Impact of human factor on likelihood of aircraft accident

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ABSTRACT
Flight safety is not a goal itself, neither it is the aim of aviation. Flight safety is the state in which all intended goals are realized. All potential threats which can influence the processes of goals achievement are controlled simultaneously. The significance of “human factor” in the aviation safety has been known for years. It was the subject of research done by many research institutions, but only at the end of the twentieth century it received its importance. We can state that the “human factor” was institutionalized. The influence of human factors on likelihood of aviation accident was indicated by taking into consideration analysis result of aviation accidents both in military and civilian aviation in Poland. The statistics of US civilian aviation were taken into consideration for comparison. Possible prevention steps aimed at improving the level of flight safety for the areas related to the human factor were indicated.

KEYWORDS: human factor, aviation

1. The concept of safety in aviation

Aviation is a special kind of human activity, through which the dream of entering the sky comes true. With time, the dream of gliding pleasure changed into desire to use the plane to realize more practical, commercial tasks. It soon turned out to be accompanied by several hazards. They escalate when the safety rules which are in force in aviation are abused, regardless of the pilot, his or her experience, the kind of aircraft the flight operation is carried out on. The conception of safety in aviation can have different connotations, i.e. no accidents, no menace to realization of flight operation, avoidance of errors. Regardless of the connotation being taken into consideration, the participants of flight operations, i.e. pilots, technical and safety personnel are tasked with controlling all elements being within their competence and influencing the level of safety during preparations and realization of flight operations. The tools on the disposal of aviation organizations’ managers seem to allow to specify all variables which can lead to unwelcome flight situations. Elimination of such situations through activities adequate to anticipated menace (group of menaces) can lead to reaching full control of unwelcome factors. However, open and changing dynamically environment of preparation and realization of flight operations makes the aims impossible to reach. Each flight accident is a new unwelcome flight situation, regardless of similarities to the ones which happened in the past. Concluding, unwelcome flight situations occurred, occur and will occur in aviation, despite the huge efforts put by aviation organizations to avoid them. Our aim should be to take actions to minimize frequency of their occurrence and their effects if they occur.

1 For this article needs, it was assumed, that an unwelcome air situation is an air accident or air incident defined by art. 134 Ustawy Prawo Lotnicze z dnia 03.07.2002 r. (Dz. U. z 2006 r. Nr 100, poz. 696, z późn. zm.) oraz § 20 Instrukcji Bezpieczeństwa Lotów Sił Zbrojnych RP, WLOP, Warszawa 2004, WLOP 346/2004.
“No human activity, no system built by human gives guaranty, that it will be entirely free of inner menaces and operational errors”.

For this reason, safety should be treated as a conception fitting more the theory of likelihood than the theory of certainty, according to which increasing safety risk is the consequence of menaces, which are necessary to be accepted, appearing in the environment of preparation and realization of flight operations. The fundamental safety factor is still included in correctly functioning system of aviation organization control. Therefore, as long as unwelcome flight situations occur at an acceptable level, i.e. not awakening the feeling of danger within the users of flight equipment, aviation will be seen as safe, regardless of its kind and application.

“Technical failures and operational errors at an acceptable level will be tolerated by safety system of aviation organizations”

Owing to complexity and openness, we can encounter different attitudes to defining safety in aviation. J. Lewitowicz 2 defined safety analyzing mutual relations of aviation system elements C-SP-O (Human-Aircraft-Environment) as a set of system’s features including an aircraft, ground means of flight guidance and navigation as well as air traffic management, aircraft crew, ground service and maintenance personnel, preventing arising of failure situations, protecting people taking part in the flight from possible damage and assuring rescue in the case of equipment damage, crew or ground services errors, and also in the case of unwelcome external influence. Roland and Moriaty stated, that “System safety can be defined as its characteristics allowing to function considering risk factors characterized by acceptable level of likelihood of situation occurrence.” According to J. F. Federer, system safety is “creating evaluation of the organization in retrospect based on identification and risk management.” Conclusion of the safety definitions above defined is that stated in the Textbook of Safety Management, where safety was defined as “a state, in which the likelihood of a person’s injury or possession damage is reduced and kept at or below the acceptable level through realization of continual danger identification process and management of risk level in aviation safety”. 4

Nowadays safety is seen as a result of main processes management realized in the managing organization, whose aim is to maintain the desired level of safety resulting from dangers in operational context. The so far experience of aviation operations and research results of accidents which occurred in the past show, that human is the most unreliable element of the managing organization system. For this reason, that much attention is paid to human factor in the field of aviation safety.

