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Flight Simulators in the Research Units of the Polish Armed Forces and Polish Air Force Universitys

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Abstract

Flight simulators represent a pivotal component within military pilot flight training systems. The role of these simulators in pilot training is increasing, and it is anticipated that integrating advanced technologies and artificial intelligence will enable trained pilots to fully engage their senses. The use of simulators in flight training programmes ensures pilot safety and concurrently reduces the financial burden on the training establishment. The implementation of exercises that would pose a threat to the pilot's health and life in real conditions is facilitated by simulators. These simulators have been shown to facilitate the enhancement of critical flight skills, including take-offs, landings, navigation, and crisis management procedures. The use of simulators confers numerous advantages, including enhancing the air force's training efficacy and potentially augmenting its operational effectiveness.

The primary objective of this article is to identify and examine simulator-based flight training for cadets and military pilots conducted at the Military Institute of Aviation Medicine and the Polish Air Force University. This article also outlines the solutions, possibilities, and regularities that are driving the growing use of flight simulators in the flight training of PAFU cadets and military pilots of the Polish Armed Forces.

The research process employed theoretical methods, including analysis, synthesis, generalization, inference, and practical methods, namely expert interviews.

Keywords: flight simulators, flight training, military pilots, Polish Air Force, Polish Armed Forces

1. Introduction

The advent of the Internet, virtual reality, and synthetic environments has precipitated a paradigm shift in our quotidian lives, thereby inaugurating a novel epoch in the annals of humanity. Human activity is being transferred to the virtual world. This transition has led to a significant shift in human activity, with our lives becoming increasingly concentrated in artificial spaces. The Internet has become a multifaceted platform that extends beyond mere entertainment, encompassing a diverse range of activities. A substantial proportion of our daily activities is now conducted both online and in the virtual realm. The advent of cyberspace has thus given rise to a new domain of human activity. Following the mastery of the water environment, airspace and outer space, humankind has created an environment far more extensive than that which the creators of science fiction could have imagined. The advent of cyberspace as a significant domain of human activity has concomitantly introduced challenges and threats that must be addressed.

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Cyberspace, which is the product of the latest interactive information and communication technologies and digital media, has created a plethora of opportunities in the domain of aviation training. The advent of aviation coincided with the emergence of simulators, which have proven instrumental in reducing the operational expenses of contemporary military assets. These simulators are capable of recreating even the most advanced flight mission scenarios and aircraft systems. The virtual environment affords unparalleled control over the sequence of events in a simulated training scenario, enabling the allocation of tasks that, in real-world conditions, would jeopardize the safety and well-being of the trainee.

The world's leading armed forces have conflicting views on the introduction of artificial intelligence into combat operations. There is a consensus on the utilization of artificial intelligence; however, divergences emerge with respect to its implementation, specifically in the domain of data processing. There is widespread consensus on the importance of artificial intelligence in aviation. The contemporary pilot is supported by numerous onboard systems that are underpinned by artificial intelligence. The analysis of information transmitted from the expanding array of onboard sensors has become a task beyond the capabilities of a human pilot. Solutions and tools for expedited data processing and pilot assistance have been incorporated into aircraft onboard systems for an extended period. The United States Air Force has demonstrated the potential of artificial intelligence (AI) to substitute for human pilots in aircraft. As part of research on the use of AI, the US Air Force organized an air fight between an F-16 fighter controlled by a human and an F-16 controlled by artificial intelligence. The Variable In-flight Simulation Test Aircraft (VISTA), an X-62A, flew for a duration of 17 hours without interruption in February 2023, powered by AI. This experiment showcased the reliability of AI control in a simulated dogfight with a second piloted aircraft, marking a significant milestone in aviation history. In the future, VISTA will enable the USAF to develop and test cutting-edge AI techniques in parallel with new unmanned vehicle designs.

Flight simulators are currently widely used for many reasons: economics, safety, capabilities, and availability. The simulator's ability to be utilized by training providers is also important. A well-known application is the simulator's use in emergency situations, providing a more realistic and safer alternative to the existing scenarios. Military simulators enable weapons training in scenarios that are readily available for peacetime deployment (Nählinder, 2019, p. 7). This article discusses the use of flight simulators in selection for military aviation and flight screening training in the Polish Armed Forces.

