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FUNCTIONAL ASSUMPTIONS "HELICOPTER SIMULATOR FOR POLISH POLICE AVIATION"

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Abstract. The analysis of the training needs for the crews of police multi-purpose Black Hawk S70i helicopters serving in Polish Police Forces has been an impulse to attempt the construction of the simulation system within the research and development project financed by the National Centre for Research and Development entitled "Helicopter Simulator for Police Aviation" consisting of three components, i.e. a training stand for a pilot (cockpit), a stand for a cargo handler, a training stand for the police officers practicing the air drop operations. The simulator is supposed to provide an opportunity to drill various emergency situations, which consequently will allow to prepare the crews and technical personnel in the full range to perform the tasks as far as theoretical knowledge and practical skills are concerned. Replacing real exercises by the training held in virtual environment will contribute to the decreased costs to be incurred by Police and increased safety for any persons participating in the actions remaining the subject matters of the said trainings. The article presents the designing assumptions resulting, among other things, from multidisciplinary research performed over the determination of the detailed training needs and equipment requirements with regards to the Full Flight Simulator. The said research was conducted in collaboration with the officers of the Police Aviation Board in the High Command of the Police Headquarters as well as the operators of the counter terrorism sub-units of Polish Police Forces.

Key words: Simulator; helicopter; Police, security; training

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1. Introduction

Police Aviation in Poland has been struggling with low technical and social standards for many years. Obsolete fleet of helicopters as well as insufficient modernisation of the flying equipment for police officers have constituted the most evident problematic issues. The majority of equipment remaining at the disposal of the Police Aviation has been taken over from other formations. On top of that, the insufficient number of flying personnel within the Police Aviation, bringing about potential staff shortage in the near future (retirement of the flying personnel), ought to result in the development of new training solutions, which would allow to enhance the skills for helicopter crews in the years to come (Frątczak 2008, 52).

January 2019 brought a milestone in improving the situation for the Police Aviation, as three Black Hawk S70s multi-purpose helicopters to support Police forces were purchased so were three patrolling and observation Bell 407-GXi helicopters within the governmental programme entitled "Modernisation programme for Police, Border Guard, State Fire Service and State Protection Service for the years 2017-2020" (To był… 2020, 5). Currently, Polish Police have 13 helicopters in six bases: two Bell-206, three Bell-407, one Bell-412, two PZL W-3 Falcon, two Mi-8 and three S70i Black Hawk.

Providing Police with a new fleet of helicopters is related to meeting the training needs for their crews. However, most of the relevant trainings cannot be held in Poland. Training bases do not remain in the possession of training helicopters, specialist didactic aids an experienced staff. For the time being, specialist trainings for technical personnel including a full range of S-7- Black Hawk helicopter servicing and for the flight technicians including tactical use of the helicopters are held predominantly in USA, i.e.in Sikorsky Training Academy based in Stuart (Florida), Flight Safety – West Palm Beach (Florida) and GE Customer Training in Cincinnati (Ohio). The said centres hold theoretical and simulator-based trainings for S-70i helicopters or practical trainings for test pilots. Additionally, instructor trainings for S-70i Black Hawk helicopters are held in Mielec by PZL Sikorsky- Mielec. Completing the aforementioned trainings remains compulsory in order to obtain the authorizations to fly a given type of a helicopter. This brings about high costs to incur by Police as well as Polish Armed Forces, which purchased four helicopters of this type on 5th January 2019.

In order to meet the need to improve the flying techniques and servicing of helicopters in our country, new, alternative training solutions must be sought for (Gudzbeler, Struniawski 2017, 188) involving modern advances in IT, automatic controls, electronics, optical electronics, mechanics, electric and hydraulic drives as well as other related sciences . The most characteristic feature of such devices, especially simulators, includes the most credible reflection of real conditions (Sun, Li, Xiong…2018, 136). In order to reach the highest level in the servicing of equipment and devices, simulation training techniques are commonly used. Modern training devices are designed for such purposes (Grabania 2012, 133).

