Prof. Andrzej Fellner (corresponding author)
Director of the Central-East Europe Civil Aviation Personnel Education Center – Silesian University of Technology
Head of the Department of Aviation Technology – Silesian University of Technology
andrzej.fellner@polsl.pl
Mariusz Osowski, M.Sc. Eng.
Head of the Department of Human Resources and Professional Development – GTL S.A.
mosowski@gtl.com.pl

Implementation of „Human Factors" in the safety analysis of human resource management process

Summary

The present article is based on the findings of scientific research conducted within the FP7-GALILEO-2011-GSA-1 project, acronym SHERPA (Support ad-Hoc to Eastern Region Pre-operational Actions in GNSS"[1]). The implementation of novel techniques and technologies triggered the requirement for preparation of a safety case, while generating a scientific problem of how this should be done. The working hypothesis adopted was verified both theoretically and empirically, while the obtained results allowed the development of a new model for assessing risks related to the implementation of satellite techniques and technologies for the purposes of aviation, upon which the safety case was built. The model was adopted at the international forum during the SHERPA project workshops (Eurocontrol and GSA). This article discusses only issues related to human factors, which are essential for the Safety Management System (SMS) and the subject of permanent certified trainings in the aviation industry. The model was developed which underwent positive empirical verification and became the subject of training offered to the staff of the Voivodeship Inspectorate of Road Transport, for the first time in Poland. Based on scientific research conducted and its results, it can be concluded that the implementation of organizational, technical or legal solutions requires the safety case to be built using the model presented herein. Additionally, human factors training is an indispensable SMS element and it should be applied to every sphere of human activity, particularly those involving human resource management.

Keywords aviation, human factors, risk analysis, safety case, Reason's model, SHELL Hawkins' model, SMS, SHERPA, safety management

Introduction

The scientific and technical development, stemming from the increasing level of knowledge, is not free from errors, mistakes and technical failures, which may result in incidents and accidents. The technological development observed in the aviation industry is possible owing to parallel procedures in terms of control, analysis of potential risks and the possibility of compensation thereof, carried out in order to maintain the proper level of security. At the same time, the number of aviation incidents and accidents has significantly decreased [15] (Fig. 1) after the implementation of certain safety management recommendations and the change of attitude towards safety from standard (an adverse event triggers a reaction in terms of developing means and procedures aimed at preventing future events of this type) to proactive (any change requires a risk analysis, assessment of an acceptable level of safety and preparation of measures that will compensate for potential risks).

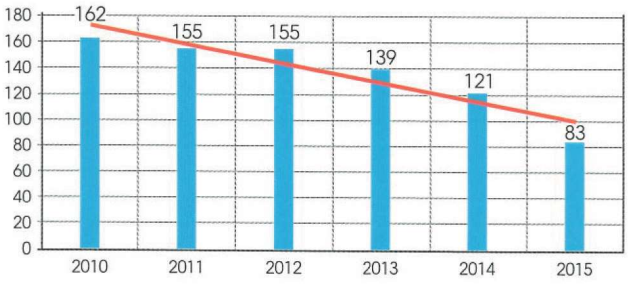

Fig. 1. Accidents in the years 2010–2015.

Preflight / Taxi	Takeoff / Initial Climb	Climb	Cruise	Descent	Maneuvering	Approach	Landing	Other
3,5%	23,4%	3,3%	15,7%	2,6%	13,0%	9,7%	24,1%	4,7%
	2%	13%	60%	10%	11%	3%	1%	
Exposure – Percentage of Flight Time								

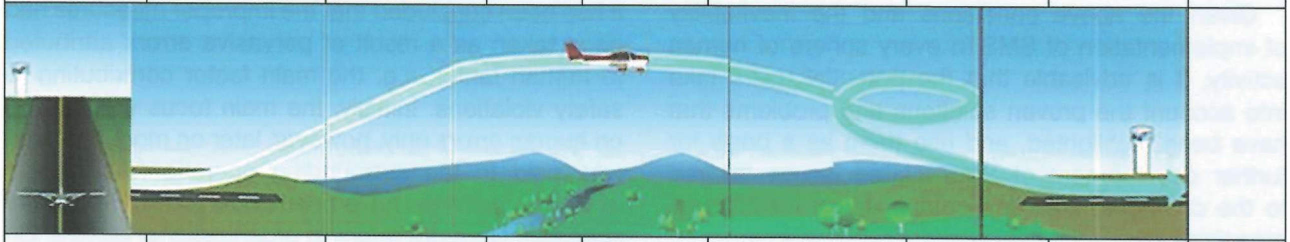

Fig. 2. Percentage of general aviation accidents depending on the phase of flight.