The Polish Air Force is leveraging virtual reality and artificial intelligence to enhance the flight training of its military pilots. The utilization of flight simulators exemplifies the integration of contemporary technological advancements. These simulators, equipped with advanced artificial intelligence capabilities, offer a comprehensive training environment. The recently acquired F-35 aircraft will provide Polish Air Force pilots with comprehensive combat support through artificial intelligence systems, including target analysis and, most significantly, assistance in decision-making. Fifth-generation aircraft are replete with electronic and artificial intelligence systems that support pilots in operating onboard systems and weapons. The F-35 represents a synthesis of human decision-making and computerized analysis underpinned by artificial intelligence. The integration of artificial intelligence and reality-based training for F-35 pilots has already been demonstrated to enhance the efficiency and safety of flight training.

The author defines an aviation simulator as *a modern didactic tool that allows training in a synthetic environment, reproducing the features of a real operational environment. The equipment of an aircraft is reproduced with a visual system that provides a flight experience similar to the real one. It may be equipped with a motion system that allows the user to experience forces simulating the movement of a real aircraft. It is typically a life-size replica of the flight deck of a specific type or make, model and series, equipped with all the necessary devices and computer programs to reproduce the aircraft in ground and air operations. A visualization system provides a view from the flight deck that is selected for the training purposes. This comprehensive system enables the training of a wide range of flight tasks and missions, thereby ensuring the development of a complete set of skills and competencies* (Bogusz, 2023, p. 56).

The primary objective of the present article is to indicate flight simulators used in the flight training of cadets and military pilots in the Armed Forces of the Republic of Poland, and to identify solutions, possibilities and regularities that determine the growing role of the use of flight simulators in the flight training of PAFU cadets and military pilots of the Polish Armed Forces.

The article identifies the flight simulators employed in the training of candidates for military pilots in Poland, grouping them according to institutions and tasks assigned to them, into two main categories:

- research and flight simulators at the Military Institute of Aviation Medicine (MIA) are predominantly used for research and scientific endeavours in aviation medicine, as well as for the evaluation and selection of candidates for the role of military pilots. Additionally, the simulators serve as a platform for advanced training, as well as for the testing of pilots' resistance to overloads in combat aircraft;
- at the Polish Air Force University (PAFU), flight simulators play a pivotal role in the selection and evaluation process for prospective military pilots. These simulators are used to assess candidates' theoretical knowledge and practical skills, as well as their mental and physical aptitudes. The PAFU’s simulators are meticulously tailored to align with the programme's training objectives at the fundamental stage, and are integrated with the aircraft used by aviation university cadets during their training. This encompasses a range of simulators, from rudimentary trainers to sophisticated spatial disorientation models.

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The article's structure reflects the adopted assumptions, which identified simulator training conducted in the research and training units of the Polish Armed Forces.

Simulator training plays a significant role in aviation training and the development of military pilots. The use of simulators in training enables the execution of procedures and scenarios that would otherwise be impossible in actual flight conditions, thereby enhancing safety. The simulator training and equipment in use within a given nation reflect the prevailing aviation training system. In the context of Poland, the implementation of simulator training is a pervasive aspect of aviation training, extending across all its stages, from the initial recruitment stage (Bogusz, 2025a, p. 15).

The research problem was posed as the question: What flight simulators are used in flight training for military pilots at the Military Institute of Aviation Medicine and the Polish Air Force University?

The research process used mainly theoretical methods: analysis, synthesis, generalization, inference, and practical methods: expert interviews.

2. Research simulators of the Military Institute of Aviation Medicine

Poland was one of the first countries in the world to establish a separate scientific institute dedicated to the health of aircrew. The Military Institute of Aviation Medicine (MIAM) is one of the few scientific-research-training and clinical-diagnostic centres in Europe specializing in aviation medicine. Its traditions date back to the inter-war period when Józef Piłsudski, Minister of Military Affairs, established the Aviation Medical Centre in 1928 (Kwarecki & Terelak, 1980, p. 221). The structure of MIAM includes specialized facilities and laboratories where scientific research and R&D work related to aviation training and the use of simulators is carried out.

Among the required skills, the military pilot profession requires numerous attributes, including motor coordination, motor skills, spatial orientation, situational awareness, and management skills. To assess aviation aptitude, testing equipment has been developed to identify potential and related areas where a candidate pilot may encounter learning difficulties. MIAM is equipped with simulators that enable optimal candidate selection by identifying training-related issues and deciding whether to discontinue flight training or propose alternative training solutions (Koblen, 2012, p. 80). The flight simulator provided an ideal platform for selecting military pilot candidates.