"Helicopter simulator for Police Aviation" may serve as an example here. The construction of the simulator was initiated by the Police Aviation Board of the Police Headquarters and is financed within the competition no 10/2019 of the National Centre for Research and Development regarding state defence and security. The simulation system is being erected by a consortium including two scientific units and one entrepreneur. The competences brought forward by the Police Academy in Szczytno (the leader) in the field of training Police officers are of high value here, as they are supported by Police experts form the Police High Command (including a fully trained Black Hawk S70i helicopter crew from the Police Aviation Board) and the Police Central Counter Terrorism Unit "BOA". The quality of the substantive side, especially with regards to scientific area related t security, is provided by the War Studies Academy in Warsaw. The fact that ETC-PZL Aerospace Industries Co. Ltd., as a manufacturer of aviation simulators since 1984, remains in the possession of advanced technological solutions in flight simulation and is highly knowledgeable in the technologies and software applied therein may be regarded as the key to the project's success.

2. Research method

Within the last several decades flight simulators have been playing an important role in training the civil and military pilots alike. Financial aspects prevail when it comes to the manufacturing or purchasing of such ones. Despite that fact that initial financial investment is high, taking advantage of simulation systems remains more cost-effective in the long-term perspective, in comparison to training pilots under real conditions (Zhao, Wu, Gu 2021). What is more, limited financial resources of various services may bring the trainings in real conditions to a hold or noticeably limit their numbers. The costs of jet fuel contribute to drastically limited training times for police, military or civil pilots. Hence, alternative training methods for the flying personnel have become the subject of seeking new solutions.

The determination of the research methods and range have been the starting point for a more detailed analysis.

The document analysis based on qualitative analysis technique remained one of the methods applied in the course of scientific inquiries. The source data obtained from the designing documentation for the "Helicopter Simulator for Police Aviation" no DOB-BIO10/07/2019 have been analysed thoroughly. Another method applied by the authors of the following article included the analysis and criticism towards the literature, mainly the literature of the subject, as well as the syllabuses of the specialist trainings for Police officers, pilots, flight technicians and counter terrorism units. As the following study fails to present the detailed description of the simulator itself due to the restrictions as to intellectual property rights set forth in the agreement to execute and finance the project, the research is marked with evident scientific constraints.

3. Functionalities of the helicopter Simulator for Police Aviation

The main objective of the project "Helicopter Simulator for Police Aviation" includes the construction of a Full Flight Simulator (FFS) for Black Hawk S70i helicopter (Stephens, Lewis, Johnson 2016)[1] with an airborne dismounting place.

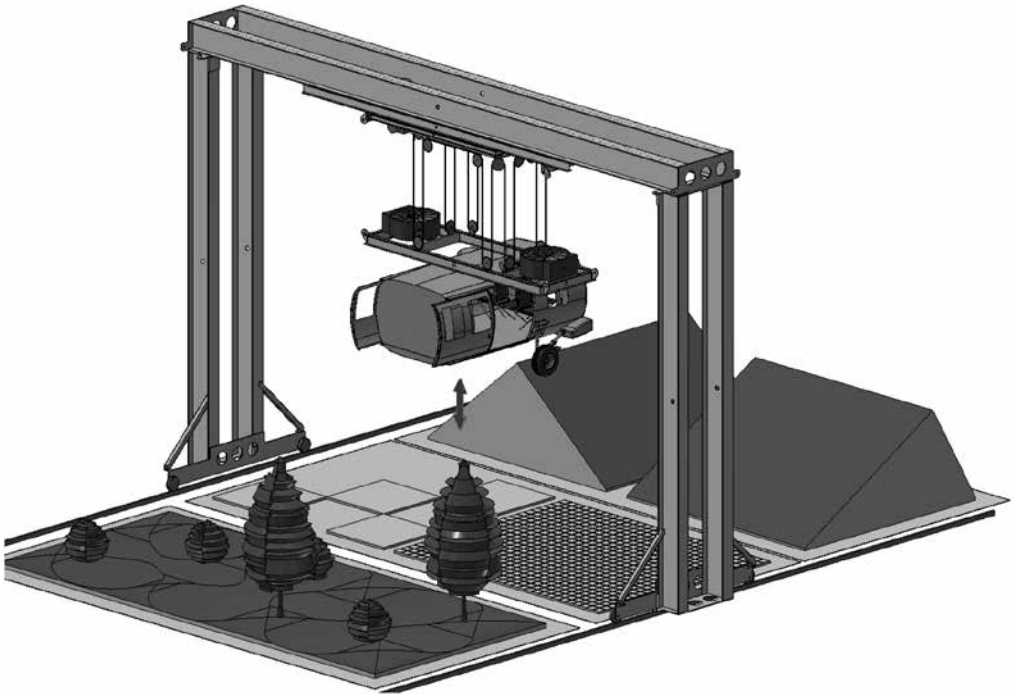

Figure 1. Visualization of the Landing module - a position that allows up-down movement.

