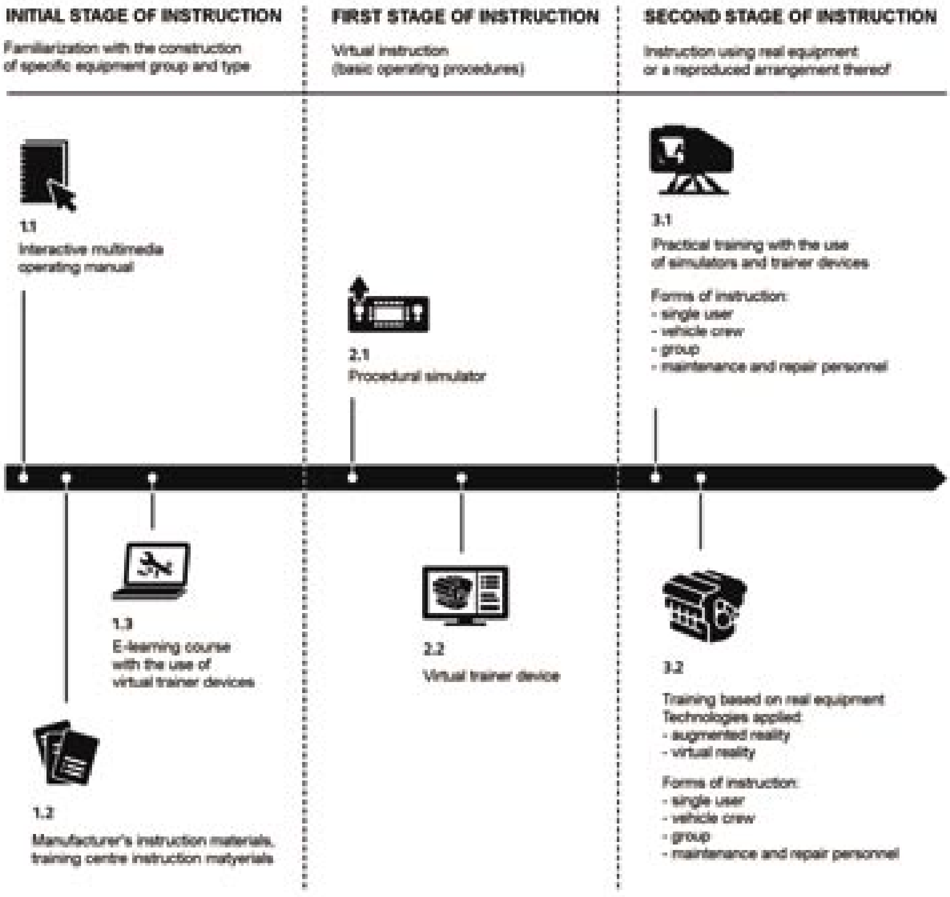

Fig. 1. Instruction stages and instruction tools

2. INITIAL INSTRUCTION STAGE

In the initial stage the aim is for the trainee to grasp the general structure of the equipment used/operated. Tools of the following type are used for the instruction:

2.1. Multimedia, interactive instruction manual;

2.2. Virtual trainer device.

2.1. Interactive multimedia instruction manual

Instructions for Use (IU), Technical Maintenance Instructions (TMI), Repair Instructions (RI) or Spare Parts Catalogue (SPC) are inseparable elements of almost any equipment delivery - not only military equipment. These documents specify the procedures and rules for carrying out activities necessary to ensure the safe use of military devices and equipment. The user should get acquainted with them before taking any action related to the equipment. In the context of instruction, they are therefore the first element among all teaching materials with which the user deals. To improve this early "preparatory" stage, some manufacturers of equipment, especially of the more complex equipment, decide to also provide interactive instruction materials.

The times when paper instructions counting several hundred pages where attached to each purchased piece of equipment are nearly over. Multimedia instructions recorded on electronic data carriers are taking their place.