Safety is the most important factor to aviation, and therefore it is given priority. Ideally, any adverse events should be completely eliminated. However, it is not possible to achieve a 100% safety level as any human action or human-made system are subject to risks. Therefore, the safety in aviation has been defined as a permanent process of risk identification and management, aimed at full compensation or achieving an acceptable level of risk. It should be born in mind that both safety and security should be considered. Aviation incidents and accidents are also presented as percentages, depending on the phase of flight (Fig. 2.).

Management comprises a set of activities, including planning (setting goals and determining the way they are achieved), decision making (selection of actions from among the available options), organizing (grouping of actions and resources, creating structures), managing human resources and controlling (monitoring of progress and effects of actions with the aim of improving the processes). Management also relies on the application of knowledge, experiences, tools, methods and techniques. The basis for the management of the institution are the inter-related resources which fall into one of four categories: human resources (skills, knowledge, abilities, predispositions, staff, personnel), financial (financial assets), tangible (infrastructure) and information (data required to make decisions). Without doubt, human resources, perceived as the characteristics and properties, which enable operation under specific conditions and on specific positions within the team carrying out assigned tasks, are of key importance to the management. The above means that the human resources category comprises of such elements as knowledge, skills, abilities, health, attitudes, values and motivation, whereby these elements are inherent to every member of the TEAM (in the aviation sector translated as Together, Everyone, Achieve, More – a rule that is, unfortunately, often forgotten in everyday life). An effective team requires human resources management which consists in undertaking proper actions, adequate to one's potential, in order to achieve the required results.

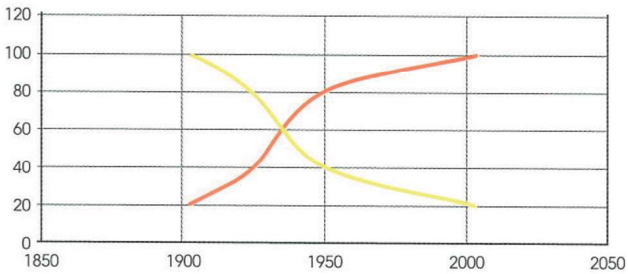

Fig. 3. Causes of aviation accidents: human error – red line; equipment failure – yellow line.

The analysis of aviation incidents and accidents registered from the onset of aviation up to the present day (Fig. 3) revealed that initially the main cause were technical errors. However, with the appearance of jet propulsion and pilotage-navigation systems, another cause showing a considerable upward trend became apparent – human errors. Thus, preventive measures became necessary consisting in compensating for risk factors. Consequently, the proactive safety approach has been adopted, e.g. taking any possible measures to minimize human or technical errors. To this end, substantial organizational factors have been identified, including institutional management, procedures, trainings and institutional safety policy. Subsequently, national requirements for safety management were adopted at the ICAO forum, specifically:

- Security programme – integrated set of provisions and operations improving security;
- Safety Management System (SMS) – organized approach to safety management, incorporating indispensable organizational structures, responsibilities, policies and procedures [2].

The identification and assessment of risks are the basic SMS assumptions and therefore, the first methods and rules of conduct regarding safety management in civil aviation were set forth by ICAO in 2001. Subsequently, in 2012, ICAO decided to add a new Annex entitled "Safety Management". Also the EU acknowledged the gravity of this problem by adopting Resolution 965/2012 which obliged air carriers to implement SMS. The implementation process in certified aviation training organizations was completed in the current year.

Given the above conditions and the inevitability of implementation of SMS in every sphere of human activity, it is advisable that the potential users take into account the proven solutions and problems that have been highlighted, and use them as a basis for further development of SMS-related issues tailored to the character, size and complexity of institutions/ organizations.