Source: ETC-PZL Aerospace Industries Co. Ltd.

However, the detailed objectives shall include:

1. Analysis of the provisions set forth by the Civil Aviation Office and the range of operation as well as training for Police pilots.
2. Elaboration of the detailed functional guidelines to design the training devices and the helicopter simulator software
3. Designing and manufacturing of the training devices for the helicopter simulator
4. Designing and development of the helicopter simulator software
5. Assembly of the training devices as well as the implementation of the helicopter simulator software

[1] Full Flight Simulator (FFS) – the most technically advanced type of a simulator. Complete full-size and functional replica of the cockpit for a given type, model or series of an aircraft combined with the relevant computer system indispensable for aircraft representation during operations on the ground and in the air. The system of visualization provides the view outside the cockpit and the system of actuator represents mobility sensations. The device of this type is used to train flying personnel under dangerous flying conditions in order to get into the relevant habits.

The determined objectives are related, among others, to : the Development Strategy of the National Security System for the Republic of Poland 2012-2022[2], the Sustainable Development Strategy unit 2020 (with the perspective towards 2013), EUROPA 2020 Strategy (the Strategy for intelligent and sustainable development contributing to social inclusion)[3], i.e. the improvement of the conditions for running research and developmental activity and enhancing the level of education, the National Research Programme (Assumptions for the scientific and technical as well as innovative policy of the state), Priorities of the Police Commander in Chief for the years 2016-2020.

The project duration has been assumed for 48 months and shall be implemented in the following stages:

1. The stages related to scientific research
a) Development of the main designing assumptions as well as technical requirements for the system – resulting in a detailed specification for the training devices.
b) Verification of the basic components for individual system's modules
c) Verification under the conditions resembling the real ones for individual system's modules
d) Elaboration of the system demonstrator.
2. The stages including developmental works
a) Integration of the system components – the elaboration of the prototype, system examination under operational conditions for the system prototype, report on the tests an system demonstrations
b) Testing and demonstration of the ultimate form of the system
c) Report on the system tests and demonstrations under operational conditions
d) Checking the system under the real conditions (the manufacturing of the ready-made products, elaboration of the system technical documentation, elaboration of the system manual including, among others, the guidelines and standards for the system-based trainings).

Each stage shall terminate when a subsequent Technology Readiness Level (TRL) (Technology Readiness 2021) has been reached in line with the requirements set forth by an appendix to the Enactment of the Minister of Science and Tertiary Education dated 4th January 2011 on the manner to manage by the National Centre for Research and Development the implementation of scientific research or developmental works intended to state defence and security (Journal of Laws from the year 2011 number 18, item 91). The Technology Readiness Level to be achieved is IX. The project assumes that the simulator will be certified to grant the authorization for flight manoeuvres.

The research and developmental works (including the functional and operational requirements for the system resulting form the pragmatics of the tasks implemented by Police) shall lead to the creation of the FFS simulator for Black Haws S70i helicopter consisting of:

1. Pilot's training position (cockpit of the helicopter developed in collaboration with PZL Mielec and Sikorsky Company.
2. A position of the cargo handler.
3. Training position for the Police officers who train landing operation by means of an original cockpit.

The cockpit of the Black Hawk S70i helicopter shall be equipped with all devices and software required to represent an aircraft in ground and air operations. The visualization system shall consist of two modules: the visualization unit providing the imaging of the view outside the helicopter's cockpit along the plane of the horizon and additional TV-sets/monitors to observe the ground by a pilot while hovering .

2 https://www.bbn.gov.pl/pl/prace-biura/publikacje/8811,National-Security-Strategy-of-the-Republic-of-Poland.html (accessed 8 June 2021).