According to the head of the Construction and Operation Cycle at the Logistics Training Center in Grudziądz, Major Tomasz Smoła: *In the current period of technology development, the role of a teacher of technical subjects is becoming more and more difficult. The problem is not in the transfer of knowledge itself, but in such transfer that the trainee fully understands the easier and more difficult content, and becomes interested in them, and subsequently broadens his/her knowledge independently while this knowledge does not discourage him/her. In the twenty-first century, the message to the student is transferred mainly by vision and colours. When teaching difficult technical issues, lecturers and instructors use a trick, a trap: make one interested through the dynamics of motion, free and spatial access, and the approximation of computer-aided learning to intuitive file viewing* [16].

At a time when electronics expel paper, and the new generations use mobile devices connected to a wireless network, rather than a book or a magazine, it becomes necessary to apply new organizational and teaching solutions, also in the area of soldier training [16]. The use of multimedia techniques in the process of army training is not a new idea. Already in 1999 the issues of modernization of instruction systems in the field of creating and circulating instruction manuals seemed important due to the planned cooperation with NATO, where e-learning was already in use. This allowed the trainee not only to get acquainted with the equipment, its model, complexity, mechanism, individual parts, but it also enabled access to instruction materials and library resources [16]. It was then believed that not only the combat units should be highly educated and trained, but also the maintenance services and workshops/repair shops should be at a high level. Military equipment of the time, also that of the engineer troops, was to some extent saturated with electronics, optoelectronics, and its operation required specially trained soldiers. Shorter compulsory military service in the Polish Army, the inability to make selections during the recruitment and the necessity to provide good basic soldier training constituted new tasks for the personnel [17]. In 2011 the Minister of National Defence issued a decision, no. 349/MON, of key importance in this case, entitled "Instruction on defining the requirements for technical documentation of Armaments and Military Equipment", which contained provisions on interactive instructions and the requirement to provide it with each product implemented to the Polish Armed Forces. According to the Armament Inspectorate, the purpose of developing interactive documentation is to facilitate the use of technical documentation (TD) of complex armament and military equipment in the processes of instruction, use and maintenance. Interactive documentation should be reproduced on a portable computer (or a specialized device) adapted to work in an environment in which a given item of documentation will potentially be used [Ministry Decision No. 349/MON]. However, the definition of interactive documentation contained in this decision and the requirements concerning its form are scant and ambiguous. They require

- the ability to work on multiple windows;
- the ability to use *zoom* function;
- fast insight into selected fragments of documentation;
- hierarchical layout (from general to particular/from particular to general);
- accessible hyperlinks to manufacturers' websites;
- use of multimedia - photos, graphics, films, animations.

In 2017 the delivery of ten MS-20 Daglezja transportable bridges by OBRUM to the Polish Armed Forces was associated with the need to meet the above-mentioned requirements. OBRUM's Simulators Department was then responsible for creating an interactive instruction manual. The same team was also designated to produce a multimedia training instruction for personnel using and repairing tracked vehicles, based on a PT-91 stand used at the Logistics Training Centre in Grudziądz. Based on the experience gathered and after consultation with the client, interactive instruction materials (Fig. 2) were developed, which not only met each of the listed requirements, but significantly expanded the functionality of the application, improving its use.

Fig. 2. Multimedia instruction manual - fragment

Below is a list of functionalities which, in addition to those required by the Decision No. 349/MON, were included in the interactive technical documentation:

- hyperlinks in the text (to specified text fragments, etc.) and to external documents;
- interactive references, buttons, active fields and diagrams;
- interactive, complete operating procedures conducted within the application;
- animations and 3D model viewing;
- passwords;
- vector graphics suitable for large format printing;
- compatibility with Adobe and Autodesk software;
- free and public domain platform for viewing the contents of documentation;
- links that enable smooth switching between the instruction and virtual training device or procedural simulator.