2. Human factor – concept, significance for flight safety

According to Polish Ergonomics Society, ergonomics is an applied science aiming for optimal adjusting of tools, machines, technology, organization and material work environment as well as items of common use to requirements and human’s physiological, psychological and social needs. 5 In other words, projects done according to the rules of ergonomics help keep to the health and workers’ safety standards. Ergonomics is the concept preferred by European countries, Australia and New Zealand. Americans, however, preferred to name the same concept human factor. At present, both terms are used by Americans interchangeably. In Europe, the term human factor is used more liberally and applied to all factors connected with human which influence the preparation and realization of all kind of operations (human activity) and includes issues connected with such fields as ergonomics, psychology, natural environment etc. Therefore, regarding aviation operations ergonomics is often treated as a sub-discipline of the fields connected with the term human factor, excluding the fields connected with projecting.

A similar attitude towards these concepts has appliance in the case of ICAO. In the documents of ICAO there is a statement, that the term “human factor” is so broad that it is difficult to define it explicitly. It is defined in a multi-disciplinary depiction, focuses mainly on interactions between members of aviation organizations – people and their work environment (and also their lives) and providing solutions for good fit of human and work environment. In the multi-disciplinary depiction human factor is shown as a discipline providing knowledge from a wide range of subjects such as psychology, physiology, anthropometrics, biomechanics, biology, chronobiology, projecting, statistics etc. Ergonomics is a term used often instead of the term human factor, however only applying to the relation human-technician /technique. Summing up, human factor refers to a human being in their work and life environment, their relations with machines, procedures, influence of the environment on people and

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2  J. LEWITOWICZ, Podstawy eksploatacji statków powietrznych, cz. 3 – Systemy eksploatacji statków powietrznych, ITWL, Warszawa 2006, str. 264
relations between members of aviation organizations in work environment. In aviation the term human factor is also used referring to search for ways of adapting personnel, medical and biological factors to optimal aviation structures and operations of air traffic control.  

Commonly accepted model referring to depicting interactions between human and elements of aviation system in the organizational and operational context allowing to understand human factor better is so called SHELL model (fig. 1). The SHELL model was developed and described for the first time by Edwards in 1972, and it was supplemented with another L element by Hawkins in 1975 and it is defined as SHELL from that time. Human being – operator (L1) is not as a predictable and reliable element as it is a certificated piece of equipment which occurs in aviation environment, owing to the fact, that as a private person they possess definite abilities and limits. Therefore, this model refers to interactions between its central element L1 and its remaining components, i.e. S, H, E and L  2, but it does not refer to reactions outside the areas connected directly with the human element, i.e. S-H, S-E and H-E. Occurring in the center of the model human being (L1) is an element susceptible to adaptation to surrounding environment, legal-procedural and training (S), technical (H), broadly understood work environment (E), aviation organization (L2). Therefore, on the one hand it is considered to adjust the elements above to human (project stage), on the other hand, it is considered to adjust human to the elements of the model (project, put into practice, utilize). Discrepancy between human and the other four elements of the model within the confines of the interaction leads to human error during the preparation or realization of flight operations.

Human being is seen as the most critical and flexible component of aviation system considering their ability to act as an operator (pilot, mechanic, air traffic controller, etc.). Human is characterized by several groups of factors influencing safety of preparation and realization of flight operations, which can include:

- physical features – shape, dimensions, strength, weight, senses, etc.;
- physiological needs – requirements connected with food, liquids, air, etc.;
- psychological factors – meeting training requirements, acquiring knowledge, gaining experience, stress and overwork resistance, coping with overloading information and personal problems, ability of management, etc.;

ability to receive, process and apply information;

environment tolerance – temperature, pressure, humidity, time of day, meteorological conditions, etc.