3 Smarter, greener, more inclusive? INDICATORS TO SUPPORT THE EUROPE 2020 STRATEGY. 2019 edition, Printed by Imprimerie Bietlot in Belgium, ISBN: 978-92-76-09826-3
https://ec.europa.eu/eurostat/documents/3217494/10155585/KS-04-19-559-EN-N.pdf/b8528d01-4f4f-9c1e-4cd4-86c2328559de?t=1570181425000 (accessed 9 June 2021).

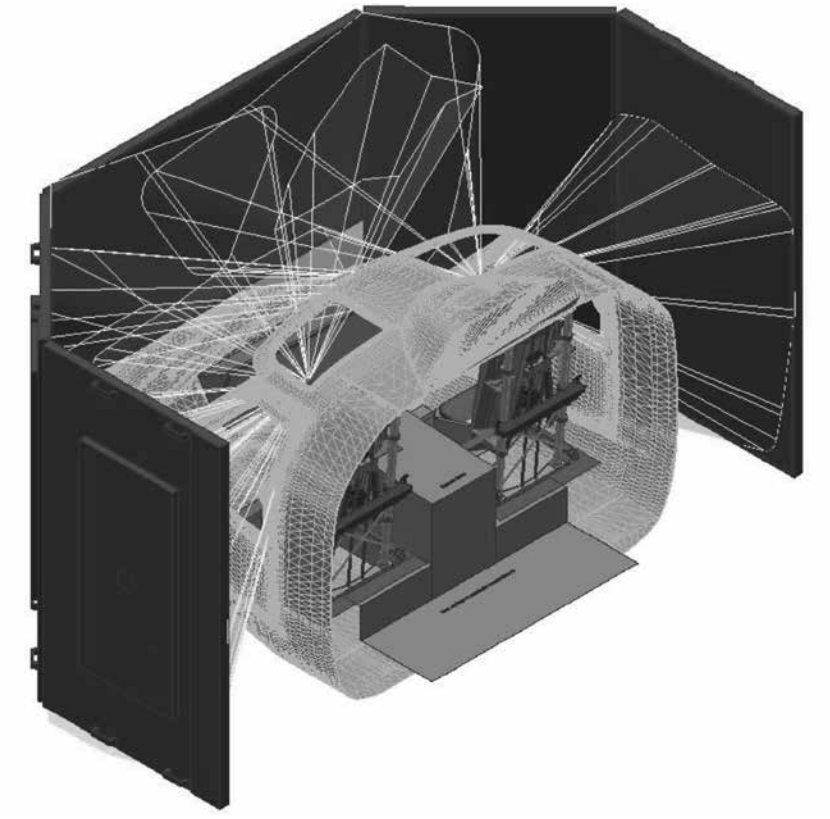

Figure 2. The concept of a visualization system with the use of large-format displays.

Source: ETC-PZL Aerospace Industries Co. Ltd.

The data base of the ground as well as 3D structures for Poland shall be performed by means of photogrammetry, which will provide the pilots with real impression of the helicopter motions (helicopter's dynamic model)

The adequate number of measurement flights were performed for the need of the construction, owing to which the simulator may be used to train the pilots and the navigators. The motion platform intended for the simulation system will be provided with all necessary certificates meeting the requirements of CS-FSTD(H) – the norms that a simulator of a given class must comply with. There are several training devices for flight simulation (FSTD) in Poland. The most important of such ones include:

1. Simulator W-3WA "Sokół", class Full Mission, manufactured by ETC-PZL Aerospace Industries Sp. z o.o. Currently in the course of the modernization process.
2. Flying training device (FTD level 2) SW-4 , extended by a mobility system, similar to FFS manufactured by CAE.
3. Flight training device (FTD level 3) EC 135 manufactured by Eurocopter.
4. Flight and navigation procedure training device (FNPT II) with exchangeable cockpits for SW-4 and Schweizer 300 helicopters, manufactured by ETC-PZL Aerospace Industries Sp. z o.o.
5. Flight training device (FTD) Guimbal Cabri G2 manufactured by Tech Sim Sp. z o.o.
6. Device "Selekcjoner" – the system to evaluate the aptitude for being a military pilot. The device is equipped with exchangeable cockpits , e.g. a simplified cockpit for W-3PL " Głuszec", manufactured by ETC-PZL Aerospace Industries Sp. z o.o.
7. The device to train spatial disorientation, equipped with the exchangeable cockpits for F-16 and M-28 aircrafts as well as W-3PL "Głuszec" helicopter, manufactured by ETC-PZL Aerospace Industries Sp. z o.o.