In addition to text descriptions, available in standard instruction manuals, they contain a number of multimedia materials illustrating the subsequent steps of the procedure. The applications enable creating information structures contained within the instruction manuals, conferring meaning onto individual text fragments - by creating hyperlinks, paragraphs, headers, and lists - and embedding file objects, e.g. multimedia, in the text. Hyperlinks facilitate moving among the information contained, which may refer to another document, another location in a given document, chapter, described concept, photograph, diagram or film or application being part of the Comprehensive Teaching Base - Virtual Training Device or Knowledge Base. Photographs and diagrams included in the application bear descriptions in the form of interactive links. This enables quick finding of the individual components (highlighted after clicking). Videos and interactive animations that refer to fragments of text help understand the principles of operation, the method of installation or repair, presenting a step-by-step way of carrying out specific stages of procedures. Graphic (vector) representations of machines and control devices located inside the instructions are composed of "active fields", which when hovered over or clicked with the mouse cursor trigger different types of interactions according to the specificity of the device. This functionality enables not only effective absorption of knowledge, but also its verification at an early stage of instruction. The software will not allow the user to go to the next step of the procedure unless the user performs appropriate actions (such as: clicking the appropriate button on the graphical equivalent of the machine controller).

Instruction with the use of multimedia can be carried out:

- in a training room (instruction provided by a lecturer/tutor);
- on an individual computer station (own work);
- on a mobile device or portable computer (own work);
- on several stations supervised by lecturer/tutor (work using local network/Intranet);
- on multiple stations using wide area network, e.g. Internet [15].

A complete system of support for the use, operation and repair of which interactive multimedia instructions are an element translates directly into:

- reduction of the cost of using military equipment by the Polish Armed Forces;
- reduction of the cost of instruction and of preparation of training materials;
- faster transfer of knowledge to new members of teams of support and use of military equipment in the structures of the Polish Armed Forces - instruction within the Polish Armed Forces and instruction provided by the supplier;
- improved failure rate - reduced cost of maintaining equipment by the supplier;
- meeting the formal conditions specified in Decision No. 349/MON..

Interactive instructions enable the delivery of the following elements of the comprehensive technical documentation described in document [18]:

- Operating Instructions (IU);
- Technical Maintenance Instructions (TMI);
- Repair Instructions (RI);
- Spare Parts Catalogue (SPC);
- Special Tools Catalogue (STC).

2.2. Virtual trainer device [22]

The basic element of the training device are accurate, three-dimensional models of parts, machines and devices. Operations on 3D models are the principal functionality of the software. The user can get into complex interactions on a virtual device or machine. The main objective of the instruction conducted with the use of virtual training devices is to familiarize the student with the specifics of operation, diagnostics and repair of equipment before the first contact with the real object.

Implementation of virtual training devices in the process of instruction helps:

- improve safety in operating and conducting maintenance;
- improve the effectiveness of training, while reducing its cost;

- conducting introductory or refreshment (periodical) instruction without the need to use original equipment units;
- improve the reliability of the equipment being operated or maintained;
- increase the attractiveness and comprehensibility of the instruction content and scope [20].

The spatial geometry of the models used in virtual training devices is reproduced at such level of detail that enables study of the structure and functions of equipment. However, in view of the sensitive nature of the data, the record format of the model prevents its duplication or transfer of the geometry of the visualized object. In order to meet the limitations, the geometry must be represented in a discrete form, i.e. a spatial raster consisting of volumetric elements (voxels).

This technique, unlike surface (polygon mesh) or edge modelling (segments and curves), provides a secure geometry representation. The quality of the models used depends on the settings defined by the author of the 3D model prepared in the CAD environment or software programs such as 3DsMax, Maya or Blender.

Spatial models (divided into individual parts, such as bolts, nuts, switches, etc.), combined with an intuitive interface, allow for a number of interactions, including:

- removal and replacement of subassemblies;
- moving, rotating, illuminating and hiding/revealing parts;
- displaying the view in various modes: context, framework, x-ray;
- making cross sections;
- creating explanations.

Virtual 3D training devices, developed by OBRUM and implemented for use in Logistics Training Centre in Grudziądz, enable:

- learning the construction of individual assemblies, subassemblies and parts of equipment;
- learning the procedures of assembly and disassembly of individual assemblies, subassemblies and parts;
- learning the operating principles of individual systems;
- learning the safety rules of operation;
- becoming familiar with the set of tools and instruments used;
- practising the acquired skills by carrying out procedures on a virtual model;
- verifying the skills and knowledge acquired;
- searching part databases by unique name or identification number;
- making objective assessments of the trainee's skills and knowledge and document these assessments in an automated manner.