The MIAM is equipped with the Japetus simulator. This is a comprehensive flight simulator equipped with a six-degrees-of--freedom motion system. It is a simulator of a twin-engine jet military trainer aircraft that reproduces the cabin and dynamics of the I-22 "Iryda" aircraft. Initially, it supported training on this type of aircraft. In 1997, the simulator was extensively modernized. The need for modernization arose from the need to adapt to new research conditions. The modernisation radically changed the device's scope, from a typical flight simulator to a comprehensive system for selecting candidates for military pilot training and for research in aviation medicine. During the modification, modern medical equipment was installed in the simulator cabin to measure the pilot's physiological parameters during flight.

It is still used today in various research programmes, including the selection of military pilot candidates. The "Japetus" research and training simulator can be used to carry out:

- flight screening of candidates for military pilots in order to check the aptitude of candidates for the profession of military pilot;
- training of military pilots and tests to check military pilots after long periods of inactivity;
- research and scientific work in the field of aviation medicine.

Fitted with modern medical equipment to monitor the pilot's physiological parameters during a simulated flight, Japetus is a research simulator in the fields of: physiopathology, aviation medicine and psychology. Simulators of this type have the ability to introduce any training sequence with so-called "difficult flight conditions", which allows a multi-profile assessment of the efficiency and predisposition (suitability) of candidates for aviation training. Selection tests can be carried out for different purposes, e.g., a medical certificate or suitability for military aviation, across a range of equipment.

Another device is the spatial disorientation trainer "Gyro-IPT" (Integrated Physiological Trainer), which enables pilots to conduct practical training and education in spatial orientation. During the pilot-controlled flight, the visual and motion stimuli presented create disorientation illusions. Unlike devices that only demonstrate the phenomenon of spatial disorientation (passive activity of the pilot), in the "Gyro-IPT" the pilot has full control of the flight before, during and after the disorientation illusion is generated. This feature creates a fully interactive environment in which the pilot must maintain full control of the aircraft or helicopter flight.

The trainer reproduces the visual and vestibular illusions that occur in real flight conditions. Training in the "Gyro-IPT" simulator allows you to learn to recognize illusions, to avoid manoeuvres in which illusions occur and to regain control of the flight in accordance with the indications of the onboard instruments. In addition to disorienting illusions, the simulation programs available also include desensitization to motion stimuli (counteracting motion sickness) and training in recovering the aircraft from unusual positions. The "Gyro-IPT" trainer is also used in scientific and research work to improve flight crew training systems and methods (Skrzypkowski, 2012, p. 238).

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The Hyperion Flight Simulator has been developed and manufactured at the Military Institute of Aviation Medicine. The device is equipped with a wide-angle information display system with a 180° horizontal and 27° vertical field of view (display resolution: 8000 x 1200 pixels). The simulator has been adapted to simulate flights in various terrain conditions, times of day and changing weather conditions. It reflects the characteristics of the MiG jet.

To date, the "Hyperion" simulator has primarily been used as a research and training tool in the following areas:

- Selection tests for candidates for military pilots, specifically for verifying the suitability of candidates for the profession of a military pilot;
- Conducting flights with selected phenomena of illusion in spatial disorientation;
- Flights under conditions of reduced visibility (dawn, night) using night vision goggles;
- Research work in the field of aviation medicine.[1]

The "Gyro-IPT" and "Hyperion" simulators are also used at MIAM to present spatial disorientation illusions. Both devices are adequate, but they are outdated. Currently, pilots undergoing spatial disorientation testing have the option of testing illusions on new types of training devices, such as the spatial disorientation simulator used at the Polish Air Force University in Dęblin.

A particularly valuable tool for pilot testing and training is the centrifugal overload trainer (Figure 1). Tests on the centrifugal overload trainer enable future pilots to determine their overload resistance threshold in simulated conditions before they fly the aircraft in a real flight. By changing the configuration of the gondola, the device enables the reproduction of the cockpits of the F-16 and MiG-29 multi-role aircraft. Pilots in Poland are required to undergo regular tests and exercises on the centrifugal overload trainer to assess their resistance to overload-induced stress.[2]

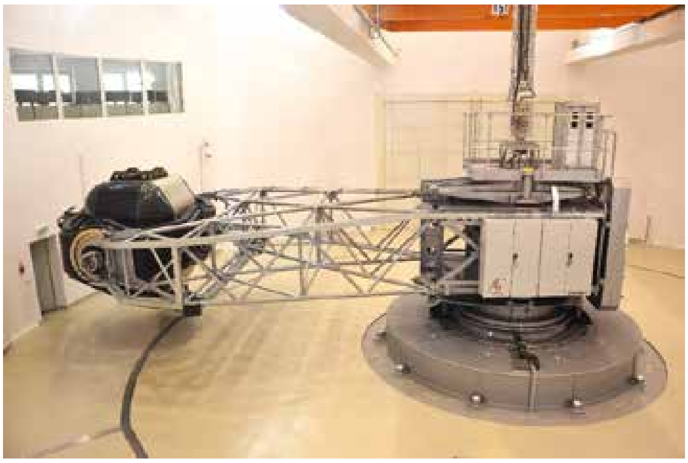

Figure 1. Centrifugal Overload Trainer. Source: the authors' own work.

