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FLIGHT SIMULATORS – A TOOL FOR REDUCING THE HUMAN FACTOR IN ACCIDENTS

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Abstract

This article looks at the role of flight training devices in the process of instruction and training pilots. It also examines the impact of pilot training using flight simulators on reducing the human factor in accidents.

Key words: human factor, flight simulators, flight training, safety in aviation.

Introduction

While studying the history of aviation, one can find accounts which describe daredevils attempting to take off into the sky and fly. Attempts that unfortunately ended in failure. It took a long time for human dreams of flying to finally come true.

The Wright brothers are considered to be constructors of the aircraft which completed the first successful flight. Their first attempt to fly an aircraft called the *Wright Flyer* ended in them flying 36 metres in the air and slight damage to the aircraft upon landing. The construction of that aircraft was far from perfect. It caused problems with the aircraft's stability, which resulted in handling difficulties. Despite all that, after several days, the trials were resumed and they were successful. Wright managed to fly 37m on the first flight and in the fourth flight, which lasted 59 seconds, he was able to cover as much as 260m.

Later flight attempts gave the Wright brothers practical knowledge of their aircraft capabilities, and that enabled further improvements and modifications. This gave the pilot more experience in mastering the principles of flying an aircraft.

The experience gained over the following five years of working on the aircraft did not prevent a crash. In 1908, during a demonstration flight organised for Army

representatives over Fort Myer, Virginia, an accident occurred during which the propeller broke off, resulting in the plane crashing into the ground. Wilbur Wright and the representative of the Army, Lt. Thomas Selfridge were injured. Wright survived despite serious head injuries. Lt Selfridge, however, died from head injuries and became the first victim of an air accident.

Causes of accidents

The example of the air history of the Wright brothers given above shows that the beginnings of aviation were very difficult. The materials used in aircraft construction did not always meet the requirements of adequate strength, and each time new ideas and new construction solutions had to be verified in real-life flight tests, during which the pilot had to take great risks. Unfortunately, this was the only way to find out whether the solutions and modifications applied to the airframe or engine would meet the expectations of the aircraft designer, and also whether they would be safe. This is how we can imagine the beginnings of aviation, with the first planes being far from perfect in terms of construction and aerodynamics.

It is also worth bearing in mind that aviation pioneers had limited aviation knowledge and little flying experience. It was they who, based on the experience they gained, created knowledge that we can now use without limitation.

The main, i.e. the most common, causes of air incidents and accidents at that time were technical, e.g. propeller or wing breakage, engine failure, wheel fall-off, etc. The mere fact that pilots did not yet have much flight experience could not be the basis for naming the human factor as the cause of an accident when, for example, the wing broke off in flight.

With the development of technical thought and the use of improved, more durable construction materials, aircraft became more reliable. Along with the development of aviation technologies and the improvement of aircraft, the possibilities of the wider application of aviation also increased. New tasks for aviation were, at the same time, new challenges and new threats.

Aircraft were becoming more and more reliable, but the use of new construction solutions, various types of pilot-assisting devices, and on-board systems meant that operating the aircraft was also becoming more and more complicated. A natural consequence of that is that more and more demanding requirements are imposed on aviation personnel operating and maintaining aircraft. Nowadays, aircraft technicians are highly qualified specialists. Pilots are also no longer expected only to be able to fly an aircraft, but to have comprehensive aviation knowledge, and have, among many other skills, the skills that allow them to operate computers and onboard systems. This is necessary to ensure an adequate level of air operation safety.