It has been planned to use a motion system with 6 degrees of freedom in the simulation system in order to secure maximal realistic impressions regarding the impact of all forces bearing importance for the pilots' training. Additionally, the motion system ought to generate the motions of the simulator cockpit which allow to simulate a series of situations to be encountered in the air. Mobility impressions shall be correlated with other stimuli (visual, sound, etc), providing a high degree of realism for the simulation. The stand shall be equipped with a documentation module as well, the foreplay module including all necessary scenarios that can be encountered by the officers on duty. The functionalities of the pilot's training stand shall include: basic and advanced flying manoeuvres, simulation of the failure and cooperation with a cargo handler.

An original cargo loading section of the helicopter will be used to erect the stand for a cargo handler as well as original equipment of such one, including a winch and fast rope. The preliminary examination of the actions performed at the stand for a cargo handler reveals that observation of the surroundings and communication with the pilots as well as the mobility of the entire cabin remain important for the actions performed by a cargo handler. Consequently, a special visualization system has been assumed to secure observation along the plane of the horizon and underneath the helicopter itself. An optimal solution for the visualization system shall selected based on the examination of the most cutting-edge technologies available, e.g. cave type or 3D goggles – the projectors perform imaging on the lateral walls and TV-sets under a sheet of Plexiglas (as the floor) secure imaging of the area underneath the helicopter.

Figure 3. Goggles Htc vive pro

Source: own materials

In order to simulate the progressive movements and angular movements of the helicopter, which noticeably hamper the actions for a cargo handler, a cargo handler stand will be installed as a motion system. The examinations shall be directed towards, among others, providing the adequate level of training. The functionality of the stand for a cargo handler shall include the following trainings: for a cargo handler, cooperation between a cargo handler and the pilots, dismounting, extracting of an injured person, cooperation between a boarding party with a cargo handler, emergency situations.

In order to provide a maximum level of realism of the trainings held for the officers practicing the landing operation, the purchasing of a real cargo section of the helicopter has been assumed together with its equipment, e.g. FRIES system with a winch and a hook. The range of the works anticipated assumes the development of a device to simulate landing operations from a low-altitude hovering as well as from high altitudes. The simulation of the changes in the positions of the cabin, where a team of officers stay and from which they land, remains an extremely important aspect. For this purpose, a special motion system has been assumed and shall be developed and applied.

Figure 4. Steward's platform Moog MB-EP-6DOF/40/8000KG.

Source: https://www.moog.de/produkte/bewegungssysteme/bewegungsplattformen/MB-EP-6DOF-40-8000KG.html (accessed 11 June 2021).

Another important element with regards to the landing stand includes a dedicated visualization unit, e.g. of cave type or based on 3D goggles – an optimal solutions shall be chosen based on the examination of the most cutting-edge technologies available. It shall consist of the imaging of the space surrounding the helicopter and a sub-unit to visualize space underneath the helicopter itself. Another product shall include a reinforced transparent floor and a screen placed underneath to visualize the space under the helicopter. In this manner , the options to perform jumps on the floor and to carry out evacuation shall be provided. The functionalities for the stand shall include: enhancing the skills to enter and leave the helicopter, mastering the skills to load and unload people (including the casualties), landing operation from a small height , trainings with different light intensity.

It has been assumed that individual stands (modules) of the simulator under construction shall cooperate within one simulation environment, which shall make simultaneous training for the pilots, officers performing the landing operation and a cargo handler possible.

The simulation system will be equipped with a module to exchange information with the Integrated Platform for Crisis Management Entities . Five simulators have been operating with the said Platform in Police and the State Fire System, i.e. the Simulator for Police Actions during Critical Situations, the Simulator to Drive Emergency Vehicles in Typical and Extreme Situations, the Simulator of the Training to Support Command during Rescuing Actions involving Fires in Multi-Storey Buildings and Traffic Accidents, the Simulator of the "Gryf" and "Ibis" Pyrotechnic Robots as well as UAV Simulator. All systems cooperate within one federation and use one HLA protocol. Communication occurs through the Internet and the standard services possesses by the entities where the systems are located. This diminishes noticeably the costs of the exercise when it comes to cooperation. Adding to it the helicopter simulator for the Police Aviation shall create a unique training platform worldwide for the entities subordinated to the Ministry of Internal Affairs and Administration.