The centrifugal overload trainer also offers training capabilities in the following areas:

- Pre-flight procedures;
- Instrument flight and navigation (navigating and landing approaches using VOR, VOR/DME, and TACAN, navigating and landing approaches using NDB, radio procedures – operation of communication devices, procedures for night flights, controlled approaches from the ground, ILS approaches, group flights, and navigation in adverse weather conditions, use of NVG);
- Recovery of the aircraft from unconventional attitudes;
- Emergencies, e.g., engine fire, control system malfunction;
- Combat applications (air target interception, defensive manoeuvres, use of weaponry, etc.);
- Situational awareness (5 profiles);
- Spatial disorientation (11 illusions).

The simulator acts as a laboratory, allowing tests to be carried out on pilots of highly manoeuvrable and acrobatic aircraft under conditions of high stress and to assess the pilot's response. Pilots learn to control their body's physiology. The pilot is exposed to physical and information overload, operates in a time deficit, and the simulator contains medical equipment (with the possibility of expansion) that allows the study of how the person being tested behaves under these conditions.[3]

1 Based on an expert interview with Major Pilot Rafał Lewkowicz.

2 Based on an unauthorized expert interview with Krzysztof Kowalczuk, Head of the Department of Simulator Research, Training and Aviation Medical Training at MIAM.

3 An expert interview with Jerzy Achimowicz, professor of neurobiology.

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In addition to the above-mentioned simulators, the institute has extensive research infrastructure, including low-pressure chambers, a decompression chamber, and a catapult, which support research and experiments in cardiology, neurophysiology, laryngology, and aviation ophthalmology.

The MIAM works in close collaboration with military aviation units, aviation training units, and the Air Force Military Academy, conducting tests on military pilot candidates from the recruitment stage through aeromedical evaluations to determine their admission to the Air Force Academy. It also conducts research with pilots of units of the Polish Armed Forces and promotes aviation prophylaxis.

The "Selection" system and its elements located in MIAM, as well as the use of the "Selector" flight simulator, provide tools and methods to support the processes of making the right decisions in the selection process of candidates for military pilots, and enable continuous monitoring of the progress of pilots in their education and training. The "Selection" system and the "Selector" simulator will be described in the next part of the article dedicated to PAFU training devices. Thanks to joint research and scientific projects with the PAFU, MIAM specialists participate in the process of selecting candidates for military aviation.

Screening training aims to increase the effectiveness of flight training and enable the achievement of current and future objectives, both for the flying school and the pilots being trained. The activities of the MIAM and PAFU fulfil a modernizing function in the training of military pilots in Poland, related to the need to update the knowledge and skills of employees, and an innovative function, which involves creating conditions for progress and searching for new solutions (Sztobryn, 2024, p. 56).

From the point of view of aviation training, the main task of MIAM is the qualification of pilots, which consists in assessing their fitness for flight and qualifying candidates for flight training and ground service. In addition, an important aspect of the institute's activity is to carry out scientific and research work, research and development and scientific and technical work in the field of basic and applied sciences for the needs of aviation medicine. MIAM's infrastructure and simulators play an important role in the training of military and civilian personnel, including pilots and flight crews.

3. Simulator base of the Polish Air Force University

The Polish Air Force University (PAFU) is the only university that trains military pilots for the needs of the Polish Armed Forces. Aviation education takes place in didactic units, mainly in the Faculty of Aviation, and flight training is carried out in the Academic Aviation Training Centre (AATC), an organizational unit of the university with a Flight Training Organisation (FTO) certificate. The AATC provides flight training (theoretical and practical) for military pilot candidates, including foreign ones, and civilian students studying in Dęblin.

The Flight Simulation Section is an organizational unit of the AATC, which provides flight simulation training for cadets, civilian students and Polish Armed Forces aircrews.

