SIMULATORS IN AERONAUTICAL TRAINING OF MILITARY AVIATION OF THE POLISH ARMED FORCES

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Summary. The article describes and characterizes flight simulators used by the military aviation of the Polish Armed Forces. A division of simulators as a training tool for aviation personnel is made and their construction and usage is presented.

Keywords: simulator, aeronautical training, air force, Polish Armed Forces, aviation personnel.

1. INTRODUCTION

One of the basic types of the Polish Armed Forces is the Air Force. Appropriate training of aviation personnel and continuous improvement of soldiers' skills is the guarantor of their success in future activities. For many years relevant doctrines, instructions and training programs have constituted the basis for flight training, however pilots, navigators and engineers have yet an appropriate tool – simulators. Along with the development of aviation and improvement of aviation facilities, simulators have become a significant teaching aid which allows to prepare aviation staff for the proper use of the facilities. The term 'simulators' originates from 'simulation' that is an artificial reproduction of features of a given object, phenomena with the use of a laboratory-generated model [1]. Therefore a feature that distinguishes simulators from majority of devices is as faithful as practicable reproduction of real conditions. To meet these requirements, contemporary flight simulators used by the Polish Army apply special hydraulic-driven motion platforms. The novelty are flight simulators taking advantage of advanced computer simulation together with complex visualization systems[1] [2]. However, it was not always so ….

2. FLIGHT SIMULATORS USED IN POLISH MILITARY AVIATION IN THE YEARS 1950-2000

Until 1939, flight simulators in Polish aviation were not used [3]. Their dynamic growth took place in the fifties with the introduction of 'very modern' at that time aircraft: Yak-17, Yak-32 and Mig-15. In the world, the rise of simulators dates back much earlier. In 1917 the first results similar to a simulation were obtained by suspending the airframe along with the pilot at the line and interacting with him by the stream of air generated by the propeller. However, it is considered that the beginning of the simulators is the period 1910-1911, when France used the unfit for flying apparatus for control study. Mounted on a hinged bracket it allowed students to observe any position of the apparatus relative to the visible horizon of the earth [4].

[1] Contemporary flight Simulator are electronic devices whose main element is a computer which enables model ling of features and functions of the aircraft.

Photo 1. Simulator of MiG – 15 (TŁ-1M**)**
Source: photo Dariusz BOGUSZ

In times of the Polish People's Republic, Polish aviation was based on aircraft constructed in the former Soviet Union. Retrofitting them with more and more advanced avionics imposed on aviation personnel performance of increasingly complex tasks. The more demanding requirements the higher training costs, therefore their reduction became an issue of consideration. The effects were supposed to be provided by simulators (Figure 1).

