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## FUNCTIONAL ASSUMPTIONS FOR THE “HELICOPTER SIMULATOR FOR POLICE AVIATION”

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### Abstract

An analysis of 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 execute drills of various emergency situations, which consequently will allow preparing 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 training held in a virtual environment is expected to contribute to a decrease in costs to be incurred by Police and enhanced safety for any persons participating in the actions remaining the subject of the said trainings.

The article presents the design assumptions that arise, 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.

**Keywords:** Simulator, helicopter, Police, security, training

## ZAŁOŻENIA FUNKCJONALNE „SYMULATORA ŚMIGŁOWCA DLA LOTNICTWA POLICYJNEGO”

### Abstrakt

Analiza potrzeb szkoleniowych załóg policyjnych śmigłowców wielozadaniowych Black Hawk S70i służących w polskiej Policji stała się impulsem do podjęcia próby budowy systemu symulacyjnego w ramach projektu badawczo-rozwojowego finansowanego przez Narodowe Centrum Badań i Rozwoju pt. „Symulator Śmigłowcowy Lotnictwa Policyjnego”, składającego się z trzech komponentów, tj. stanowiska szkoleniowego dla pilota (kokpit), stanowiska dla ładowacza, stanowiska szkoleniowego dla policjantów ćwiczących operacje zrzutu. Symulator powinien umożliwić przećwiczenie różnych sytuacji awaryjnych, co w rezultacie pozwoli na przygotowanie załóg i personelu technicznego w pełnym zakresie do wykonywania zadań w zakresie wiedzy teoretycznej i umiejętności praktycznych

Zastąpienie ćwiczeń rzeczywistych szkoleniami w środowisku wirtualnym przyczyni się do zmniejszenia kosztów ponoszonych przez Policję oraz zwiększenia bezpieczeństwa osób uczestniczących w działaniach pozostających w zakresie przedmiotowym tych szkoleń.

W artykule przedstawiono założenia projektowe wynikające m.in. z interdyscyplinarnych badań nad określeniem szczegółowych potrzeb szkoleniowych i wymagań sprzętowych w odniesieniu do pełnego symulatora lotu. Badania te zostały przeprowadzone we współpracy z funkcjonariuszami Zarządu Lotnictwa Policji w Komendzie Głównej Policji oraz operatorami pododdziałów antyterrorystycznych polskiej Policji.

**Słowa kluczowe:** Symulator, helikopter, policja, bezpieczeństwo, szkolenie

### Introduction

Police Aviation has been struggling with low technical and social standards for many years. The most evident problematic issues comprised an obsolete fleet of helicopters as well as insufficient modernisation of the flying equipment for police officers. 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 that may give rise to a potential staff shortage in the near future (retirement of the flying personnel) should lead to the development in the development of new training solutions, which would allow enhancing the skills for helicopter crews in the years to come [1, pp. 3–4].

January 2019 brought a milestone in improving the situation of the Police Aviation, as three Black Hawk S70s multi-purpose helicopters were purchased to support Police forces, and so were three patrolling and observation Bell 407-GXi helicopters under the governmental programme entitled “Modernisation programme for Police, Border Guard, State Fire Service and State Protection Service for the years 2017–2020”.

Providing the Police with a new fleet of helicopters was necessary to meet the training needs for their crews. However, most of the relevant trainings cannot be

held in Poland. Training bases do not have at their disposal training helicopters, specialist didactic aids or experienced staff. For the time being, specialist training for technical personnel, including a full range of S-7- Black Hawk helicopter servicing, as well as that for the flight technicians including the tactical use of helicopters, are held predominantly in USA, i.e. in the 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 training for S-70i helicopters or practical training for test pilots. Additionally, instructor training for S-70i Black Hawk helicopters is delivered in Mielec by PZL Sikorsky-Mielec. Completing the aforementioned training courses remains compulsory to obtain the necessary authorizations to fly a given type of a helicopter. This brings about high costs to incur by the Police as well as Polish Armed Forces, which purchased four helicopters of this type on 5<sup>th</sup> January 2019.