The helicopter simulator shall possess real boards with functional components for steering, switches, instruments as well as basic and secondary flight steering devices which shall function in proper direction and within the proper motion range. The relevant switches in the cabin shall be located in the same layout as in the helicopter and they shall operate correctly while performing operational procedures or in case of defects requiring the crew reaction. Forces on the controlling instruments and the range of their motions shall correspond to the ones typical for Black Hawk S70i helicopter under the same conditions. The cockpit and the instructor's stand will be entirely closed and

encased in order to eliminate distractions. The lighting of the boards and instruments shall correspond to the one in an original helicopter and shall provide the same illumination level which will not distract a pilot. The Simulator shall provide the effect of aerodynamic changes for various combinations of flight speed and power commonly encountered during the flight, including the effect of changing the helicopter's location, forces and aerodynamic moments as well as drive forces, temperature, altitude, mass, centre of gravity and the configuration. Hence, a high-class dynamics model of the Black Hawk S70i helicopter shall be applied for this purpose. Representative aerodynamic data shall be used, adapted to the helicopter and marked with high accuracy sufficient to meet the objective testing requirements and to enable the correct operation and signalling of the systems. The readings of the relevant on-boards instruments shall react automatically to any steering movements made by a member of the crew, to the helicopter performance or to external, simulated environmental impacts over the helicopter.

All communication, navigation and warning devices shall be exact replicas of the real instruments installed in the helicopter, i.e. they shall have the same functionalities and the same reactions. All simulated navigations aids available will be used without any constraints and limitations. The simulator shall simulate the functioning of the helicopter's systems on the ground and in the air. The operational range for the system shall enable to perform operational procedures intended for normal, abnormal and emergency conditions. Apart from the stands for the flight crew members , additional seats for an instructor and an additional observer will be provided with the proper insight into the crew panel an the front window. The seat for the observer will be integrated to an extent sufficient to limit the mobility of the person who takes it in a safe manner in the course of any anticipated movement of the cockpit related to the simulation of the helicopter flight.

The proper functioning of the system after its start-up shall constitute an outcome for the system management by the helicopter crew and no actions through the software to be taken by an instructor shall be required. The instructor will be capable of controlling the simulator's variables as well as to enter the changes to the helicopter's systems, by doing which they will be generating proper conditions (normal or emergency ones) for the training process. The simulator represents the impact from the ground (helicopter's reactions to the contact with the surface while landing as well as aerodynamic impact of the ground closeness) and other data required to identify the flight conditions and configuration. It will also include various characteristics related to manoeuvring while being on the ground, including the controlling signals All actions will be harmonised with the vision projection module and the sound generating module. The instructor shall posses an option to modify the atmospheric conditions such as: wind direction, turbulences, cloud cover, temperature, atmospheric pressure, mist, precipitations. They will be able to change the time of the day and the state of the landing surface.

The simulator will minimize any delays between the actions of a trainee and the reactions from the simulated systems of the helicopter. This will refer to all module of the systems, such as visualization system or a mobility platform.

The system shall make it possible to visualize all indispensable elements of the surroundings at any time of the day, which will ameliorate the proper evaluation of the situation in the course of the manoeuvres taken and to recognize any landmarks. The simulator will be equipped with the state-of-the-art sound system, which will allow to generate the sounds typical for the helicopter, instruments and surroundings during ever phase of the exercise.

During the construction of the simulator the guidelines number 1 of the Civil Aviation Office President dated 14th February 2013 will be taken into consideration on certification specifications for aircraft training devices for flight simulation and certification specifications for helicopter training flight simulation devices.