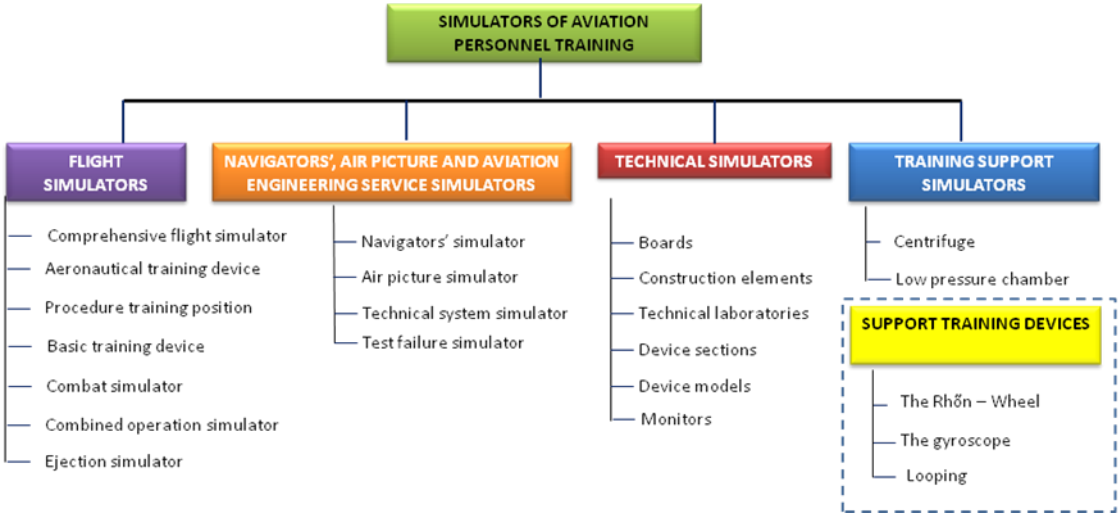

Figure 1. Division of flight simulators
Source: Own development

Flight simulators are an essential and the most comprehensive group of simulators that support aviation personnel training. In the fifties, Polish aviation acquired first simulators (Figure 2) which were provided together with MiG-15 aircraft. These were TŁ-1 cabins and STŁ-1 and 2 firing simulators. TŁ-1 cabins(photo 1) were designed to prepare pilots for instrument flights. At that time it was a very difficult task because pilots had to be authorised for 'cloud penetration', and the artificial horizon very often provided wrong indications about aircraft position. TŁ-1 was an excellent help in understanding how to perform a manoeuvre and what direction should be taken, after cloud penetration, to be positioned just above the aerodrome. Undoubtedly, the advantage of this device was the ability to simulate some emergency situations as well as to

programme wind force exerted during flight and its direction. STŁ-1 and STŁ-2 simulators were designed for firing exercise training. STŁ-1 consisted of a metal frame with sight affixed to it, control stick with the trigger, rudder pedals and a gunner seat. The task of a trainee was to track and guide simulated fire into the target – model aircraft suspended on a perimeter-stretched wire. STŁ-2 was equipped with firing instruments, aircraft control levers, gyro sight and fire-guide imitator. In front of the cabin, the screen displayed photographic image of the sky which moved proportionally to the angular velocity of simulated aircraft, and the horizon line responded adequately to aircraft banking. The second projector displayed a silver silhouette of the targeted aircraft (fighters or bombers) against the sky. Next, depending on the speed, the target was approaching, moving away or remained at a fixed distance. The trainee assignment was to properly track the target, that is, to keep the focal point of the sight grid thus introducing the distance to the target, to get closer to a rational distance firing and pull the onboard weapon trigger. Hitting traces were marked by red dots on the screen. The instructor desktop accessories, located just behind the cockpit, allowed monitoring of the exercise and the evaluation of its results.

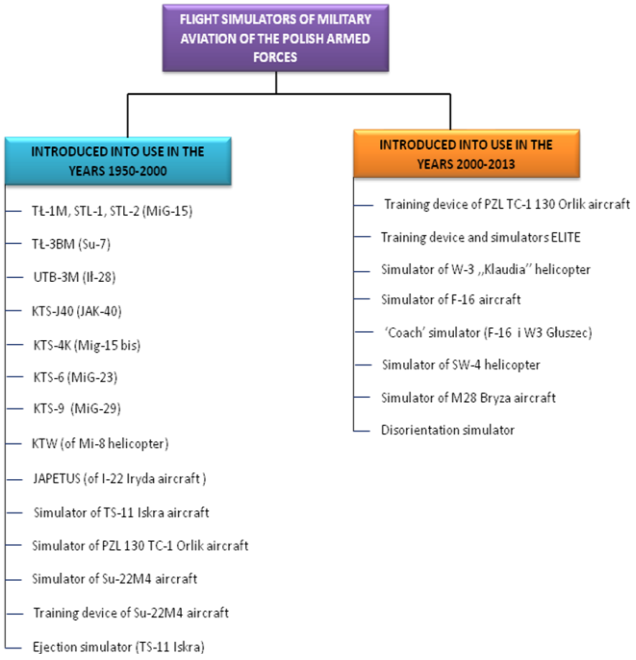

Figure 2. Flight simulators used by military aviation of the Polish Armed Forces in the years 1950-2013
Source: Own development

Another simulator is TŁ-3BM which was designed to train pilots on the basis of onboard instruments of Su-7 aircraft. It consisted of a cabin, the instructor position and a visual firing system. The system was composed of a projector mounted behind the pilot whose task was to project targets into a front-positioned screen. One of the assignments during pilot training was firing cannons and missiles at the target controlled by the instructor.