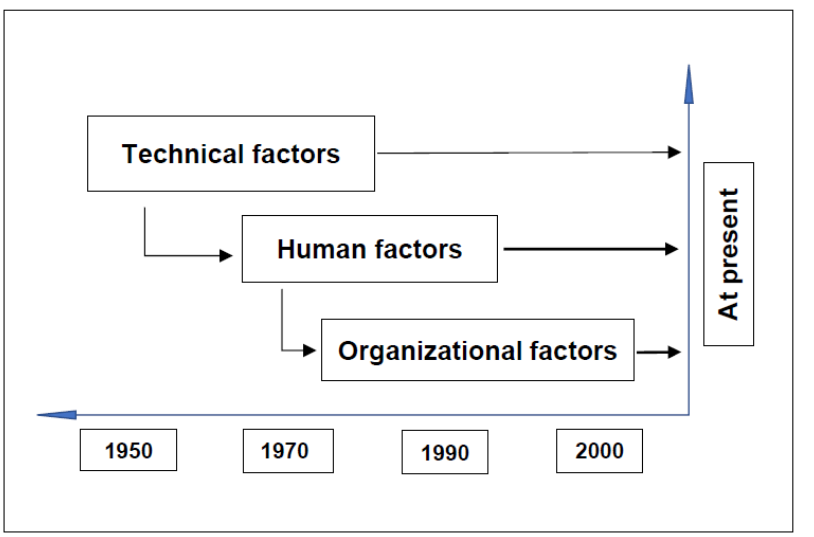
Human factor

Human beings are not perfect. They happen to be wrong and make errors. The effects of those errors may have different dimensions. In aviation, human errors can have devastating effects and that is why so much attention is paid to the impact of human factors on safety.

The "human factor" as a general concept may be seen as the human impact on the surrounding environment. In aviation, it is a broad concept, difficult to define precisely. The human factor in aviation is a multidisciplinary concept, based on psychology, human physiology, biology, biomechanics, anthropometry, etc. The human factor in aviation is dealt with because of its impact on the emergence of dangerous accidents. From the beginning of aviation until the 1960s, accidents in aviation frequently occurred because of technical reasons. However, when determining the causes of air accidents, the role of the human factor was also paid attention to.

In 1934, after a series of accidents in which 12 pilots were killed in approximately six months, the Americans decided to buy "*Link Trainer*" training devices and train pilots to perform IFR flights. It was established that the cause of the disasters was flying into the clouds at night, which resulted in total spatial disorientation.

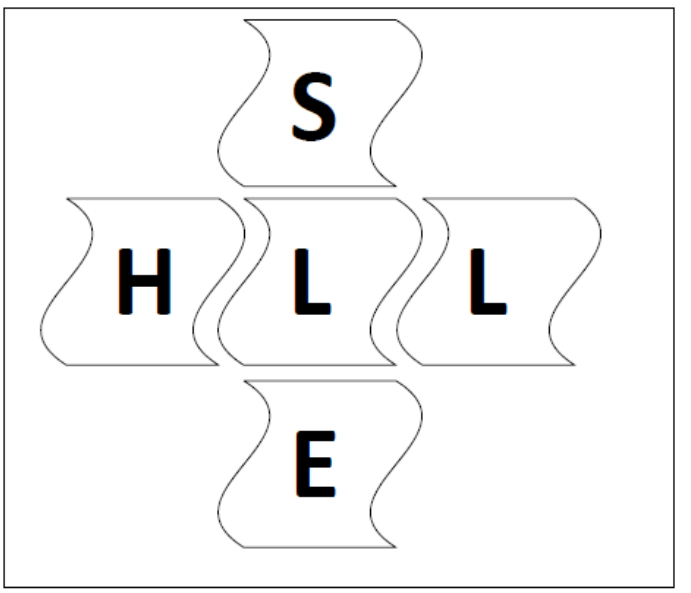
During World War II, disturbing statistics of air accidents which were not directly related to combat operations were noticed in the Royal Air Force. Losses suffered in combat were comparable to those resulting from human errors made during training flights, or e.g. during landings. With the technical, technological, IT progress, aviation developed dynamically. There was also a change in the perception of the role of human factor in maintaining the proper level of flight safety. The impact of the human factor on safety in aviation began to be examined.



Source: Podręcznik zarządzania bezpieczeństwem, s. 18 (Załącznik do wytycznych Prezesa ULC, 24 November, 2015).