The browser of the virtual 3D training device enables four operating modes: viewing, training, practising and testing (verification). In the viewing mode the trainees may study the structure of assemblies, subassemblies and parts. Individual assemblies and subassemblies may be disassembled down to individual parts. This solution enables a thorough study of the structure of the equipment, the nomenclature used, and provides maintenance services with the capability of finding spare parts by Uniform Material Index (UMI) numbers that identify a product or service within the IT system of the national defence department [19]. In the second mode, the training mode, where 3D animations are used, the user becomes familiar with the operating and maintenance procedures of the military equipment incorporated in the training device. Another operating mode is the practising mode, where the user carries out every step of the procedure. The user carries out an assembly or disassembly operation on its own.. The user is provided with advice on how to carry out the step and what to pay attention to. The last operating mode of the client's module is the verification (test) mode, wherein the users receive instructions from the training device to perform specific procedures. The users must now carry out each of the tasks on their own, without any support from the training device. Questions also appear in the form of single choice and multiple choice tests. The results of tests and of the remaining practical instructions can be monitored through a customized learning management system SCORM [20]. Typical verification data may include information about the number of attempts made, as well as time spent on the entire task or individual step in the procedure [20].

The instructor (developer) module of the virtual training devices includes a course and procedure editor. Instructors (Subject Matter Experts) can modify existing instruction scenarios and create and add new ones based on the provided 3D models of objects using dedicated application modules. The subject matter experts can modify the operating and maintenance procedures and remotely conduct instruction using the e-learning platform of the National Defence Ministry. Software for instructors has an intuitive interface, friendly for users having experience with MS Office applications. The instructor module allows the target client to update, modify and expand the application in any way with new instructions, thus expanding the scope of the instruction.

Learning with the use of virtual training devices is based on practical activities, which enables achieving the instruction objectives in a shorter time than with other methods. Due to the attractive and varied form of presenting and verifying the knowledge of the trainees, the learning rate is undoubtedly improved. Conclusions can be drawn from the several applications effected at the Logistics Training Centre in Grudziądz. The completed projects included the construction of a 3D virtual training device for the MK-44 Bushmaster gun and engine (Fig. 3) of a Jelcz 0442.32 vehicle [21].

Fig. 3. Virtual trainer device

Everything indicates that both planners and fabricators (mechanics, electricians or warehousemen) will soon work in the virtual world, which will allow to minimize mistakes while working on equipment - asserts the manager of the Construction and Operation Cycle at the Logistics Training Centre in Grudziądz - Major Tomasz Smoła [21], [24].

3. FIRST INSTRUCTION STAGE - VIRTUAL INSTRUCTION

Upon proceeding to the subsequent stage if instruction, the learner gets acquainted with the basic operating procedures. This stage uses new teaching tools:

- procedural simulator;
- virtual trainer device.

3.1. Procedural simulator

Procedural simulators are instruction and training devices based on virtual reality technology. The user conducts operations in a virtual environment using instruments based on standard computer interface devices, such as a keyboard, mouse or touchscreen. A feature that increases the realism of instruction is the ability to connect real human-machine interface elements (e.g. operating panels, controls or button panels). Procedural simulators are an important element of the training cycle proposed by OBRUM, due to the fact that they combine the initial stage of instruction with advanced operator training carried out using advanced simulators. For some types of military devices and equipment, the operation and use of which consists in performing precisely defined steps described in the form of, for instance, procedures, creating advanced simulation systems that use elaborate representation of operating spaces becomes completely pointless if the training effects achieved are taken into consideration. A good example of the devices described above are MS-20 (Daglezja) bridges on truck chassis manufactured by OBRUM. The Simulator Department has developed a trasining device for these bridges: SMS-20 (Fig. 4).