In the years 1961-1964, for the needs of the then Military Aviation School, UTB -3M bombardier's simulator was used for Ił-28 aircrew training. The simulator was made of the cut front inner part of Ił -28 aircraft where the pilot and bombardier's positions were located. The cabin contained handling & navigational instruments together with real AP- 5 autopilot imitator which enabled practice in an automatic output into combat course. The aim of the training was to develop bombardier habits during imitated bombing on movable and immovable ground targets using in the process of targeting a variety of sights, as well as entry of ballistic bomb data which enabled training in bombing with various types of bombs. Additionally, the device allowed to use pictures of

real photographic reconnaissance of the target or area where the task was executed for practicing simulated combat mission.

In the mid-1980s, WSK PZL began work on the adaptation of the Soviet simulator KTS-4 for Mig-21 bis aircraft. Finally, as a result of the application of modern imitators, equipment and visualization system, the first comprehensive device for pilot training under the name KTS-4M was developed in Poland. The simulator consisted of the cockpit and the screen placed in front of it. The movements of flight controls were simulated using a mobile television camera. The advantage of the simulator was the ability to simulate aerodynamic loads as well as the ability to play sound effects such as the engine. Subsequent modification (KTS-4K) allowed the use of a simulator with simulated weaponry, the on-board radar and sighting systems. Noteworthy is the fact that in just a year of operation, the number of KTS-4K working hours was 1476, which gives an average of five hours a day.

Another 'modern' at that time simulator of the USSR production was KTS-6 developed for Mig-23aircraft. The simulator consisted of a cabin with 'Safir' radar station and three monitors placed in front of it. The advantage of the simulator was the ability to train pilots in the scope of airborne target interception and engagement. In addition, the simulator allowed training of flight with interferences, en-route flying or practicing start-up procedures, the on-board systems and cabin check.

With the introduction of Mig-29 fighter, KTS-9 simulator of 'Russian' production was introduced. Used to this day in 23 Tactical Air Base in Mińsk Mazowiecki, it allows the simulation of the on-board armament and the cabin. Due to its limited capacity and the old design it does not allow for accurate reproduction of the real behaviour of the aircraft. Along with the modernization of Mig-29 aircraft and the extension of the TBO, efforts were initiated on the acquisition of a new simulator. It is supposed to consist of the cabin, which is a modernized replica of a fighter, the instructor position, computer and visualization systems. The new device will have the ability to practice air combat, emergency procedures and to perform a number of missions and will be one of the most advanced simulators in the country.

The only helicopter simulator used at that time was KTW simulator of Mi-8 helicopter. It was used for procedure and emergency situation training. It was equipped with a platform of three degrees of freedom and a black & white visualisation system. Currently, Polish pilots undergo Mi-8 simulator training but this modern device is available in the Czech training centre of aircrews and ground personnel 'Helicopter Training Point' located in Ostrava international airport.

In the eighties, further development of simulators, but of domestic production, took place. First, in 1987, the Simulation and Electronic System Innovation and Implementation Plant was established, then in 1991, it was replaced by a company called 'Aerospace Industries Ltd' which has produced simulators for the Polish army to this day. By incorporating the Spanish capital, Polish industry had an opportunity to use advanced technologies. As a consequence, in 1992 the JAPETUS simulator of I-22 Iryda aircraft was installed at the Military Institute of Aviation Medicine. It was the first device in Poland equipped with a system imitating an aircraft on a hydraulic platform consisting of six cylinders. The simulator is equipped with a three-channel system for the presentation of the external situation, as well as sound imitation system, onboard armament system and communication & onboard equipment system. In 1997 it was modernised by installing medical apparatus for measurement of pilot physiological parameters. As a result, it has become a modern device for pre-selection of candidates for military pilots [5].