Issues related to human factor in cause and effect models

Initially, the aviation was characterized by a low-level technology, lack of appropriate infrastructure and limited supervision. At that time, ambitious production targets were outlined, based on the principles of safety systems, yet without implementing the measures necessary to meet these objectives. The probability of breakdowns increased along with increasing potential. Hence, early aviation experienced frequent accidents that were subject to analysis, with the conclusions drawn and recommendations laid down being the only preventive measures against future accidents. In these times, air accident investigations were incapable of providing the necessary information, owing to the insufficient technical and scientific development. It was not until the proper infrastructure emerged, legal supervision was increased and novel technologies were applied to air accidents investigations that the gradual yet steady decline in the number of accidents was observed. It is assumed that until the 1970s, the safety was determined predominantly by technical factors, hence the focus had been placed on their improvement.

The following years brought the implementation of jet propulsion, on-board weather radars, flight management systems, area and satellite navigation and air traffic management systems (increased airspace capacity and flexibility). The analysis and research of air accidents revealed that the number of technical failures is negligent, the majority of accidents being caused by humans. Based on research results, it has been concluded that the improper measures had been taken as a result of pervasive errors attributed to human factor, e.g. the main factor contributing to safety violations. Initially, the main focus was placed on human errors only, however, later on more attention was paid to the surrounding operational reality, in which the activities have been undertaken. Hence, the specialist literature refers to organizational factors. On the other hand, operational reality is, after all, created by human activities and as such it can be categorized as human factor.

The term "human factor" is difficult to define, and therefore it has been accepted after Arthur Reber that it refers to a professional discipline that deals with human-machine relations and focuses on psycho-physical aspects underlying the decision-making process as well as other aspects of information processing. Sometimes, this term also refers to such factors as equipment, physical environment, tasks and persons performing work [8]. For the first time, the term "human factor" came into view in the US at the beginning of the 20th century. Sadly, until recently, human factor was insufficiently taken into account as the potential cause of air disasters during the ensuing investigations. With the evolution of procedures for investigating air disasters it became apparent that the human factor analysis system was necessary, which would serve as a framework for modern investigation methodologies. To this end, the Human Factor Analysis and Classification System (HFACS) has been developed. This tool provides a possibility to draw general conclusions, and thus undertake ad hoc and systemic measures aimed at minimizing risks linked to the presence of human factor.

In view of the above, it can be reasonably concluded that the accident is always a function of several factors and it results from active and hidden circumstances. Technical failures are often an effect of negligence or erroneous human decision-making. Fig. 4 is the best representation of mutual relations between systemic

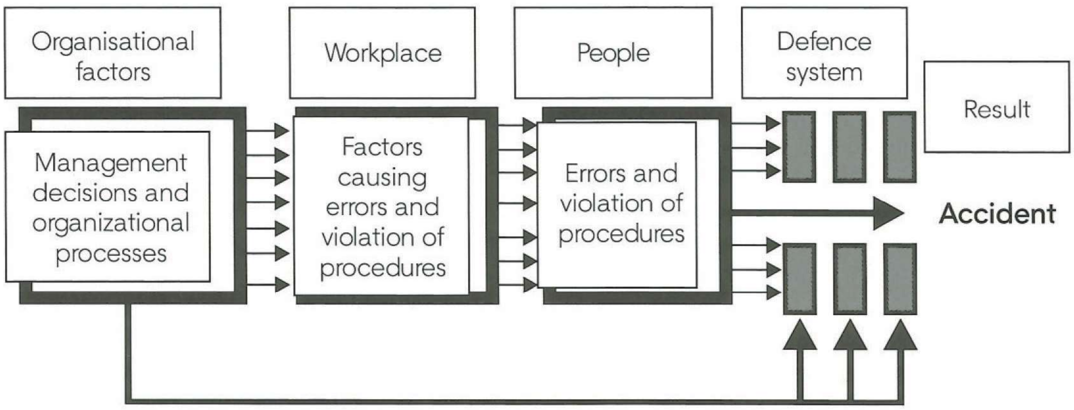

Fig. 4. Accident causation model.

factors (related to organization and management) which contribute to accidents. Despite certain elements in the aviation system designed to protect from inadequate actions and erroneous decisions at all levels, the model shows that these elements can simultaneously create hidden conditions which lead to accidents. Also certain errors and violations of procedures by operational personnel may diffuse through different preventive elements of the aviation system, thus causing an accident. According to the model, such actions may result from either unintended mistakes or deliberate breaches of existing procedures and practices.