In order to meet the need for improving the flying techniques and servicing of helicopters in Poland, new alternative training solutions must be sought for [2], 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, involves the necessity of assuring the most credible reflection of real conditions. In order to achieve the highest level in the servicing of equipment and devices, simulation training techniques are commonly used. Modern training devices are designed for such purposes [3].

The “Helicopter simulator for Police Aviation” may serve as an example at this point. The simulator construction was initiated by the Police Aviation Board of the Police Headquarters and is financed under 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 from 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 to 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 possession of advanced technological solutions in flight simulation and is highly knowledgeable in the associated technologies and software may be regarded as the key to the project’s success.

## Research method

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

The establishment of research methods and range have been the starting point for a more in-depth 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 author of the article included an analysis and criticism of the literature available, mainly the literature directly dedicated to the subject, as well as syllabuses of specialist training courses for Police officers, pilots, flight technicians and counter terrorism units. As the following study fails to present a detailed description of the simulator itself due to the restrictions applicable to intellectual property rights set forth in the agreement to execute and finance the project, the research is marked with evident scientific constraints.

## 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<sup>1</sup> with an airborne dismounting place. However, the detailed objectives shall include:

1. Analysis of provisions set forth by the Civil Aviation Office and the range of operation as well as training for Police pilots.

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<sup>1</sup> Full Flight Simulator (FFS) – the most technically advanced type of 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 visualization system provides a view outside the cockpit while the actuator system represents mobility sensations. The device of this type is used to train flying personnel under dangerous flying conditions in order to work out the relevant habits.

2. Development of 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.

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

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

1. Stages related to scientific research
  - a) Development of the main design 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 modules.
  - c) Verification in conditions resembling the actual ones for individual system modules.
  - d) Elaboration of the system demonstrator.
2. Stages including developmental works
  - a) Integration of system components – development of a prototype, system examination in operational conditions for the system prototype, report on the tests and system demonstrations.
  - b) Testing and demonstration of the ultimate form of the system.
  - c) Report on system tests and demonstrations under operational conditions
  - d) Checking the system in the real conditions (manufacturing of ready-made products, devising of technical documentation of the system, elaboration of the system manual including, among others, guidelines and standards for the system-based training courses).

Each stage shall terminate when a subsequent Technology Readiness Level (TRL) has been reached in line with requirements set forth by appendix to the Regulation of the Minister of Science and Higher Education dated 4<sup>th</sup> January 2011 on the manner of managing by the National Centre for Research and Development the implementation of scientific research or developmental works for needs of

state defence and security (Polish Journal of Laws/Dz.U. from 2011, No. 18, item 91). The Technology Readiness Level to be achieved is IX. The project assumes that the simulator would be certified to grant the authorization for flight manoeuvres.

The research and developmental works (including functional and operational requirements for the system resulting from the pragmatics of the tasks implemented by the Police) are to enable the creation of a FFS simulator for Black Haws S70i helicopter comprising the following:

1. Pilot's training position (cockpit of the helicopter developed in collaboration with PZL Mielec and Sikorsky Company).
2. Cargo handler position.
3. Training position for the Police officers to learn landing operation with the use 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 during ground and air operations. The visualization system shall consist of two modules: the visualization unit providing imaging of the view outside the helicopter's cockpit along the horizon plane and additional TV-sets/monitors to observe the ground by a pilot while hovering. The data base of the ground as well as 3D structures for Poland shall be performed by means of photogrammetric to provide the pilots with real impression of the helicopter motions (helicopter's dynamic model)

A sufficient number of measurement flights have been carried out for the design needs so that the simulator can be used for pilot and navigator training. The motion platform intended for the simulation system will be provided with all necessary certificates meeting the requirements of CS-FSTD(H) 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 ones include:

1. "Sokół" Simulator W-3WA, Full Mission class, manufactured by ETC-PZL Aerospace Industries Sp. z o.o. Currently in the course of a modernization process.
2. Flight 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.
4. Flight training device (FTD) Guimbal Cabri G2 manufactured by Tech Sim Sp. z o.o.
5. "Selekcjoner" device – a 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.