In the nineties the company PZL-Aerospace Industries undertook the next task, namely creation of modern devices for pilot training. The outcome of this project was installation of modern TS-11 Iskra simulator (photo 2) in Dęblin Eaglets' School in 1994 and 'Orlik' aircraft simulator in 1995 (photo 3). PZL TS-11 simulator is an advanced stationary training device mapping the operation of TS-11 'Iskra' aircraft equipped with SO-3 engine. The fundamental element of the simulator is the cabin reproducing all onboard instruments. Installation of background noise system as well as image visualization system composed of three collimators allow to make the flight more realistic. The control of the entire operation of the device is provided from the instructor position having an additional capability of exercise programming and monitoring. Study and training of procedures, emergencies or

basic handling & navigational assignments puts it at the forefront of simulators used for cadet training.

Photo 2. Simulator of TS-11 Iskra aircraft
Source: photo Dariusz BOGUSZ

On 15 May 1995 Dęblin Eaglets' School received another stationary training device mapping the operation of PZL-130 TC1 'Orlik' aircraft with Walter M601T engine of Motorleta production and V510 five-blade propeller of Avia Praga production. The simulator was provided with an advanced image generation system of Silicon Graphics company composed of three collimators and a fast Novell company computer. A trainee can observe the environment through the cabin front and front-side screens in a horizontal angle of 120° and an elevation angle of 30°. During exercises the simulator generates digital sound and artificial load corresponding to the actual forces occurring during flight. Forces exerted on the control stick during simulator flight are adequate to the actual load. The device allows training in various weather conditions, different times of day and seasons of year, which makes it an excellent teaching aid.

Photo 3. Simulator of PZL 130 TC-1 Orlik aircraft
Source: photo Dariusz BOGUSZ

In 1998 the company PZL-Aerospace Industries developed and submitted to the use the simulator of Su-22M4 combat aircraft. The primary purpose of the simulator is to train pilots in real combat mission using a variety of weapons such as television, anti radar, laser and infrared missiles. To enhance realism, the essential part of the simulator is placed on a mobile platform with 6 degrees of freedom. In addition to this, ONYX Silicon Graphics visualization system generates the image of external environment of 40 000 km2 surface on a three-channel display and sound & audio system plays all sounds related to aircraft operation. An additional supplement of the simulator was the squadron stationary EUT Su-22M4 training device. It allows pilot training in the scope of navigational

procedures and weapon employment. All cabin devices were developed as the most faithful reproduction of onboard (flight) instruments, and their method of use is identical to the real. This relatively simple device costs 15% of the mobile full mission simulator (FMS) [6].

The last simulator introduced for use in the Polish army before 2000 was the ejection simulator of TS-11 Iskra aircraft. The device allows to practice procedures and proper preparation of aircraft emergency leaving. The simulator cabin is a simplified replica of the real aircraft equipped with elements of high altitude rescue equipment and the exact replica of the ejection seat. The instructor position allows control of the operation and the technical efficiency of the device as well as monitoring of the conduct of exercises. It is also important that the simulator can be equipped with a different aircraft cabin, therefore the same simulator, but with F-16 cabin is located in Łask air base.

3. FLIGHT SIMULATORS USED IN POLISH MILITARY AVIATION AFTER 2000

The dynamic development of computer graphics and multimedia devices after 2000 caused that the simulator designers' environment began to seek newer solutions related to the art of piloting . The native manufacturer o simulators, PZL - Aerospace Industries, did not remain indifferent to this trend. The result is the abandonment of mobile platforms and their replacement by modern projectors with few of them in recent simulators. A good example to illustrate is a training device of PZL-130 TC-1 'ORLIK' aircraft introduced in 2002. It is a device designed to conduct ground training in the scope of handling the onboard aircraft equipment and systems as well as performing emergency procedures and tasks. It consists of a cabin being the reproduction of a real aircraft, the instructor position, the visualization system and additional accessories. An excellent visualization is provided by a new generation computer with image presentation system that generates the image of the external environment and displays it on a 50" screen placed in front of the cockpit.