Taking these factors into consideration, relationships between the elements of SHELL model can be described as follows:

1. Human – Machine (L1-H). This relationship is one of the most broadly considered problems connected with a member of aviation personnel work environment. For example, projecting the pilot's seat, a constructor should consider characteristics resulting from body build, projecting the monitor of the instrument panel or instrument dial in the cabin to fit sensors and characteristics to human’s perception abilities and information processing by human through application of coding, kind and dimensions of marks, colors and their symbols most appropriate in accordance with ergonomics. As far as the instruments (monitors/screens) are concerned, their placement on the panel is as important as presenting information. Exploitation parameters and placement of all the devices and instruments in the cabin should match the adaptation characteristics resulting from human nature (build, perception abilities, information processing in the complex work environment, etc.), and minimize at the same time

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8 For this articles needs, the elements represented by letter L are divided into: L1 - human – operator, L2 - aviation organization.
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It is the human factor that has the greatest impact on the likelihood of an aircraft accident. Human error can result from a lack of knowledge, skills, and experience, or it can be caused by environmental factors such as weather conditions or noise levels.

Human – operator meeting the criteria defined by aviation law (health, knowledge, skills, flying experience, etc.) and taking into consideration experience resulting from exploitation of the technical device, e.g. plane, should not be afraid of interaction results between L1-H. Adaptation abilities resulting from experience, knowledge, skills and human nature should allow to optimize L1-H system and neutralize possible defects impossible to predict in the earlier stages of technical devices’ development (e.g. planes).

2. Human – Law, procedures, controlling and managing computer programs, etc. (L1-S). Interaction L1-S includes relationships between human and assisting systems in the work place i.e. regulations, manuals, documentation defining service or executing activities, special cases during the flight, standard operational procedures (SOPs), training and assisting computer programs. These relationships refer to easiness and explicitness of application of the elements above, which should be characterized by commonness, exactness, legibility of illustration / transmission, specialized phraseology, explicitness, standard symbolism. It means, that information should be given by the use of specialist terminology, it cannot be ambiguous, confusing or complicated. Specialist computer programs used in aviation should be written in the way, which is not a challenge for a person with average abilities in the areas connected with programming and using. At the same time, the information should be unambiguous, legible, and meet the requirements defined by the certification standards for e.g. onboard instruments, aviation maps, etc. The term procedure refers in this case to the knowledge of operational procedures and the ability of applying them as well as exactness of procedures realization including the knowledge of dangers’ situations and the ways of counteracting them, obeying the air traffic regulations and airfield procedures as well as procedures referring to pre- and post-flight activities. The term training refers to obeying the exactly defined procedures and training curriculum, use of modern training aids (simulators, e-learning) and current regulations, books and manuals. Experienced instructor staff possessing broad specialist knowledge is still a crucial element of training. Furthermore, training basis in the disposal of an aviation organization should allow to prevent arising of circumstances for an operational error through continual self-training of aviation personnel.

3. Human – Environment (L1-E). This relationship refers to mutual relationships between human and inside and outside environment of human activities. The inside work environment of flying personnel includes such elements as temperature, lighting, noise, vibrations. The outside work environment includes such elements as visibility, weather conditions (clouds, turbulence, aircraft icing, wind fault) and height of terrain above sea level. It should be emphasized, that all elements describing outside and inside work environment of flying personnel is characterized by high level of changeability and unpredictability referring to normal body rhythms (time of day, time of year). Additionally, aviation personnel realize operational tasks in a defined organizational environment susceptible to economics changes, which can influence considerably the environmental elements of the organization, i.e. technical equipment, supporting infrastructure (training, technical, social, etc.), financial situation of the institution and its employees, and at the same time elements determining the desired safety level during realization of the tasks by members of aviation organization.

4. Human – Organization (L1-L2). Interface L1 – L2 is seen through relationships between members of the organization in work environment, considering especially interactions operator – manager. These relationships are seen through work organization prism, considering relationships between people at different levels and areas of management, and their understanding of safety problems. Training of aviation personnel (pilots, technical personnel, air traffic controllers etc.), especially during the initial phase of gaining power is realized in relation to the individual, and not the crew (the team) skills. Long-term experience indicate the fact, that lack of understanding and insufficient skills of the crew were reason for a range of unwelcome flight situations, despite the highest level of knowledge and specialist skills presented by its individual members.

The creators of the SHELL model suggested the use of specific strategies aimed at prevention and elimination of operational errors committed by the team (crew) i.e. with reference to flying personnel - CRM, with reference to air traffic service (ATS) - TRM ATS and with reference to maintenance personnel – MRM. Implementing effective training programs for flight crews, teams of operational services, air traffic and technical services to prepare them for better co-operation and communication should result in a considerable reduction in the likelihood of operational error referring to L1-L2.