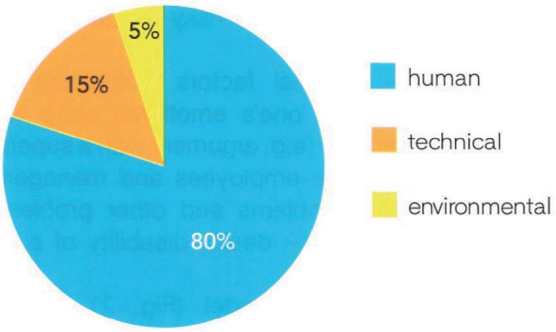

Fig. 5. Causes of aviation accidents.

The analyses revealed that only 15% of air accidents were due to technical reasons, 5% to the environment, whereas 80% resulted from human factor (Fig. 5) [7]. It can be inferred from the data compiled that erroneous actions and decisions are undertaken by efficient and adequately qualified employees, since new techniques and technologies are introduced in haste, whereby the people operating the devices and systems are often neglected. Certainly, other causes of accidents lie in poor equipment, inadequate procedures, trainings and operations manuals. Safety management requires the understanding of capabilities, limitations and human behavior in an operational context. The more so that humans, being the most flexible element of the aviation system, are at the same time the most exposed to the negative impact of various factors. Very often, human error is a result of a system structure, inadequate equipment or training, flawed procedures etc. Due to the extensive nature of this subject, human error can be the starting point for finding the appropriate solutions that would prevent future errors and compensate for the potential risks. In view of the above, it is imperative to understand the context of the operational environment which fosters human errors as well as the factors and circumstances that affect human activities at the workplace. Currently, the most popular models in the aviation sector are the SHELL Hawkins model and the Reason "Swiss Cheese" model.

In the SHELL Hawkins model, the workplace is a set of inter-connected factors and circumstances which substantially affect human activities. It is a simple yet meaningful conceptual tool that enables analysis of the components and features of a multipurpose aviation operating system, also in the context of their interactions with humans. The SHELL model developed by Hawkins in 1975 built upon the SHEL model proposed by Edwards in 1972. In the context of the aviation industry, SHELL is an acronym for five principal, interactive components, whereby human-to-human interactions are also taken into account (Fig. 6).

S (Software)	– procedures, trainings, technical support, etc.;
H (Hardware)	– machines and devices;
E (Environment)	– operational environment;
L (Liveware) in the middle	– humans (operative personnel, despite high adaptation capabilities, their actions are prone to changes);
L (Liveware)	– humans (collaborating with the above personnel).

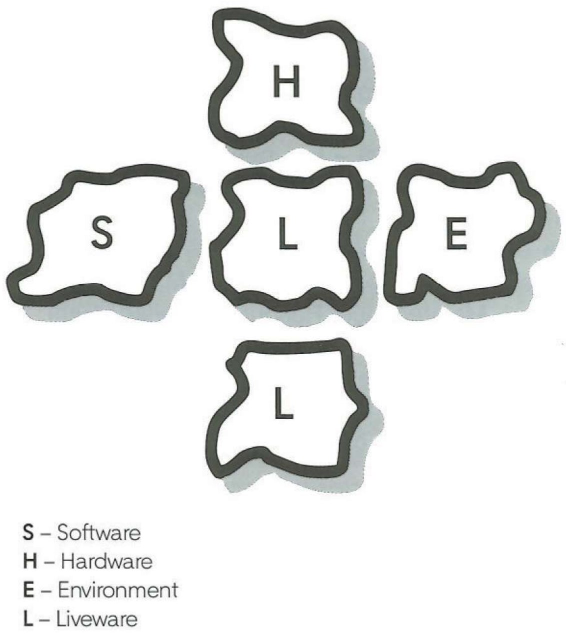

Fig. 6. SHELL Hawkins' model.