Fig. 4. Simulator of truck-mounted bridge

This is a procedural simulator for training the procedures of launching and retrieving bridge spans under various environmental conditions (weather, time of day, type of land/soil), and in the various available modes (automatic, manual, emergency). The SMS-20 simulator enables carrying out a complete instruction in the operation of the truck-mounted bridge. The implemented software allows for the representation of all elements/steps of the procedures, and in addition, at moments important from the operating safety point of view, the system gives the user additional guidance in the form of computer animations or test messages. In order to increase instruction effectiveness, and to quickly implement the simulator for use in locations where the truck-mounted bridge is stationed/used, the end-user's and client's comments were taken into account during the design work. The procedural simulators developed at OBRUM are delivered to the user in the form of mobile instruction kits based on:

- laptop computers;
- cables;
- small size projector;
- signal converter for connecting original controllers/panels;;
- dedicated housing.

The kits delivered allow conducting instruction in virtually any location, and the simulation system can be made to work in a few minutes. If for the purposes of instruction it is possible to use original operating panels, the system will automatically detect the device connection, and then the trainee will be able to use a portable operating panel to carry out the steps related to setting control signals.

The basic task of procedural simulators is to simplify the process of learning the use of devices, while increasing the effectiveness of instruction. This task is effected by reproducing with the maximum possible accuracy the way the simulated device is operated. An additional advantage of procedural simulators is the quality of the rendering software used (Image Generator). While operating in the virtual world, the trainee observes and performs all activities using the same perspective as in reality. The only exceptions are situations where, for the sake of the safety of using the simulated device and providing additional knowledge, the simulation system shows elements that are normally invisible to the operator. The procedural simulators are also distinguished by the fact that, as a standard, they enable work in two instruction modes:

- learning/practising mode
- examination mode.

While working in the learning mode, the trainee uses exactly the same elements of the simulator equipment as in the examination mode, but in addition the system guides the trainee through the subsequent steps by giving a series of hints and explanations. In the learning mode the software provides the trainee with information in the form of detailed text messages and computer animations that run on individual elements of the simulated vehicle. The operator can interact only on selected equipment elements, in addition, the system suggests which components should be used in a given step of the procedure. In the examination mode, the number of text messages is limited only to providing the trainee a simplified list of actions to be carried out. All elements of the simulated device used in a given operating procedure are "active". This means that the operator can perform actions/interactions on them, and the embedded software assesses whether the actions taken by the trainee comply with the procedure. After a set time or upon completion of the instruction, the system automatically generates an evaluation sheet. Thanks to the use of such solutions, procedural simulators can be used to continuously improve skills in operating devices as well as to help retain the knowledge gained. There is no need for an instructor to be present during the instruction.

4. SECOND INSTRUCTION STAGE - PRACTICAL INSTRUCTION

Due to the multitude of definitions and interpretations of the terms: simulator and trainer device, the following definitions have been adopted:

- Trainer device – a device used for learning the construction and maintenance activities (in the field of handling or carrying out repairs or current servicing), built on the basis of the components of the actual object, or components very similar to those of the actual object.
- Simulator – a device, software or system for learning the construction and operation of equipment (e.g. within the scope of operating in the driver compartment) with the use of software and mechanical installation. In the case of simulators designed for training crews, the installation that closely resembles the real object (within the defined scope of operation, e.g. the lack of some equipment components not required for carrying out trainer tasks). Simulators, unlike training devices, make use of software components that allow a much deeper interaction of the trainee with the instruction and training device, as well as visualizations of the activity environment.

During the second stage there is practical training with the use of training devices and/or simulators. Various forms of instruction are performed depending on the needs:

- instruction given to a single user;
- instruction given to crew - team training;
- instruction given to maintenance and repair personnel.

4.1. Practical training with the use of training devices and simulators

After completing the first stage of instruction users and maintenance personnel continue the instruction cycle using instruction and training devices that represent the physical installation of the equipment (topology of spatial arrangement). Auxiliary devices designed for use in this type of training are simulators and training devices. The basic feature of instruction and training devices is their high accuracy of the representation of equipment installation. Unlike procedural simulators or virtual training devices, in the case of traditional simulators and training devices, the training is based on dealing with real equipment.