Fig. 1. The evolution of thinking about flight safety

In 1972, Professor Elwyn Edwards presented a model of the interaction between the human being – operator (pilot), the machine (aircraft) they operate, the environment, and the applicable procedures. Such a method of analysing the significance of the human factor was named the SHEL Model. In 1975, Frank Hawkins proposed supplementing the SHEL model with an additional element, i.e. another human being in the work environment (i.e. interaction between these human beings), as a result of which the model gained a broader meaning and a new name – the SHELL model.



Source: Podręcznik zarządzania bezpieczeństwem, s. 22 (Załącznik do wytycznych Prezesa ULC, 24 November, 2015).

Fig. 2. SHELL Model – components and interfaces

The SHELL Model shows the human operator as a central component of the system and analyses the relationships (interactions) between him and other components of the system. It points out the need to adapt the individual components of the system (equipment, procedures, organisation, and the environment) to the capabilities and limitations of the human operator. If those components are not properly adapted to the human being as the central component of the system, this may lead to errors in the operation of the system, and to safety-threatening situations.

The interactions of the individual components of the system were the subject of the analysis. First of all, the interaction between the human operator and the machine **(Liveware-Hardware – L-H**) was examined. It was found that already at the stage of designing the aircraft, designers should take into account not only the needs but also the limitations of the pilot. Cockpit ergonomics became important since they have a significant impact on the pilot's ability to control an aircraft safely. The importance of cockpit ergonomics may be experienced by the pilot who, with the harness tightened

before the flight will have to perform dynamic flight maneuvers, during which he will have to reach some switch or control located e.g. on the instrument panel. Cockpit ergonomics are also the optimum distribution of individual onboard instruments on the instrument panel, which makes it easier to control the correctness of the flight on the basis of their indications. Cockpit ergonomics are also the appropriate seats for pilots, adapted to the specifics of their body structure, but also to the nature of the tasks to be performed on a given type of aircraft. This also means the customisation of the aircraft control system devices for easier and safer controlling of the aircraft.

The interaction between those two components of the system is mutual. First, at the design and construction stage, the human being has an influence on what the aircraft to be produced will be like. Later on, because of its capabilities and limitations, the aircraft will "force" the pilot to learn and then comply with various rules of conduct during the maintenance and operation of the aircraft.

Liveware (human being) and software (L-S) as elements of the system interactions are interactions between the human component and, e.g. regulations, procedures, checklists, manuals, instructions, computer software etc. Within the scope of professional activity, the human operator very often has to move within the limits of rules imposed by various types of regulations, instructions etc. In order to be able to control an aircraft, the pilot must use the professional literature to acquire the required knowledge, learn the regulations governing the rules of flight, learn the applicable procedures, know checklists, and be able to operate computer programs. But the human operator also interacts with the software (being a part of the system) by having the capability to change procedures upon finding and proving gaps or errors in them. This also applies to individual documents if they lack significant regulations, or if the applicable regulations are outdated or incorrect.

Liveware-environment (L-E) components involve interaction between human operator and internal and external environments. The internal environment affecting human operators affects their psychophysical state. High temperature in the cockpit, G-load during the flight, noise, or vibration can worsen the pilot's concentration and psychomotor efficiency and, as a consequence, lead to e.g. making wrong decisions, or making errors in controlling the aircraft, in other words – to hazardous situations. The external environment includes weather factors (visibility, cloud cover, dangerous phenomena such as icing, fog, storms, strong turbulence etc.), and aviation infrastructure.

The analysis of the human-human interface **(liveware-liveware – L-L),** as elements of the system discussed, occurring between people in the work environment, allowed for a more complete assessment of the impact of the human factor on the safety of flight operations. Interpersonal relationships between flight crews, air traffic controllers, or ground crews can translate into the quality of tasks performed by individual members of these groups of people. Relations between the personnel and the management of the aviation organisation are also taken into

consideration as extremely important for the proper functioning of the organisation[1]. In all relationships between the elements of the system, the role of the human factor appears to be crucial.