The visible, irregular lines around particular shapes indicate that it is difficult to obtain a close match between humans and the system within which they operate since, contrary to the equipment, humans are impossible to normalize. It is necessary to understand the consequences of imperfect interactions between the components in order to efficiently compensate for their negative effect on the central block (human operational activity). This means that in order to avoid undesirable safety hazards, an effort must be made to match the components of the system with humans. Hence, the following areas of interactions can be distinguished:

L – S, liveware – procedures/software, this type of interaction requires user-friendly software;

L – H, liveware – hardware, most frequently considered ergonomic interaction taking into account human factor;
L – E, liveware – system's operational environment, interaction between humans and internal (e.g. physical factors such as temperature, lighting, noise, vibrations, air quality) or external (in aviation e.g. visibility, turbulences, interferences with normal biological cycle) environment. Additionally, aviation systems are characterized by political and economic limitations which influence the entire corporate environment (e.g. the adequacy of physical facilities, auxiliary infrastructure, local financial situation, the effectivenesof the legislation in place). The quality of the decision making in the operational environment can be negatively affected by the lack of appropriate infrastructure and the pressure exerted towards circumventing procedures;
L – L liveware – liveware, interaction within a team (e.g. cooperation between crew members, air traffic controllers, maintenance technicians, remaining operational personnel). Interactions include leadership, cooperation and relations between personalities. Interactions are significant, and therefore an error management system – the so called Crew Resource Management (CRM) – has been developed for flying personnel, including training sessions. Operational work results have led to the extension of trainings onto other specialist groups of the aviation industry. Hence, TRM – Team Resource Management and MRM – Maintenance Resource Management have been developed for air traffic services and aircraft maintenance services, respectively. The above groups are equally subject to interactions between employees and management, corporate culture and climate as well as various conflicts, which undoubtedly affect human activities.

Other factors influencing human activities are of the following natures:
physical – ability to carry out the required tasks (e.g. strength, height, arm length, sight, hearing);
physiological – may negatively affect one's performance or perception (e.g. oxygen availability, general health condition and physical fitness, illnesses, smoking, alcohol and drug consumption, stress, fatigue, pregnancy);
psychological – readiness to take action in foreseeable situations (e.g. training, knowledge, experience, workload, psychological performance, motivation, assessment, approach to risky behaviors, trust, resistance to stress);
psychosocial – external factors within the social system, which affect one's emotional state in and outside the workplace (e.g. argument with a supervisor, disputes between the employees and management, personal financial problems and other problems at home, random events – death, disability of a family member).

The Swiss Cheese model (Fig. 7) developed by James Reason offers an algorithm for the circumstances leading to an air accident. This model derives from a study on the role of humans in causing air accidents. The basis is the hypothesis that the air accident occurs as a result of aggregation of active and latent errors. In Poland, the Swiss Cheese model is used by the Committee for Investigation of National Aviation Accidents [5]. Importantly, a particular importance is placed on latent errors. When unrecognized and unnoticed, these errors may lead to unsafe human activities and, in consequence, to