Training devices and simulators can be used to conduct instruction in both operation and structure of military equipment. However, in view of technological progress, as well as of the increasing complexity of the military equipment and devices, the production of instruction and training systems that enable conducting instruction courses of a very wide scope, covering such areas as: structure, operation, repair, parts replacement, etc. are economically unjustified. Due to its structure, training devices are used in instruction in the field of repairs and maintenance, while simulators find increasingly wider applications in the training of vehicle crews and operators of other military devices and equipment. The described applications translate directly into the design characteristics of both training devices and simulators. Instead of using original components, devices and complete subassemblies of the real objects in the construction of simulators, imitators of identical dimensions and functionalities, but with simpler and low-priced components are used. Training devices, on the other hand, are still based on original (sometimes even "combat") components, which are built into specially designed supporting structures that adapting the original installation to training requirements. An exception to the rules described above are embedded simulators, which are described in detail in section 5 of the article.

4.1.1. Equipment operation – single user station to platoon of crews

Backed by the wide field of OBRUM's experience acquired during the project implementations, OBRUM employees, and in particular those of the Simulator Department, are able to develop dedicated equipment and instruction and training systems. Until now the key area in training with the use of simulators and trainer devices was on the job training, less often FMS (Full Mission Simulator) training for several crew members. The most common simulators are devices that can best be described as 'task-oriented'. These are instruction and training devices designed for training in specific activities, most often within a very limited range of simulation parameters (e.g. limitations of map underlay, generated opponent forces, etc.). Examples of such devices include shooting simulators or driving simulators. Another group, once very popular, includes instruction and training devices that fall midway between trainer devices and simulators. These are devices designed for learning the arrangement and operation of human-machine interfaces built into weapons and military equipment. They are characterized by high fidelity of work space reconstruction, and additionally the components of the human-machine interface are equipped with control units (e.g. switches, indicator lights, manipulators). The master control device allows to read the switch states and to control the status of individual indicator lamps. Some devices of this type enable practical learning of simple operating algorithms (e.g. starting the engine, activating the sighting unit, etc.), using the software installed in the instructor/operator station.

The simulators developed at OBRUM are provided with such software and mechanical installations that enable conducting instruction using one type of instruction and training device, at least at several tiers and levels of difficulty. Examples of such solutions include the SK1-Pluton simulator, a shooting simulator for AMV Rosomak crews, and upgraded version of BESKID 2M/K simulator **(**Fig. 5).

Fig. 5. BESKID 2M/K simulator

The upgrade was carried out in collaboration with the Central Military Bureau of Design and Technology. The BESKID 2M/K simulator, initially used only for training in conducting fire from a T-72 tank, acquired much wider training capabilities after the upgrade. The guidelines and upgrade requirements were developed in part by the Military University of Land Forces in Wrocław. Such activity is in line with the currently applied by OBRUM method of conducting analyzes and establishing requirements for instruction and training systems. The experience and observations of employees of training centres and military universities enables developing instruction and training devices that fit into the real training needs of the Ministry of National Defence. The various modules of BESKID 2M/K may easily be used in individual training (e.g. training of drivers and gunners of T-72 tanks). This functionality was attained with the help of good quality mapping, integration of all key vehicle interfaces, as well as embedding most of the control algorithms into the simulator software. The SK1-Pluton training system is an extension of this method of designing simulators. Instruction and training devices comprise three basic types of modules: driver, turret and instructor station. In its standard configuration the system consists of 9 modules (4 driver modules, 4 turret modules, 1 instructor station) which enable training of a platoon of AMV Rosomak crews. In addition, SK1-Pluton can be connected to additional CBT (Computer Based Training) type stations. CBTs enable involving additional persons in the training (e.g. platoon commander, infantry squad, etc.). SK1-Pluton can also easily be used in much less complex types of instruction. As in BESKID 2M/K, individual stations can be used in individual training mode. It is also possible to run a network scenario using incomplete hardware configuration (less than 4 sets of modules), or to replace some crew members with objects controlled by simulation software (e.g. vehicles can be driven by "computer players"). Both BESKID 2 M/K and SK1-Pluton are based on modern simulation software, that allows unrestricted defining of scenarios and variants of the exercise, and provides access to a large database of simulation objects or map underlays. In addition, these simulators can be combined and use common exercise scenarios (provided they operate in a common network), and can be quickly adapted to be integrated with external simulation systems (built-in support for network protocols such as HLA or DIS).