Summing up, the conclusions drawn from the analysis of interactions between a human operator and the remaining elements of the SHEEL model indicate that keeping
an acceptable level of safety in the preparation and execution of air operations will be possible if the following conditions are fulfilled:

1. Taking a number of ergonomic factors into consideration by an airplane designer and meeting high standards of health, knowledge and skills by the pilot - operator (L1-H).

2. Each aviation organization should have a flight training base to allow adequate preparation of its personnel to carry out the tasks and the hardware that we can define as staff friendly (L1-S).

3. Organization staff should be prepared to respond to the challenges arising from the specific work environment, as well as the optimal disposition of the funds considering the elements which have a major impact on safety (L1 E).

4. Members of the flight crew, air traffic control services and technical security of flights should be adequately trained to work in the crew - the team (L1-L2).

3. Human factor versus unwelcome air situations

The factor determining occurrence of an unwelcome air situation is usually occurrence of several consecutive errors in the air transport organization management system, deficiencies in the operation of aircraft, air traffic control and/or crew operator errors. The pilot is the last link in this chain of cause-effect, and it usually bears the consequences of mistakes made by others.

History of air accidents is as old as aircraft. The first air accident took place at the time of Thomas Selfridge and first lieutenant of USA artillery Orville Wright’s flight on 7 September 1908, on the Fort Myer landing field – California.

According to the statistics of Aircraft Crashes Record Office in Geneva, 19,908 aircraft accidents killed 129,920 people around the world in the years 1905-2010. The main causes of these situations were classified into three main groups: human error - 68%, technical failure, and other (sabotage, collisions with birds, unexplained, etc.) (Fig. 2).

Then Boeing Aircraft Company, adopting more detailed division of main air accident causes, indicates errors done by aircraft crew (55%) as a fundamental reason of 183 air accidents in the years 1996-2005 (Fig. 3). It should be mentioned that maintenance errors (4%), air traffic services errors (6%) or errors in aviation communications / misunderstanding (8%), can be also counted to the group of human errors. It means that the main cause of approximately 73% of the analyzed air transport aircraft accidents were human factors.

The results of the analysis of aviation accidents occurred in the Polish Armed Forces in the years 1946 - 2003 show that 71% of them were caused by errors committed by people (flight crew, technical staff, air traffic services), 16% by technical failure, and the remaining 13% by other causes, such as weather conditions (Fig. 4).

In the case of the U.S. general aviation in the years 2000 – 2009 indicators of the main causes of accidents differed a little from those shown on the figures above. 75% of 2799 serious accidents were caused by human error (Fig. 5).

The results of the analysis of aviation accidents regardless of the type of aviation, aircraft type or nationality of the aircraft, regardless of the time interval in which the analysis of the phenomenon was carried out, clearly show that human, described from the perspective of the human factor is the cause of about 70% of all air accidents. In the context of this analysis, methodology of accident investigation, drawing appropriate conclusions, and consistently carrying out preventive activities aimed...
The impact of human factors on the likelihood of aircraft accidents is of particular importance. In the above mentioned context E. Klich's statement that "Hitherto existing methods and manners of forming awareness of threats limited to one-time ventures being organized after an air accident seem insufficient" seems to be correct. The methods used on a short-term basis and limited range, irregularly are forgotten in a short time. Repeated from time to time accidents, caused by the same errors confirm that the effectiveness of steps taken so far is insufficient. Presented statistics indicate, that above statement refers mainly to aviation personnel. Too often, preventive measures defined by the Air Accident Investigation Unit with reference to a crew member, an aircraft mechanic or an air traffic controller were limited to the perpetrators of unwelcome air situation and had the limited nature of activities conducted in the period immediately after the occurrence of the situation. Scientific - research facilities that are currently available to organizations involved in the study of unwelcome air situations enables to conduct a broad analysis of the main causes of errors made by flight crew. The results of these studies should help define the risk areas and develop an appropriate methodology of actions to neutralize them. These actions should be systemic in nature and include the group (groups) of aviation personnel selected through the prism of characteristics of the offender (offenders) of unwelcome air situations.

"If we know the risks, we should seek ways of avoiding them, even if not all situations will be possible to eliminate."

Past experience and conclusions from the reports of air accidents indicate that the guilty part of any unwelcome air situation can be characterized by defined factors affecting committing the error.