At the turn of 2000 another helicopter simulator was developed - W-3 'Klaudia'. This Polish construction has been used for pilot training in the 25th Air Cavalry Brigade since 25 June 2003. It's essential part is a faithful copy of 'Sokół' cabin with side number 810 , and the whole is placed on 6-point hydraulic cylinders that support the reality of pilot feelings during the flight. The aircrew cabin was equipped with flight controls along with a number of imitators of all flight instruments and switches that strikingly resemble a combat helicopter . In addition, it has two generators simulating vibrations located in pilot seats. The instructor position is equipped with monitors and flight controls system that is used to activate the simulator, to control the exercise conduct, to simulate failures and to control the virtual environment. An important element of this position is to oversee simulator systems and crew behaviour in the cockpit of the helicopter. The dynamic hydraulic platform was designed and constructed specifically for stringent requirements of the simulator. Its total capacity is 8500 kg , and the maximum acceleration up to 0.9 G. An important element of the simulator is a real-time computer system consisting of PC computers and ONYX Silicon Graphics computer that fulfil the functions of the visualisation system image generator. In addition, the simulator uses a five-channel system of rear projection PANORAMA with the field of view of 200o horizontally and 60o vertically [7]. The simulator allows training in emergency conditions or performance of simulated combat missions with the use of onboard armament.

An important element of the simulator training is also training in the scope of instrument flight rules (IFR). This purpose is served, inter alia, by training devices of ELITE PI-135 type and BITD ELITE S-612 simulators used in the Academic Centre of Aviation Training of the Air Force Academy. These sophisticated tools enable military pilots to practice and train, based on the instruments, all procedures and flight simulation elements in given meteorological conditions.

As a result of the agreement concluded in 2004 by PZL - Aerospace Industries with the company L-3 Communications Link Simulation and Training on the delivery of simulators and training devices of F-16C/D aircraft for the Polish Air Force, mission simulators and squadron simulators were installed, among others, in Krzesiny. The mission simulators have a visualization

system that allows observation of the external area even from the rear, while the squadron simulators use only visualization on the front screen and two side screens. Both simulators are an exact copy of the multi-role 'Hawk' aircraft.

The latest simulators which are used during pilot training for the needs of the Polish Armed Forces are: 'coach' simulator, M-28 Bryza aircraft simulator, SW-4 helicopter simulator and disorientation simulator. They are all at the possession of the Air Force Academy in Dęblin. The 'coach' simulator is a technically advanced device which allows objective testing of candidates and automation of the assessment of suitability for the profession. Thanks to the modular design it enables to carry out tests using both F-16 and W-3 cabin , and the cabin change takes place in less than 15'. An important element of the simulator is spherical projection system of the wide field of view as well as the instructor position with six monitors installed. Thanks to innovative applications the instructor can play the role of a pilot of another aircraft and operate in the same virtual space as a trainee. Instructions are given by the speech synthesizer and they are displayed on LCD screens placed in the cabin. The simulation system offered by 'the coach' is so powerful that it can run training of a person who has never flown or a pilot with experience in the successive stages of his training. It is worth noting that it allows to familiarize trainees with e.g. principles of operation of a head-up display (HUD) or the instrument landing system (ILS).

The only simulator of a military transport aircraft utilised by the Polish Armed Forces is the simulator of M-28 Bryza aircraft. Its characteristic allows the realization of a large part of the practical training rather than to be performed on the plane. Training provided by this simulator gives the unique ability to practice emergency situations that cannot be safely carried out during the actual flight. In addition, it also enables an introductory familiarisation of aviation personnel with the construction of the cabin or the layout of the instruments at an extremely low cost (without the need to arrange a real aircraft). The cabin is mounted on a suitably high frame that allows application of a wide variety of visualization systems , including large spherical screens with a very wide field of view (horizontally and vertically). High resolution is provided by a mechanism of smooth image linking from six projectors. A set of electronically controlled filters ensures good quality picture not only in the daytime scenes, but also realistic imaging of the night, and the multi-channel soundtrack system realistically simulates the acoustic environment of the pilot, including communication in the cabin. An additional piece of equipment is dashboard and control panels. With advanced systems, such as flight controls loading system, simulation allows the reproduction of forces occurring in the real aircraft. In addition, the flight trainer accounts for all radar aids installed on the military and civilian airports. An important element of the simulator is the multi-crew cooperation (MCC) module that allows to carry out practice in aircrew coordination. In this way, the trainees learn about communication and cooperation between pilots and mechanics both during routine flights and in emergency situations. The simulator allows to perform flights in different times of day and in different weather conditions. In accordance with the requirements for devices of this class, the instructor position was placed directly behind the cabin, which provides complete control of the exercise. The second instructor position is equipped with the image preview from the camera in the cabin and additional monitors showing the image of visualization and instrument displays.