The section is also responsible for conducting training to assess the aptitude of candidates for PAFU military studies in pilot specialities, including the speciality of "Unmanned Aerial Vehicles and Target Indication (Pilot Operator UAV)".

The PAFU Academic Aviation Training Centre is equipped with flight simulators and trainers to provide training in accordance with civil aviation and NATO standards. The simulator base consists of (Table 1).

Table 1. List of the PAFU's simulators

No.	Simulator type	Quantity
1.	R ELITE Pi-35 BITD Simulator	7
2.	Simulator "Selector" (with interchangeable cabins of the "Głuszec" helicopter and the "F-16", TS-11 "Iskra" and PZL-130 "Orlik" aircraft)	1
3.	FNTP – II Simulator of the SW-4 "Puszczyk" helicopter and the "Schweizer 300" helicopter	1
4.	FNTP-II Simulator of the M-28 "Bryza" aircraft + MCC / "Seneca", "Cessna 172 RG"	1
5.	FNTP II DA 40/DA 42 Flight Simulator	1
6.	Spatial disorientation symulator	1
7.	FNPT MCC Level II LETOV Convertible 4 w 1 HiBIRD	1
8.	DA-40/42 FNTP II class Simulator	2
9.	ALSIM AL4X-5 Simulator	1
	Total	**16**

Source: the authors' own work.

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The simplest university trainer is the Elite PI-135 BITD (Basic Instrument Training Device). They are used to teach the use of radio navigation equipment, interpreting onboard instruments and the use of R/NAV aids (ILS, VOR, DME). They are primarily used to train procedures for behaviour in the air. Instrument Flight Rules (IFR) training is also an important part of simulator training. The BITD Elite S-612 Cessna 172 RG simulator is used for this purpose. This training device enables military pilots to practise and train all procedures and elements of flight simulation under given meteorological conditions on an instrument basis. Elite PI-135 BITD and BITD Elite S-612 Cessna 172 RG will be gradually withdrawn from training and replaced by newer devices.

Another simulator is the FNTP II device of the SW-4 "Puszczyk" helicopter and the "Schweizer 300" helicopter. It has a modular design, which means that the same screen and cabin shell can be used to create different configurations. All that is needed is to replace the instrument panels and some of the controls. Thanks to this, the SW-4 "Puszczyk" training helicopter simulator can be transformed into a simulator of the "Schweizer 300" light piston helicopter. The device is used by students for training before flights in training helicopters of the same class, the Cabri G2 (Bogusz, 2025b, p. 116).

The FNTP II simulator is designed for practical training of military students specializing in helicopter piloting during the second stage of training, i.e., on SW-4 military helicopters at the 41st Training Aviation Base. It has an advanced 3D visualization system with an automatic calibration and positioning system for a group of eight spherical screen projectors. Another modular simulator is the FNTP II simulator of the M-28 "Bryza" + MCC/"Seneca" aircraft, the Cessna 172 RG (Figure 2). Using the same cabin and different types of instrument panels and controls, three types of aircraft configurations can be created. As a result, the M-28 "Bryza" transport simulator can be used to train pilots for flights on Cessna 172 and Piper Seneca V aircraft.

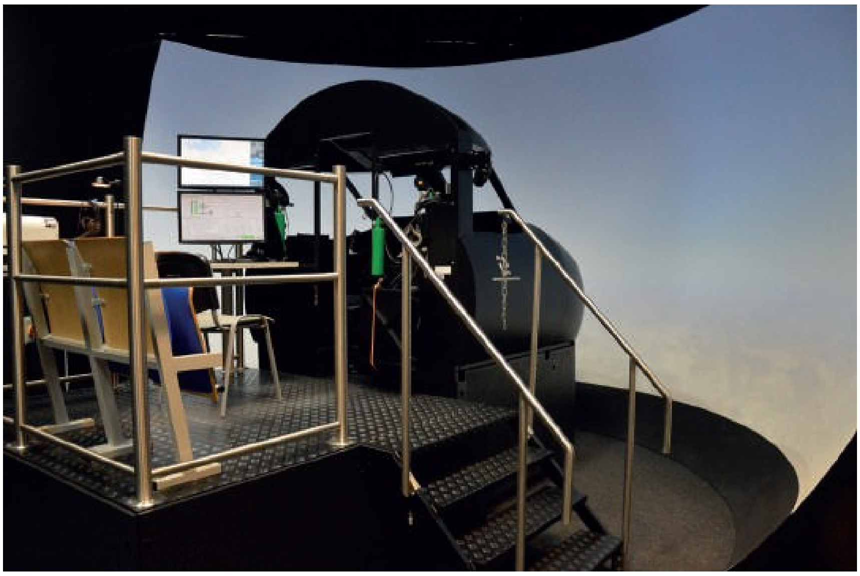

Figure 2. FNTP II simulator of the M-28 "Bryza" + MCC/"Seneca", Cessna 172 RG. Source: the authors' own work.