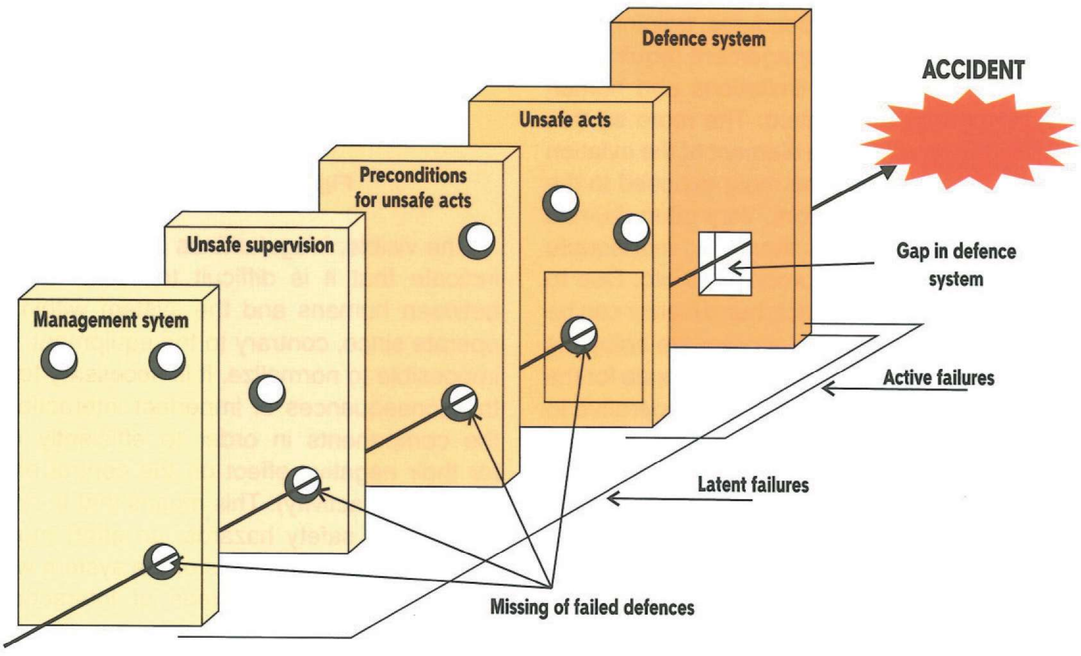

Fig. 7. James Reason's Swiss Cheese model.

an accident. Additionally, they may occur at the least expected time [6]. The use of Reason's model enables identification of other factors contributing to improper actions of flying personnel (e.g. poor supervision and management of an aviation company, unsafe practices of the crew). Consequently, preventive measures can be implemented, such as permanent modification of the aviation systems and training methods or the selection of suitable candidates for the positions offered. According to Reason's model and theory, in the aviation industry every specialist is responsible for safety, in line with the position held. Thus, safety depends on flying and ground personnel as well as organization and management system [5].

It results from the above that each accident causation model assumes the appearance of certain harbingers, which may become noticeable only after the event. Hence, in order to evaluate and assess such dangerous hidden conditionalities, an objective in-depth and rational risk analysis needs to be performed – a Safety Case.

Model for developing a "Safety Case" on the basis of the SHERPA project

Prior to introducing a new organizational, legal or technical element into the functional aviation system, it needs to undergo safety assessment and risk analysis, which determine the probability of occurrence of a hazardous event and the ensuing consequences. Safety assessment is a tedious and labor-intensive process, during which an acceptable level of safety and a satisfactory risk mitigation measure are determined through a series of seven consecutive stages:

I. Preparation of description of the proposed system or change should include: purpose, application, functionalities, boundaries and interoperability between the system and the external elements as well as a description of the operational environment. The scenario of the SHERPA project presents the aviation operational environment, including the delivered Air Traffic Services (ATS), communication, navigation and surveillance equipment, ground infrastructure, airspace and the procedures developed in particular areas. The purpose of the operational description was to outline the Concept of Operations (CONOPS) for a selected airport as compared with the standard [3].

II. Hazard identification, should take into account the potential sources of inefficiency and, depending on the nature and size of the system, it should include:
   - equipment (e.g. localized in the operating part of the airport), hardware and software,
   - operational conditions (e.g. winter, night) and environment (e.g. physical conditions, aviation area, flight routes),
   - human factor (e.g. change of crew, equipment operators),
   - areas of liveware - hardware interactions,
   - operational procedures (e.g. inappropriate division of tasks),
   - technical procedures (e.g. night inspection of electrical equipment within the operating part of the airport),
   - services provided by external parties, users (e.g. handling companies), security agency vehicles.

When considering this point, one should take into account any possible system configurations, whereas all personnel participating in the identification of hazards should be aware of the significance of latent factors. It is particularly necessary to identify the hazards stemming from the wrong interpretation of new procedures by the employees and the deliberate or unintentional misuse of new system possibilities. Hazard identification should be initiated as early as possible and it takes a form of identification sessions at the requisite level of detail, depending on the complexity and cycle stage of the system concerned. The identification session is a structured approach to hazard identification, enabling indication of all potential risks. To this end, the following techniques are applied:

a. hazard identification checklists – developed on the basis of analyses of the available accident/incident data or the operation of similar systems. Potentially hazardous areas are subject to further analyses.
b. group sessions – group brainstorming analysis used to verify the hazard identification checklist, carry out an in-depth hazard assessment or the detailed scenario analysis.