6. A 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.

Plans assumed the use of 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 that are of importance for the pilots' training. Additionally, the motion system should generate to generate the motions of the simulator cockpit which allow simulating a series of situations to be anticipated in the air. Mobility impressions would be correlated with other stimuli (visual, sound, etc.), providing a high degree of realism for the simulation. The stand is also to be equipped with a documentation module, 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 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 its original equipment, including a winch and fast rope. The preliminary examination of actions performed at the cargo handler stand reveals that observation of the surroundings and communication with the pilots as well as the mobility of the entire cabin remain important for all actions to be performed by a cargo handler. Consequently, a special visualization system has been assumed to secure observation along the horizon plane and directly underneath the helicopter. An optimal solution for the visualization system will be selected based on the examination of cutting-edge technologies available, e.g. cave type or 3D goggles – the projectors perform imaging on lateral walls and TV-sets under a sheet of Plexiglas (as the floor) secure imaging of the area underneath the helicopter. 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 focused, among others, on assuring an adequate level of training. The functionality of the stand for a cargo handler shall include the following training courses: 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 and diverse emergency situations.

To provide a maximum level of realism of the courses addressed at officers practicing the landing operation, a real cargo section of the helicopter was planned together with its equipment, e.g. FRIES system including a winch and a hook. The anticipated range of works assumes the development of a device to simulate landing operations from low-altitude hovering as well as from high altitudes. An extremely important aspect is the simulation of dynamic changes in the position of the cabin containing the disembarking team of who disembark from it. For this purpose,



a special motion system has been planned and shall be developed and put into use. A further important element related to the landing stand includes a dedicated visualization unit, e.g. of cave type or based on 3D goggles – an optimal solution will be chosen based on an examination of available cutting-edge technologies. It will consist of imaging of the space surrounding the helicopter and a sub-unit to visualize space directly underneath the helicopter. Another product shall include a reinforced transparent floor and a screen placed underneath to visualize the space under the helicopter. This assures the opportunity of performing jumps onto the floor and to carry out evacuation procedures. The functionalities for the stand are to include enhanced skills of entering and leaving the helicopter, mastering the skills of loading and unloading people (including casualties), landing operation from a small height, and training involving different light intensities.

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

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 the Police and the State Fire System, i.e. a Simulator for Police Actions during Critical Situations, a Simulator to Drive Emergency Vehicles in Typical and Extreme Situations, a Simulator of the Training to Support Command during Rescuing Actions involving Fires in Multi-Storey Buildings and Traffic Accidents, a Simulator of the “Gryf” and “Ibis” Pyrotechnic Robots, as well as an UAV Simulator. All systems cooperate within one federation and use a single HLA protocol. Communication takes place through the Internet and the standard services at disposal of entities where those systems are located. This perceptibly reduces the costs of the exercise with respect to cooperation. Its expansion by the helicopter simulator for the Police Aviation shall create a unique training platform worldwide for entities subordinated to the Ministry of Internal Affairs and Administration.

The helicopter simulator will be equipped with real boards having functional components for steering, switches, instruments as well as basic and secondary flight steering devices which shall function in the proper direction and within the proper motion range. The relevant switches in the cabin will be located in the same layout as in the helicopter and they would be operating correctly while operational procedures are being performed or in case of defects requiring a reaction of the crew. Forces on the controlling instruments and the range of their motions must correspond with the ones typical for Black Hawk S70i helicopter operating in the same conditions. The cockpit and the instructor’s stand will be entirely closed and encased in order to eliminate distractions. The lighting of boards and instruments will correspond to the one in an original helicopter and will provide the same



illumination level that may not distract a pilot. The Simulator is expected to provide the effect of aerodynamic changes for various combinations of flight speed and power generally encountered during a 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 configuration. Hence, a high-class dynamics model of the Black Hawk S70i helicopter will be adopted for this purpose. Use will be made of representative aerodynamic data, 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 relevant on-board instruments will react automatically to any steering movements made by a crew member, to the helicopter performance or to external, simulated environmental influences on the helicopter.