The successful character of the project will be determined by the selection of the already existing technologies and the development of the new ones, all of which will contribute to the trainings to be held in the following areas:

a) Cooperation between other types of services, e.g. State Fire System, Border Guard, Mountain Rescue Service, The Tatras Mountain Rescue Service , special units of the Polish Armed Forces;
b) Cooperation between a helicopter pilot and the headquarters of the Police operation commander and

Police sub-units, especially while serving emergency events (e.g. public gatherings, mass events marked with high risk, natural disasters, etc.)

c) Cooperation between a pilot and special units of Police forces, especially with the Central Counter Terrorism Police Sub-unit 'BOA", independent Counter Terrorism Sub-units
d) Trainings for a cargo handler;
e) Actions to be completed while performing air drop operations;
f) Guiding a pilot while landing;
g) Flight manoeuvring within urban area, e.g. due to the impact of high buildings over the local gusts of winds bearing importance to the piloting techniques applied
h) Cooperation of the Simulator within he Integrated Platform for Emergency Management Entities

4. Conclusions

The performed analysis of the simulators market allows us to state that the only installation including a simulator for a Black Hawk S70i helicopter marked with a similar functionality to the developed system is located in Lockheed Martin training centre based in Florida (USA). What is more, none of the simulation solutions provides the capabilities to train techniques for air dropping or rescuing operations. They all focus on training the pilots. Combining the system with the Integrated Simulation Platform for Emergency Management Entities will change it into one of the most modern training environments for the entities responsible for internal security.

Owing to its modular characteristics, the solution shall provide training not only for the pilots of a Black Hawk S70i helicopter but also a joint training of the helicopter crew with a cargo handler and the services practicing the air drop. The number of the operators in the counter terrorism sub-units and having only three Black Hawk S70i helicopters in service makes it impossible to train the officers on the basics of the air drop, evacuation and extracting an injured person in a quick manner.

The aforementioned solution ought to fill in this gap and result in much better results when it comes to the trainings of new techniques as well as mastering and reinforcing of the already acquired ones. The fact of the cooperation between flying crew of the S70i helicopter and a flight instructor must receive special attention. This remains a unique arrangement that ought to be highlighted due to a capability to provide trainings of the emergency situations, which may be extremely dangerous for the lives and health of the officers when performed under real conditions (Merkisz, Nykaza 2017, 340).

The introduction of the simulator into the Police training system shall remain one of the ways to diminish its costs. Training the officers by means of the simulator will eliminate the material losses and the threat of losing the lives and deterioration of health that could result from the insufficient level of skills demonstrated by a trainee (Gudzbeler, Struniawski 2017). Other benefits related to the use of the said simulator shall include a possibility to conduct scientific research serving to evaluate the impact from the factors that could influence the quality of actions taken when assisted by a helicopter. The system will be used to develop and optimize the universal, benchmarking procedure for the conduct of the officers, predominantly for the helicopter's crew. This will allow to take advantage of their potential in a more effective manner. The system in question will be used to support the selection of the candidates for individual positions, excluding the commonly applied randomness which result in decreased security level for the society. The simulator will allow to evaluate mental burden accompanying the performance of tasks by the trainees and the individual examinations of the aptitude to complete them. An option to evaluate the impact of external factors over the speed and the quality of the actions taken by the officers under difficult conditions shall bear a special importance as well.

The system in question will ameliorate to train the Police personnel in a professional manner. Owing to mathematical models applied as well as the simulation methods used, the system reaction to the decisions taken by the trainees will be immediate and adequate to the situation that has come up (Gudzbeler, Struniawski 2017). It will involve repeated drilling of various variants, which consequently will allow to secure complete preparation of the crews and technical personnel servicing the aircraft as far as their theoretical knowledge and practical skills to perform the tasks set to them are concerned (Rypulak 2017, 54).

The introduction of the project to the market offer will fill in the gaps existing hitherto in many areas of the training crucial for the system of internal security of the state. Consequently, it will lead to better, more effective operations.

Trainings held at the simulator will provide a possibility to perform current practice in order to maintain proper flying habits. Additionally, replacing real exercises by the training held in virtual environment will contribute to the decreased fuel consumption and exhaust gas emissions. The limited equipment wear will bring about noticeable level of savings as well, which appears to be important in case of large-scale training activities to be performed. Increased safety for any persons participating in the actions remaining the subject matters of the said trainings remains a subsequent important aspect here.

Implementation of the aforementioned solution will influence not only the training process for Police forces but will contribute towards the establishment of the training systems for other entities taking advantage of Black Hawk helicopters as well. Immense training needs have been reported by the Ministry of National Defence. European and world entities using Black Hawk S70i helicopters in their actions and being involved in the security and defence sector have been anticipated to demonstrate interest in the system as well.

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