These factors are:
- the pilot's age - determining the age range in which pilots have committed the most errors;
- determining the total flying time and that of the aircraft type, which was used during unwelcome air situation - determining the influence of presented aviation experience on the probability of pilot's error in certain conditions;
- pilot's level of training seen through the prism of their qualifications - determining the influence of presented aviation experience on the probability of pilot's error in certain conditions;
- last holidays considering particularly break in flying, among them breaks related to health problems - determining the influence of breaks on the pilot's skills;
- recent unwelcome air situation if it took place - determining the impact of this event on the pilot's psycho-physical condition and his skills;
- weather condition, with particular emphasis on hazardous weather phenomena (fog, wind fault, aircraft icing, etc.) - determining influence of meteorological conditions on the likelihood of pilot's error;
- the lie of the land where the incident took place (mountains, sea, etc.) - determining the influence of the lie of the land on likelihood of the specific type of air incident;
- the type of airplane on which flight was executed - determining the influence of ergonomic factor and aircraft piloting characteristics on probability of committing an error by a pilot with definite aerial experience;
- the type of task carried out by a pilot - determining the influence of the degree of task difficulty, during which the unwelcome air situation took place, on likelihood of committing an error by a pilot with definite aerial experience;


Fig. 5. Causes of accidents in the U.S. general aviation in the years 2000 - 2009. Source: Own calculations based on the author: Nall Report AOPA Air Safety Foundation for the years 2001 - 2010.

• aviation phraseology and „density in the air” – determining the influence of the air speak on the probability of committing an error by a pilot (personnel ATS\(^{12}\)) in specific conditions of task realization, etc.\(^{13}\)

Systematically collected database of specific groups of unwelcome air situations such as loss of airspace orientation during flight in the clouds, can be used to identify groups of high risk aviation personnel and take appropriate preventive measures in the area of training perfection, flight simulator training, health care etc.

We can find examples of these type operations in hitherto existing history of aviation. Following the introduction of the new generation of jet aircraft in the sixties, the number of serious accidents in the Air Force of Great Britain increased. Taking their causes into account, which lie in the vast majority on the human factor side, a series of recommendations to improve safety of air operations was developed and implemented, including, inter alia,:

- limited range of standardization of aircraft cockpits and lack of uniformity of deck instrument placement has caused limitation of flying on many types of aircraft by a pilot under training;
- the instructors and commanders of the aviation teams were appointed from experienced military pilots holding 400 hours of flight time on jet aircraft;
- the most experienced instructors were directed to supervise the training process in aviation units;
- demands on the flying personnel for knowledge of aircraft designs, operating rules and piloting techniques of the aircraft type were increased;
- new procedures were introduced and supervision of the observance of principles of airplane equipment operation (oxygen plant, jet chair) was tightened;
- obligation to carry out the pilot's training in the event of engine shut off in flight was introduced - five training sessions per year were carried out;
- existing flight simulators training programs were improved and new tasks in existing flight simulators training programs were introduced.

4. Conclusion

Conclusions drawn from unwelcome air situations which have already occurred were the reason for these actions. It was determined, inter alia, that the unwelcome air situations occurred mainly during approach procedure and landing, which were caused by double increase in approach speed. It was indicated that most accidents were caused by pilots at the age of 19-21, and the least at the age of 26-35. The change of jet velocity parameters caused the occurrence of unprecedented events on piston engines aircraft, such as high altitude anoxia, faster growing g-force, the cabin's fog or frost, changing characteristics of the airplane, particularly in the areas near the speed of sound.\(^{14}\)

The human acting as an aircraft operator, an aircraft mechanic or an air traffic controller remains still the weakest component of the SP - C - O. The data introduced in the article clearly indicate the need for conduct of constant prophylactic activity with the aim to improve flight safety level, especially with reference to the areas related to so called human factor. This need is supported not only by deaths of flight crew or passengers, but also by huge property losses. The use of safer but complex aircraft systems put higher demands for flight crews, maintenance teams and air traffic controllers. A human, not technological development is limitation for aircraft technical characteristics in the age of twenty-first century. We should take advantage off all capabilities, even the most expensive ones, to increase the flight safety level. Therefore, unwelcome air situations should be treated as those designating various stages of development-related areas of flight safety and prophylactic applications determined by the post-accident committees. Those applications should be treated as a source of knowledge to build new and enhance existing strategies to prevent errors committed by aviation personnel. These activities should be conducted at all levels of the organizations supervising and carrying out aviation tasks.

Bibliography


\(^{12}\) ATS – Air Traffic Service


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