All communication, navigation and warning devices will be exact replicas of real instruments installed in the helicopter, i.e. with the same functionalities and the same reactions. All available simulated navigation aids will be used without any constraints or limitations. The simulator shall imitate the functioning of the helicopter's systems both on the ground and in the air. The operational range for the system is to enable performing operational procedures intended for normal, irregular and emergency conditions. Apart from the stands designated for the flight crew members, additional seats for an instructor and an additional observer will be provided to ensure proper insight into the crew panel and the front window. The observer's seat will be integrated to a sufficient extent to limit the mobility of the person occupying 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 deployment will be the result of system management by the helicopter crew and will not require the instructor to perform any actions with the use of the software. The instructor will be capable of controlling the simulator's variables as well as to enter any necessary 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 during landing as well as the aerodynamic impact of the ground closeness) and other data required to identify of 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 will be able to modify optionally the atmospheric conditions, such as: wind direction, turbulences, cloud cover, temperature, atmospheric pressure, mist and precipitations. It will also be possible to change the time of the day and the condition of the landing surface.

The simulator will minimize any delays that could take place between actions of a trainee and the reactions from the simulated systems of the helicopter. This will be applicable to all modules of the systems, such as visualization system or the mobility platform.

Furthermore, the system will allow visualising of all indispensable elements of the surroundings at any time of the day, which in turn will enhance the proper evaluation of the situation during manoeuvres and recognising the required landmarks. The simulator will be equipped with a state-of-the-art sound system intended to allow generating sounds typical for the helicopter, instruments and surroundings during every phase of the exercise.

During the construction of the simulator it is necessary to take into consideration guideline number 1 of the Civil Aviation Office President dated 14<sup>th</sup> February 2013 on certification specifications for aircraft training devices in flight simulation and certification specifications for helicopter training flight simulation devices.

The successful character of the project will depend on the selection of the already existing technologies and the development of new ones, all of which will help contribute to training to be held in the following areas:

- a) Cooperation between other types of services, e.g. the State Fire System, the Border Guard, the 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 as being 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) Training 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 of importance to the adopted piloting techniques;
- h) Cooperation of the Simulator within the Integrated Platform for Emergency Management Entities.

## Conclusions

The conducted analysis of the simulators market allows the presumption that the only installation including a simulator for a Black Hawk S70i helicopter offering

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 desired 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 all entities responsible for internal security.

Owing to its modular characteristics, the solution will offer 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 services practicing the air drop. The number of officers of counter-terrorist sub-units and having at disposal only three S70i helicopters at the moment does not allow a quick training in basic landing, evacuation and taking up the wounded

The above described solution is expected to fill this gap and allow achieving much better results when it comes to teaching new techniques as well as mastering and boosting the already acquired ones. Special attention should be given to the fact of the cooperation between flying crew of the S70i helicopter and a flight instructor. This remains a unique arrangement that should be emphasised due to a capability to provide training related to emergency situations, which may be extremely dangerous for the lives and health of officers when performed under real conditions [4, pp. 338–341].

The introduction of the simulator into the Police training system is expected to help reduce its costs. Training the officers with the use of a simulator will eliminate the material losses as well as the threat of the loss of life or health impairment that could result from the insufficient level of skills demonstrated by a trainee [5]. Other benefits related to the use of the said simulator include a possibility of carrying out scientific research intended to evaluate the impact of factors that could affect the quality of undertaken actions when assisted by a helicopter. The system will be used to develop and optimize the universal, benchmarking procedure applicable to the conduct of the officers, predominantly for the helicopter's crew. This will allow taking advantage of their potential in a more effective manner. The system in question will be used to support the selection of candidates for individual positions, excluding the commonly applied randomness that could result in decreased security level for the society. The simulator will allow evaluating the 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 will also be of great importance.

The system in question will facilitate training of Police personnel in a professional manner. Owing to mathematical applied models as well as the simulation methods adopted, the system reaction to decisions taken by the trainees will be

immediate and adequate to the individual situation [2]. It will allow repeated practice of different variants, which will consequently enable crews and aircraft maintenance personnel to be fully prepared, both in terms of theoretical knowledge and practical skills, for the tasks assigned to them [6].

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

Training carried out in a simulator will provide a possibility of performing current practice intended to maintain proper flying habits. Additionally, replacing real exercises by the training held in a virtual environment will contribute to 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 planned large-scale training activities. Increased safety of all persons involved in actions comprised by the described training remains a subsequent important aspect in this case.

The implementation of the aforementioned solution will affect not only the training process of the Police forces but will contribute towards the establishment of training systems for other entities that make use 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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