Both simulators are ULC FNPT II class certified, allowing them to train officer cadets and civilian students. Training on FNPT II class simulators mainly involves take-offs and landings, performing flight manoeuvres, and learning radio navigation and procedures for maintaining flight parameters.

Along with the introduction of the Diamond aircraft fleet for flight training, the PAFU purchased a ULC-certified FNPT II Class DA 40/DA 42 aircraft training device (Photo 2) for VFR and IFR (IR/IRME) flight training. The Diamond FSTD II simulator is an exact replica of the DA 40 and DA 42 aircraft. The instrument panel is equipped with Garmin G1000 avionics.

LETOV Convertible 4 in 1 HiBIRD Simulator. It is ULC-certified as FNPT II Multi-Crew Cooperation (MCC) according to EASA CS-FSTD (A), Edition II. The module can be configured for training on four aircraft types: Single Engine Piston Complex, Multi Engine Piston, Turboprop and Jet Generic. The simulator has received a separate certificate for each type of rating (SEP, MEP, TEP, JET). The simulator has an enclosed cockpit with two student seats and dual control systems. It is also equipped with a glass cockpit avionics system.

Screening pilot candidates is a multifaceted task that involves testing mental and physical aptitudes, as well as the candidate's theoretical knowledge and practical skills. The "Selector" simulator is used for selection training at the Aviation Military Academy (Figure 3).

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Figure 3. “Selector” Simulator. Source: the authors’ own work.

This equipment is a system of interchangeable cabins that use the same software environment, together with an imaging system based on three vision projectors. The system with the F-16 aircraft module is designed for the initial assessment of candidates' aptitude for the PAFU in the specialization of aircraft piloting, and for training flight crew members in performing flights in accordance with instrument flight rules (IFR). The PZL-130 “Orlik” aircraft module is used for basic flight training of military students. The TS-11 “Iskra” aircraft module is a simulator for conducting basic and advanced flight training for military students. The devices used in the system have a modular structure, allowing modernisation to meet new requirements and enabling cooperation with other simulation devices.

The simulator's design allows for the testing of military pilot candidates on fighter aircraft and helicopters equipped with an integrated set of onboard instruments, the so-called glass cockpit, as well as on those equipped with a classical set of instruments. It is also possible to conduct training under IFR conditions and, to a limited extent, training in the performance of combat tasks. This versatility is made possible by the device's modular design, with fixed elements including a spherical projection system with a wide field of view and an instructor's station, while the cabins are interchangeable depending on the aircraft. In addition, each cabin can easily exchange elements representing aircraft of different generations (analogue or digital instruments).

The Selector flight simulator allows you to configure training scenarios and programmes. Thanks to its ability to grade the difficulty of individual training sessions, the simulator helps in the initial qualification and selection of students for further training in the specialities of aircraft and helicopter pilots. Its use in the selection process has enabled the recognition of candidates' flying skills for military aviation. In addition, it is a very cheap and safe tool for researching candidates' characteristics. Its use has had a positive impact on the effectiveness of selection training.

The “Selection” system makes it possible to combine selection training with psychophysiological diagnostics of military pilot candidates. Conducting multidirectional analyses and taking into account a wide range of variables necessary to perform the tasks of a military pilot is aimed, among other things, at reducing the risk of student pilots' attrition during the expensive process of flight training in the initial period of training, as well as ensuring a high level of safety in the training of tested candidates.

The spatial disorientation simulator is a cutting-edge device that is widely regarded as one of the most advanced of its kind in the world. The simulator enables the safe training of pilots in the event of a virtual loss of spatial orientation. The simulator is equipped with a built-in, darkened cabin that houses a pilot seat, a six-degree-of-freedom motion system, a Stewart platform mounted on a rotating table with an unlimited number of rotations, a visualization system, an instructor station with an IT system, and a power supply system. The simulator is equipped with three interchangeable cabins: F-16 and M-28 aircraft and a W-3PL helicopter, and allows military pilots and cadets to become familiar with dangerous illusions that may occur in real flight conditions.