Selection and training of pilots – an element of limiting human factor as a cause of accidents

The awareness of the role of a human operator in maintaining an acceptable level of safety in aviation increased the requirements for pilot candidates. For many years, in order to achieve the intended objectives, this has been accomplished by the appropriate selection of pilot candidates, followed by thorough academic preparation and practical training.

Upon the successful completion of flight training, pilots obtain a licence to fly. Analysing the flight training model in general terms, one may be tempted to claim that it has changed very little over the years. Qualitative differences can be seen when analysing its individual elements in a more detailed way.

Stricter and stricter requirements concerning the health and psychophysical fitness of pilot candidates have become a kind of first stage of selection, increasingly difficult to pass. At present, great emphasis is placed on the mental state of the candidates as part of their required health level. Psychological tests have begun to play a very important role. Personality traits of pilot candidates are being verified in more and more detail. Bearing in mind the pilot's working environment, the objective of psychological tests is to check that the candidate can meet these requirements. It is assumed that a pilot should be resistant to stress, assertive in action, balanced, responsible, and, in the case of multi-crews, able to interact in a group.

The temperament traits which are particularly important in pilots are those related to the intensity of reaction, i.e. reactivity, intensity and resistance to fatigue and to the so-called distractive stimuli, as well as traits related to the time of response, i.e. time of reaction, reaction stability, reaction rate and agility[2].

It is worth remembering that depending on the nature of the air tasks to be performed by pilots, some temperament traits will be more or less desirable. Requirements that will apply to airline pilots will be different from those applying to pilots performing aerobatic flights, and still different from those applying to military pilots performing flights on combat aircraft.

While assuming that the tools used by psychologists in the selection of candidates for the pilot profession fulfil their role, it should also be remembered that this is just the commencement of the process of preparing candidates for that profession.

1 Podręcznik zarządzania bezpieczeństwem - Załącznik do wytycznych Nr 11 Prezesa ULC z dn. 24 November 2015.

2 R. Markowski, T. Smolicz, *„Czynnik ludzki" w procesie szkolenia i treningu lotniczego*, p. 56.

The initial selection stage should provide a selected group of candidates for flight training who meet the criteria imposed on them. In the case of candidates for the Air Force, the use of specialised training devices throughout the entire training period helps to significantly support the process of preparing pilots for the execution of air missions. The possibility of applying a grading of difficulty during the training provided improves its efficiency and, what it involves, also improves the fitness-conditioning of candidates for flight operations.

At the initial stage, a very important element in the selection of pilot candidates is checking their physical condition, and then improving it by means of systematic training. Various training devices are used to that end.

Loop Gyroscope

Source: http://lotnik.wp.mil.pl/pl/4_154.html (25 March, 2020).

Training with the use of the Gymnastic Training Equipment for Pilots (GTEP) such as the Rhõn Wheel, Gyroscope, and Loop is extremely important for the pilot because it affects the improvement of motor coordination, responsiveness in a dynamically changing external environment, and the improvement of spatial orientation, which is so important in the execution of air missions. In order to effectively prepare candidates for air training, training programmes should systematically be adapted to new training needs as well as to new training solutions used in aircrew training. Mastering only manual skills is not sufficient any longer. At present, the pilot must also have operator skills, i.e. programming and operating skills for various onboard devices (e.g. GPS or FMC).

Flight simulators and human factor in accidents

The use of more and more modern training tools, which may include e.g. better and better flight simulators, provides greater training opportunities. The possibility to combine theory and practice makes it possible to achieve optimum training effects. The prerequisite for this is the rational planning of the use of training tools in the process of academic instruction and practical training. This is accomplished with the

use of the appropriate training devices adapted to the level of skills to be achieved during the training. Before the pilot takes control of an advanced flight simulator (FFS)[3], less advanced and simpler training devices are used in order to teach how to master procedures or the FMS[4] operation, i.e. use the database, entering data from the flight plan, downloading necessary information, and operating individual aircraft systems.