Hazard identification sessions require the presence of experienced operational and technical personnel and they usually take a form of a directed group discussion. Hazard assessment should cover the range from the least to the most probable hazardous event and it should assume the occurrence of the worst case scenario.

The SHERPA Project involved the implementation of satellite techniques into RNAV GNSS approaches and the performance of the final Functional Hazard Assessment (FHA) analysis, using an operational model of LPV approaches in the ECAC area [4,5]. Thereby, the operations preceding the case studies have been nominally determined. To this end, each operational activity carried out by the system/human/combination during subsequent phases of flight has been assigned a particular model/mode of errors/failures. Next, each error/failure mode was analyzed for:

- exemplary causes (in order to assess their viability, credibility, veracity),
- operational consequences and simplifications,
- hazards,
- rough comparisons of risks related to Instrument Landing System (ILS) approaches and preparation of recommendations on the use of measures to minimize these risks.

Project documentation contains the detailed description of the hazard identification method. With reference to SAM FHA guidelines, an FHA brainstorm encompassing relevant operational experts was impossible to organize due to project limitations and the lack of available experts in this field. Consequently, the work was organized as follows:

first iteration included the completion of the FHA tables by the security expert supported (questions/ answers) by two technical experts,

subsequently, several FHA working sessions were organized:

- three half-day sessions participated in by 3 technical experts in the field of airframes, one of whom had a solid operational experience;
- one half-day session participated in by relevant specialists representing the institution providing air navigation services (Air Navigation Service Provider – ANSP): 5 Air Traffic Control Officers (ATCO) and one technical expert.

During the above working sessions, the operational model was for the first time brought forward for expert validation and the final FHA table (Table 1) was reviewed by RAFG participants as well as other operational and technical experts. The main results of the draft version of the final FHA assessment were submitted to operational and technical experts for validation during the safety assessment workshop, devoted mainly to the Preliminary System Safety Assessment (PSSA).

III. Assessment of the gravity and consequences of the event, takes place after the consequences of all hazards identified in stage II have been registered, At this stage, the gravity of each consequence is determined. It is important to note that risk classification schemes have been developed for applications that require regular risk analysis, e.g. „Joint Aviation Requirements – Large Aeroplanes" (JAR-25) authored by the Joint Aviation Authorities (JAA). This document is accepted by civil aviation authorities of many countries as a reference point for demonstrating the compliance with national airworthiness codes. JAR-25.1309 document and the attached Advisory Material Joint AMJ 25.1309 define the risk classification criteria used to determine acceptable risk levels, which take into account historical accident statistics and the need for an inverse relationship between the probability of loss of function and the gravity of hazard to the aircraft and its occupants. Although the criteria laid down in JAR-25 refer specifically to the airworthiness of the aircraft, they can be used as a guide for the development of similar classification schemes for other purposes. Once the gravity of consequences has been determined for all hazards identified, the results of the assessment, along with the rationale for choosing particular gravity classifications, should be recorded in a hazard register.

The SHERPA project involved the implementation of satellite techniques to RNAV GNSS approaches and the development of necessary classifications for the severity of adverse events as presented in Tables 2, 3, 4 and 5.

IV. IV. Estimated likelihood of hazard occurrence is developed through directed discussions, whereby a standard classification scheme is used as a reference point. The data produced are tabulated. The SHERPA project involved the implementation of satellite techniques to RNAV GNSS approaches and the assessment of a likelihood of adverse events with the corresponding severity levels (Table 6). The likelihoods were presented in both qualitative and quantitative terms. In some cases, the data enabling the construction of the system components as well as comprehensive historical failure rate data for a given component may be available.