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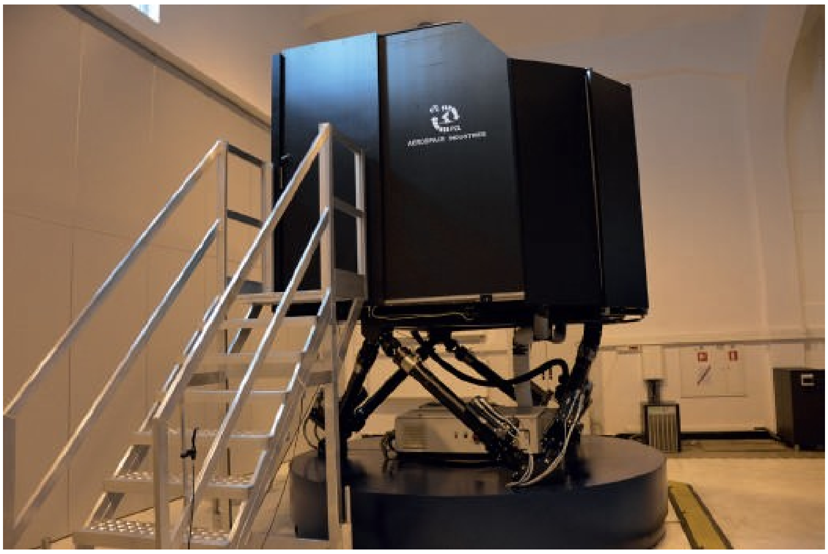

Figure 4. General view of the spatial disorientation simulator. Source: the authors' own work.

Prior to practical training on the simulator, participants must undergo a medical examination and complete theoretical training. The purpose of this training is to enable the pilot to develop a practical, comprehensive understanding of the potential for spatial disorientation that may be encountered during flight. Prior to the commencement of the training mission, each subject embarks on an instructional flight, devoid of any elements that might induce disorientation. This flight is designed to acquaint the pilot with the cabin's ergonomics and the flight characteristics of the spatial disorientation simulator for a specific aircraft type (Burek, 2013, p. 39).

The training mission is conducted individually. Depending on the nature of the training course, the instructor-pilot may initiate actions with the objective of achieving any type of disorientation at any point during the training mission. The instructor-pilot can distract the student from ongoing cockpit activities through a variety of methods, including sequentially deactivating navigation devices or introducing the SD simulator cockpit into a rotating motion during the manoeuvre (Burek, 2013, p. 40). Following the conclusion of the training mission, a debriefing session is scheduled to discuss the mission's progression.

On November 30, 2020, the Air Force Military Academy in Dęblin received a new flight simulator for Diamond DA 40/DA 42 aircraft of the FNTP II class manufactured by ALSIM. The simulator is employed in training programmes for the PPL(A), CPL(A), IR and PBN licenses on DA 40 and DA 42 aircraft. The ALSIM AL4X-5 simulator is equipped with a cockpit, an instructor station, and a visualization system (Figure 5).

Figure 5. ALSIM AL4X-5 simulator for DA 40/42 aircraft. Source: the authors' own work.

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The simulator is equipped with a modular cabin configuration that accurately replicates the cockpits of the DA 40 and DA 42 aircraft, complete with the original Garmin G1000NXi avionics suite. Additionally, it is equipped with a system that regulates the temperature and humidity of the air supplied to the crew cabin (cockpit), ensuring optimal conditions for flight. The process of changing (converting) cockpits is accomplished in less than 10 minutes.

The ALSIM AL4X-5 model reflects the characteristics of the single-engine Diamond DA-40 and twin-engine DA-42 light aircraft. The simulator is used for the training of cadets pursuing careers as jet and transport aircraft pilots. The simulator is equipped with two modules, allowing pilots of the single-engine Diamond DA-40 to train on it and, following cockpit reconfiguration, also pilots of the twin-engine DA-42. The AL4X-5 simulator permits training in Instrument Flight Rules (IFR) flights, that is to say, flights conducted without visibility of the horizon, for example, in or above the clouds. In such situations, the pilot relies on the indications provided by the navigation instruments.

The AATC PAFU is equipped with flight simulators and trainers that enable training in accordance with the standards applicable to civil and military aviation. The simulators reflect the aircraft used at the PAFU and the equipment that military pilot candidates will encounter in the later stages of flight training (including PZL-130 TC II “Orlik”, F-16, W3-PL helicopter).