Such an approach obviously contributes to reducing the costs, because the costs of training on an FFS simulator are many times higher than the costs of using a Flight Training Device (FTD)[5]. It is also worth remembering that it increases the effectiveness of training and the rationality of using flight simulators. The value of using training devices in the flight training process may be fully appreciated by analysing the initial phase of training on these devices when a pilot candidate will have to apply their academic knowledge in practice. This gives an invaluable opportunity to practically verify whether the theoretical knowledge obtained is sufficient to perform flight tasks or whether it may still require supplementation.

Checking the pilot in action using a flight simulator seems to be the best way to verify if there are any deficiencies in his professional preparedness. For the trainee, this is an integral part of flight training, aimed at mastering the correct performance of all actions and tasks during the flight. It also gives him the opportunity to learn that what previously might have seemed "not significant" may turn out to be crucial for making the right decisions or performing the correct actions.

Source: https://sillothairfield.wordpress.com on 24 August, 2019.

Photograph: Simulator of onboard equipment and systems operation procedures

3 FFS – Full Flight Simulator.
4 FMS - Flight Management Computer.
5 FTD - Flight Training Devices.

According to the principles for using training devices rationally, the pilot can commence comprehensive training using an FFS simulator only after having mastered the required procedures and the operation of individual instruments and aircraft systems.

Source: https://strefalotnicza.blogspot.com on. 24 August, 2019.

Photograph: Boeing 787-9 flight simulator (FFS)

Due to the use of flight simulators in pilot training, pilots are definitely better prepared for performing complex and complicated tasks. This contributes to the reduction of the number of accidents resulting from errors committed by aircrews.

Tasks performed by pilots require continuous instruction and training. The more complex the tasks are, the more extensive the training will have to be.

Expanding knowledge can be done individually using professional literature, but maintaining and improving practical skills requires professional training. It can be assumed that a pilot who flies regularly and systematically has his training provided, but it will be difficult to maintain an adequate level of flying professionalism when one performs a small number of flights. The flight simulator becomes the proper tool for reducing the risk associated with that. Airline pilots, despite being well-trained, are usually required to take simulator training twice a year. The duration of each training session is several hours, during which the pilot has to deal with training scenarios. The scenarios often result from the training needs or the recommendations of the airline. Trainings may comprise various tasks. They may, for example, be aimed at improving multi-crew cooperation (MCC) if the carrier decides that the level of that element is not high enough. They may also concern the training of new flight procedures introduced, or preparing aircrews for flights to airports previously unsupported and having specific procedures. The flight simulator is also useful for

training in the operation of new aircraft equipment, or in the event of significant modifications to the equipment used so far which will affect its operation. Currently, FFS simulator training also includes the simulation of commercial flights. During such a session, the crew has to train in the actions related to flight preparation and performance. The simulated flight corresponds to the reality of a flight between airports operated by a given airline. It starts with a pre-flight briefing, pre-take-off activities (engine start-up, taxiing), and radiotelephony transmissions related to obtaining the required clearances etc. During the training, flight time realities are preserved, and all the tasks have to be performed by the aircrew in the same way as in a real flight. The scenario of such a flight includes non-routine situations, i.e. emergency situations to be dealt with successfully by the crew.

Trainings with the use of flight simulators may also include the implementation of recommendations issued by aviation authorities following the conclusions of committees investigating accidents. It is an extremely important tool for increasing flight safety, as it allows the introduction, changes, and modifications in the procedures in order to improve the level of preparedness of flight crews in dealing with various types of emergency situations. These recommendations often concern non-routine situations not covered in flight manuals previously. During such simulator training sessions, the crew's task is to diagnose the situation on board correctly and take appropriate actions to prevent or limit the negative consequences of the simulated failure. It should be remembered that in aviation, having the necessary knowledge is halfway to success. The ability to use that knowledge and the correctness of actions taken by the pilot under great emotional stress during an emergency situation are the prerequisites for achieving the required standards of safety.

The aircrew who have the opportunity to practice their actions in various emergency situations are taught to diagnose such situations correctly and then train to perform the correct actions after they occur. This enriches professional knowledge and practical skills of aircrews and also importantly develops a mechanism for rational thinking and acting under great stress.