Another helicopter simulator introduced into service after 2000 was SW-4 simulator (photo 4). This simulator is one of the few having a visualization system consisting of eight projectors that display high quality image on a spherical screen. For the purpose of the training, the room where the training device is located was painted black. This is to prevent the scattering of light and the formation of the so-called light reflections. The advantage of the simulator is the possibility of landing at any airport in Poland and the ability to conduct radio communication with air traffic controllers via multi-channel soundtrack system. The instructor position was placed directly behind the cabin, which allows the instructor to fully control the conduct of the planned exercise. With LCD monitors the instructor has the ability to preview the cabin, and additional monitors showing the image of visualization and instrument displays.

Photo 4. Simulator of SW-4 helicopter
Source: photo Dariusz BOGUSZ

The newest simulator developed as a result of cooperation of ETC -PZL company, the Air Force Academy in Dęblin and the Military Institute of Aviation Medicine in Warsaw is a spatial disorientation simulator (photo 5). It is commonly defined as an incorrect position and movement sensation relative to the surface of the Earth. Safe triggering of this phenomenon during the actual flight is virtually impossible. It is impossible to trigger it on typical simulators. The solution to this problem is the special equipment for pilot training in spatial disorientation causing illusions of this phenomenon through appropriate interaction of movement and image. Pilots unwittingly become influenced by this phenomenon, as a result of which they have a false image of reality, take wrong decisions often leading to tragic events, and even aviation accidents. Therefore it is very important to be properly prepared and familiarized with this vital phenomenon. Skilful recognition of disorientation phenomenon, acquisition and maintaining appropriate skills as well as preference given to instrument indications instead of individual perception can be crucial during difficult and unforeseen situations in the air. The simulator consists of: pilot cockpit with motion system , the operator/instructor position, computer system and power supply system [8]. The cabin of the disorientation simulator is equipped with the basic systems that conform to the templates of cockpits in transport aircraft, jet aircraft or helicopter . Inside the cabin is fitted with the pilot's seat with flight controls and navigation & control devices. The image of the external situation is presented on three widescreen monitors mounted in front of the pilot.

Photo 5. Disorientation simulator
Source: photo Dariusz BOGUSZ

In addition to performance of operator activities, supervision of exercise progress and monitoring of the technical state of the device, the operator/instructor position also provides visualization of the image presented in the cabin (databases of flying areas) , the image recorded by the camera (face of student pilot) and onboard instruments in the cockpit. The operator/instructor has the option of emergency shutdown of the device, communication with the trainee as well as setting the initial parameters of the simulator as well as recording and replaying of the exercise conduct (exercise debriefing). The computer system of the simulator is primarily responsible for the registration of parameters of conducted exercise. Moreover, an important task of the system is to record radio communication, to ensure the numerically designated rate of change of the position of the controls and to change the ranges of recorded parameters (on a scale required for the flight). Additionally, it records medical examinations indicated by the Military Institute of Aviation Medicine and the camera image . The essence of training on this simulator is to increase the efficiency of flight training by constant striving to minimize the difference in pilot response to external, real and simulated signals resulting in the loss of spatial orientation.

4. CONCLUSION

Modern simulators used for aviation personnel training are very advanced devices significantly different from the structure and capabilities of their older counterparts. With advanced technology, they allow to save both time and money. It is worthwhile developing and building more and more sophisticated simulators as ‘on the ground’ simulator training allows errors, yet ‘in the air’ training does not. The high level of efficiency of aviation personnel training with the use of the simulator gives the basis for statement that it is currently the best teaching aid ever constructed.

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