7. Conclusions

In the contemporary era, the realm of aviation education and training has undergone a substantial transformation, with the integration of advanced computer systems and simulators serving as the primary driving force. These technological advancements have been instrumental in facilitating a paradigm shift towards a fully immersive learning environment, where trainee pilots are engrossed in an artificially created reality. Initially, simulators were used to assist instructors in the dissemination of knowledge to student pilots. However, the advancements in artificial intelligence and the increasing sophistication of virtual reality have led to a paradigm shift in aviation education, enabling student pilots to perform aviation tasks independently as part of their self-directed learning or to enhance their aviation skills. It is important to acknowledge, however, that the unique role of a pilot-instructor remains irreplaceable, just as simulator training cannot substitute for practical training in the air.

The differences between the types of simulators used at the Military Institute of Aviation Medicine and the Polish Air Force University results from the tasks these institutions perform. The Military Institute of Aviation Medicine is a research unit that plays a significant role in the selection of military pilot candidates. The PAFU is a flight training unit that conducts flight training and initial flight screening tasks.

The MIAM simulator infrastructure facilitates multi-directional analyses and the consideration of a wide range of variables necessary for the profession of a pilot. Among the objectives of the simulator infrastructure are reducing attrition rates among candidates for military pilot training and ensuring a high level of safety during the training of candidates tested. The institute boasts a comprehensive simulator suite capable of training flight personnel in emergency situations and loss of spatial orientation, within the scope of flights mandated by the training programme or combat scenarios.

Polish Air Force University has a simulator base of considerable breadth, allowing for high-level training at all stages. The simulators employed at the PAFU are capable of reproducing the entire fleet of aircraft utilized for flight training purposes. Candidates for the role of military pilot undergo a dual training programme encompassing both simulator-based instruction and practical flying exercises. At the recruitment stage, the PAFU conducts verification training on the “Selector” simulator, a process that contributes to reducing attrition during subsequent flight training and conserving both time and public funds.

It is evident that the PAFU and MIAM possess a simulator base that is optimally suited to the execution of their assigned tasks, thereby ensuring the efficacy of flight training.

In the context of flight training for officer cadets and military pilots in the Armed Forces of the Republic of Poland, it is possible to identify the cause-and-effect regularities that characterize the flight training devices and their utilization in the training process:

- contemporary flight simulators have introduced a new dimension to the realm of flight training. These sophisticated technological devices have become a pivotal component of sophisticated flight training systems. While the aircraft remains the primary component of the flight training system, the growing importance of trainers and simulators can be attributed to advances in virtual reality and artificial intelligence. These technological developments have enabled the provision of safe and effective flight training in accordance with didactic principles, such as the transition from theory to practice, the gradation of difficulty, and the utilization of visual aids;
- simulators of the appropriate class used in aviation training enable pilot training in a dynamic environment while ensuring the safety of trainees. Simulators are defined as training devices that facilitate the effective implementation of aviation education and training programmes;
- the use of simulators has been demonstrated to enhance the economic efficiency of flight training. A reduction in the number of hours of in-flight training required for pilots leads to a decrease in the operating costs of aircraft. Furthermore, simulators enable the extension of aircraft service life by transferring a proportion of the training to an artificial (virtual) environment;

- the primary objective for training organizers is to ensure that the standards of flight training remain consistently high. Flight training is inherently hazardous because, upon taking off from the ground, most individuals find themselves in an unnatural environment that renders them incapable of acting rationally or performing even the most basic tasks. The utilization of simulators enables the assessment of an individual's flight predispositions in a controlled environment, independent of the challenges associated with taking off from the ground. Simulators facilitate the expeditious and secure selection of candidates for military pilot roles. It is noteworthy that no other device can ensure the same level of safety during the examination of flight predispositions as that provided by simulators;
- simulators are a valuable training tool that allow for the safe rehearsal of emergencies that would otherwise be impossible to recreate in real-world conditions. These simulators can be used to recreate errors made by pilots, such as loss of spatial orientation, and to conduct simulated flights in challenging weather conditions. Additionally, they can be used to conduct advanced training and testing of pilots' resistance to overloads experienced by combat aircraft pilots;
- the design solutions of the simulators enable the training of flight personnel while preserving the aircraft's characteristics and adhering to the pilot's authorizations. The design of the simulators is modular in nature, enabling swift transformation of the cabin (or alternatively, the alteration of the cabin) and its subsequent adaptation to the designated aircraft in accordance with the established pattern.

It can thus be posited that the aforementioned regularities represent the features specific to simulator training conducted in the Polish aviation research and training units of the Polish Armed Forces, i.e., the MIAM and PAFU.

Declaration of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this article.

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