Conclusions

Nowadays, it is difficult to imagine flight instruction and training without the use of flight simulators. Bearing in mind the benefits of using flight simulators[6] in flight instruction and training, it should also be emphasised that they are beneficial in teaching flight crews how to behave in hazardous situations. During practical training in the air, teaching or training the crew how to behave in the event of an onboard fire will not be realistic enough, and, moreover, implementing the required procedures could result in reducing flight safety (e.g. when training to shut down a "burning" engine).

6 J. Kozuba, *Czynnik ludzki – rola symulatora lotniczego w szkoleniu lotniczym*.

Flight simulators allow pilots to practice difficult and dangerous flight maneuvers safely, without taking unnecessary risks, and, by properly mastering them, reduce the risks associated with their performance. Aircrews trained in acting in the event of emergencies are less prone to stress and making errors. Simulator training helps to improve situational awareness, due to which analysing and diagnosing the causes of failure becomes easier. The ability to recognise the symptoms of dangerous situations correctly allows pilots to implement the appropriate emergency procedures. Inability to determine the causes of malfunction on the basis of the symptoms is stress for the aircrew and growing nervousness over a prolonged period, which may be the reason for further errors.

It should be remembered that an aircrew's actions are based on the previously acquired knowledge and experience. While performing flight tasks, pilots systematically expand their knowledge and enrich their flight experience along with the increasing number of hours flown behind the controls of the aircraft. However, the experience gained only from flying many hours behind the controls of an aircraft is not enough for a pilot to speak of attaining a level of safety sufficient for performing flight-related tasks.

Since accidents occur in aviation, aviation authorities appoint teams of specialists from various fields to explain their causes. Determining the cause of an air accident is extremely important because it enables corrective actions to be taken. They may concern structural changes to the aircraft, or modifications to accessories or devices whose malfunction caused the accident. However, work of the air accident investigation committees also results in issuing recommendations regarding the necessity to train flight crews in proper conduct after the emergence of a malfunction. This is due to the fact that the malfunction itself was not the direct cause of the air accident, but the poor assessment of the onboard situation resulted in erroneous crew operation and, consequently, an accident.

To avoid similar situations and limit the human factor in accidents, increasingly better flight simulators are the best tools to be used in the instruction and training of flight crews. They make it possible to train in normal flight procedures, but are also invaluable in teaching and training of flight crews in the event of emergencies. It is said that we learn from our own mistakes. Flight simulators are tools that enable learning based other people's mistakes. The introduction of flight simulators for flight instruction and training greatly limits the human factor in accidents.

References

Hać R., *Symulatory w procesie kształcenia i doskonalenia lotniczego personelu latającego i naziemnego w lotnictwie Sił Zbrojnych*, Siedlce 2014.

Klich E., Szczygieł J. *Bezpieczeństwo lotów w transporcie lotniczym*, PIB Radom 2010.

Kozuba J. (2011). *Impact of human factor on the likelihood of aircraft accident*, Transport Systems Telematics 2011.

Kozuba J., *Czynnik ludzki – rola symulatora lotniczego w szkoleniu lotniczym,* Logistyka 6/2011.

Markowski R., Smolicz T., *„Czynnik ludzki" w procesie szkolenia i treningu lotniczego,* WSOSP, Dęblin 2016.

Marlinussen M., Hunter D.R., *Aviation psychology and human factors*, CRC Press, New York 2010.

Obwieszczenie Nr 21 Prezesa Urzędu Lotnictwa Cywilnego w sprawie wprowadzenia do stosowania europejskich wymagań bezpieczeństwa lotniczego JAR – FSTD A, 26 October, 2010.

Podręcznik zarządzania bezpieczeństwem - Załącznik do wytycznych Nr 11 Prezesa ULC, 24 November, 2015.

Sasim B., *Elementy ergonomii kabin samolotów wojskowych*, Warszawa 2009.

Semminar proceedings „*Symulatory w lotnictwie. Nowe technologie*", Warszawa, Dęblin, 2008.