4.1.2. Device maintenance and repair

The above-mentioned instruction and training devices allow to meet the needs of the Ministry of Defence in the field of maintenance of military vehicles and other equipment. However, they are not designed to provide training in repair and technical services. The basic method of providing instruction within this scope is the use of trainer devices. This solution allows to reduce the risk associated with the use of real equipment, while maintaining appropriate level of instruction realism. The Ministry of National Defence introduced trainer devices for instruction purposes more than 40 years ago. Since then, such devices have been successfully used in those instruction fields, where the accuracy of reproducing working conditions, and in particular of the mechanical installation, is of the greatest importance. OBRUM employees observed the demand for such instruction systems and devices, and developed new methods of construction and applications for traditional trainer devices. The simplest method to expand the possibilities and improve the efficiency of instruction based on trainer devices is to fit these devices with elements that show the operation of individual components (e.g. flows in fuel or lubrication systems, etc.). OBRUM's Simulator Department personnel draws up additional materials, such as previously described multimedia manuals or interactive instruction charts. The materials developed complement the equipment of the training rooms, allowing the trainees to get acquainted with the necessary information faster. The next step in expanding the trainer devices is to provide them with highlighting systems mounted on quick-connect elements to the base structure. The highlighting systems can be remotely controlled by a computer application (e.g. running on instructor's tablet or laptop computer), so that the trainees can quickly locate a given element or structural unit on the station. The greatest development in trainer device use is their joint use together with systems of augmented reality (detailed description in section 5.1). Instruction and training systems built in this way allow to reduce instruction time and significantly improve its efficiency. Their special advantage is the fact that in the case of traditional use of trainer devices, instruction with the use of these devices usually constitutes one of the last instruction stages. The trainee must complete several preceding instruction courses to be able to take full advantage of the potential of trainer devices. When augmented reality (AR) technology (Fig. 6) is applied, the trainee may absorb substantial part of knowledge during training on the real object, and additionally the trainee is informed about the next steps of the corrective procedure being carried out.

The use of simulators instead of real vehicles as base objects for AR applications reduces instruction time. No need to remove some parts of the housing or cover, significantly better visibility of important components of the device, reduction of the risk of destroying real equipment are the main advantages.

Fig. 6. Training in equipment operation – AR technology

5. INSTRUCTION USING EQUIPMENT

The last stage of instruction in the system proposed by OBRUM is the use of embedded simulators (in the scope of service - crew training) and augmented reality application (within the scope of training repair personnel).

5.1. Augmented reality and embedded simulators

Embedded simulators have been used in the army for a long time. The simplest applications of this type are all basic systems of shooting instruction - based on, for instance, laser transmitters mounted on live weapons. The biggest advantage of embedded simulators, which is also their biggest disadvantage, is the possibility of using real equipment in the instruction process. The instruction process that involves the use of embedded simulators is based on the use of real military devices and equipment, combined with simulation of some events or exercise conditions. To conduct this type of simulation, virtual reality, augmented reality AR, or advanced control algorithms and systems are used, allowing to generate actions and operating states for real control systems of vehicles and devices. The most advanced form of training on embedded simulators are exercises that involve a plurality of crews and diverse military equipment. Examples of such instruction and training devices include, for example, advanced laser shooting systems, where hundreds of soldiers can participate in the exercise, and the current status of the game is regularly controlled by command centres. At present OBRUM is working on a network-based simulator for the air defence forces. The solution is based on real equipment complemented with some additional special computers and rendering units. The trainee's task is to observe the foreground and to destroy computer-generated targets.

The system can operate in two modes:

- virtual reality;
- augmented reality (AR).

In the first mode, the trainee observes the fire unit monitor screen, where the computer application displays a fully virtual image of the foreground and of interactive simulation objects. In AR mode, virtual remain only the simulation objects that are laid over the real image from image recorders. In both modes, the software allows networking, where several trainees can jointly conduct the exercise.

As embedded simulators require integration of software and additional computer hardware with communication interfaces, human-machine interfaces, vision systems, etc. on vehicles and devices, they are considered to be among the most advanced simulation systems. This involves the need to use state of the art computer hardware. There is often a requirement to use simulators under the same conditions as in the case of real devices (e.g. conditions of humidity and temperature). For many years, OBRUM employees have been building their knowledge and experience in the field of manufacture and application of embedded simulators, so that the design requirements for the construction of instruction systems, and in particular of embedded simulators, are also taken into account.

In the case of instruction given to the repair personnel, the design of instruction systems is based on augmented reality (AR) technology. Instruction applications enable presentation of additional content against the background of the image recorded by a camera.

The software enables the generation of the following data:

- virtual equipment components – spatial objects;
- instructions and explanations (text, voice);
- spatial animations (e.g. rotation, door/hatch opening animations).

Appropriately calibrated training system enables recognizing the distance and orientation in the space of the real device. Based on these parameters, the software controls the manner of displaying additional data. AR applications can be run on portable devices provided with image recorders, such as tablets, laptop or notebook computers or VR headsets. The image generated by the application can be transmitted through a network to other devices for the instructor to analyze data, or for displaying data on trainees' screens. These capabilities of AR systems make them not only a perfect equipment for instruction rooms, but also very useful during repair or maintenance operations.

5.2. Equipment diagnostics and repair

The technologies developed at OBRUM, as well as analyzes and knowledge required in the manufacture of instruction systems, can successfully be applied to develop advanced systems supporting the diagnostics and repair of military devices and equipment. The Simulators Department, jointly with the Development Department, develop specialized diagnostic/maintenance applications.

The software supports the following operating modes:

- diagnostics;
- repair/operation;
- learning.

5.2.1. Diagnostic mode

In the diagnostic mode the user verifies the technical condition of a vehicle or of a device. A computer station is connected to a vehicle by means of dedicated cables and communication interface. With the help of GUI (graphical user interface) the user selects a diagnostic procedure from a database. Subsequent steps in the procedure are displayed on the screen along with hints in the form of text, image or 3D animation. Some of the steps consist in displaying operating parameters. For this purpose, the vehicle control and diagnostic system messages are received and interpreted by the communication module, and then the information is transferred to the database. Test and measurement results can be recorded and relevant reports can be generated.

5.2.2. Repair/operation mode

The repair/operation mode allows the operating personnel to easily carry out repair procedures contained in the application database. As was the case with the diagnostics mode, the user selects a procedure from the database. The system then presents the following procedure steps in the form of graphics, animation or text. When moving from one key step to the next, the user is asked to confirm the execution of the task defined in the given step. Running the application in the repair/operation mode does not require connecting to the vehicle via a communication interface.

5.2.3. Learning mode

In the learning mode the application enables reviewing the contents of the procedures of the diagnostics and repair/operation modes in a simplified form, e.g. without connecting to the vehicle. In addition, a list of documents in the form of interactive repair and operation instruction manuals is available.

All of the operating modes of the application can be constructed based on the elements of augmented reality, virtual trainer software or dedicated multimedia instruction manuals. The above software, combined with the ability of connecting to the diagnostic system of the device, allows to develop an effective method of supporting repair personnel.

6. SUMMARY

Interactive multimedia instruction manuals offered by OBRUM's Simulator Department are a proven tool that improves the absorption of knowledge in the field of operation, use and maintenance of machines and devices [23], [24].

The software offered by OBRUM is compatible with a wide range of popular multimedia resources, such as: video/audio streaming, images, Flash animations, as well as 3D models and Unity3D simulations. The topics of multimedia instruction manuals are constantly developed at OBRUM, and the technical base and intellectual potential of the specialists allow for the carrying out of complex tasks.

One must remember that the development of a full multimedia instruction manual for the operation and use of a complex product (e.g. an engineering-road machine) or another product is a complex undertaking requiring the involvement of specialists [15] with expertise in many fields. A certain compromise between expenditures, time and the end result may have the form of a staged development of selected thematic areas in a multimedia form [17].

Supporting instruction processes, tools and method/mode of conducting instruction can be modified depending on the client's needs - shortened or expanded. OBRUM can also take on projects dealing with new instruction and training devices dedicated to conduct specific specialized instruction.

One of the additional descriptive materials may include, for instance, a specialist "Knowledge Base" the structure of which is based on the well-known online encyclopaedia - Wikipedia.

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