Table 1. Selected examples of hazards in SHERPA project

OH No	OH Definition	Comments
OH1.	**Flying low while intercepting the final approach (vertical profile)**	Aircraft wrongly flying towards FAWP at a lower altitude than the approach procedure minimum
OH2.	**Attempting to intercept the final approach path from above (vertical profile)**	The condition similar to OH1 or aircraft at too high altitude prior to FAWP. In both cases aircrew fails to intercept the glide slope and, instead of launching a missed approach procedure, decides to intercept it from above, in violation of the normal procedure.
OH3.	**Failure to follow the correct final approach path**	Aircraft is not on the correct final approach path due to an incorrect path, incorrect position estimation, incorrect guidance, or incorrect maneuvering.
OH4.	**Descending below DA without visual contact**	Aircraft descends below DA while aircrew has no visual contact because they have selected wrong/erroneous approach parameters, obtained wrong airfield pressure setting or used wrong DA.
OH5.	**Failure to execute correct missed approach**	Failure to follow the expected/instructed flight profile during a missed approach.

Table 2. Risks related to aircraft operations

Catastrophic	Hazardous	Major	Minor	Not important
A	**B**	**C**	**D**	**E**
Aircraft loss	Large reduction in safety margins or aircraft functional capabilities	Significant reduction in safety margins or aircraft functional capabilities	Slight reduction in safety margins or aircraft functional capabilities	No effect on safety

Table 3. Risks to safety of persons

Catastrophic	Hazardous	Major	Minor	Not important
A	**B**	**C**	**D**	**E**
Loss of life	Serious injuries	Risk of serious injuries	Decrease in the workers capabilities to cope with the adverse conditions resulting from increased workload	Unfavourable work conditions

Table 4. Financial loss

Catastrophic	Hazardous	Major	Minor	Not important
A	**B**	**C**	**D**	**E**
Catastrophic financial loss > 1 000 000 USD	High financial loss > 100 000 USD and < 1 000 000 USD	Significant financial loss > 25 000 and < 100 000 USD	Minor financial loss > 5 000 and < 25 000 USD	Small financial loss < 5 000 USD

Table 5. Effect on airport reputation

Catastrophic	Hazardous	Major	Minor	Not important
A	**B**	**C**	**D**	**E**
Significant impact on the international reputation	Significant impact on the national reputation	Significant impact on the reputation among airports	Medium impact on the reputation among airports	Medium or slight impact on the reputation of airport

Table 6. Estimated likelihood of adverse events occurrence

Level	Descriptor	Frequency – statistics	Frequency description
5	**Frequent**	Once in a month / > 10 out of 1000 operations	May occur a few times during the whole life cycle
4	**Occasional**	More than once in a month / 5–10 > out of 1000 operations	May occur once during the life cycle of every system
3	**Remote**	Once a year / 1–5 > out of 1000 operations	Unlikely to occur during the whole operating cycle of every system
2	**Improbable**	Once in 5 years / 0,1–1 > out of 1000 operations	Unlikely to occur in a few systems of the same type but cannot be excluded
1	**Extremly improbable**	Once in 10 years / < 0,1 out of 1000 operations	Should not occur during the whole operational cycle

SEVERITY

CATASTROPHIC	5	5 ANALYSIS	10 UNACCEP-TABLE	15 UNACCEP-TABLE	20 UNACCEP-TABLE	25 UNACCEP-TABLE
HAZARDOUS	4	4 ACCEPTABLE	8 ANALYSIS	12 UNACCEP-TABLE	16 UNACCEP-TABLE	20 UNACCEP-TABLE
MAJOR	3	3 ACCEPTABLE	6 ANALYSIS	9 ANALYSIS	12 UNACCEP-TABLE	12 UNACCEP-TABLE
MINOR	2	2 ACCEPTABLE	4 ACCEPTABLE	6 ANALYSIS	8 ANALYSIS	10 UNACCEP-TABLE
NOT IMPORTANT	1	1 ACCEPTABLE	2 ACCEPTABLE	3 ACCEPTABLE	4 ACCEPTABLE	5 ANALYSIS
		EXTREMELY IMPROBABLE	IMPROBABLE	REMOTE	OCCASIONAL	FREQUENT
		1	2	3	4	5

LIKELIHOOD

		PROBABILITY				
		A ALMOST CERTAIN	B LIKELY	C MODERATE	D UNLIKELY	E RARE
SEVERITY	SEVERE 5	5A	5B	5C	5D	5E
	MAJOR 4	4A	4B	4C	4D	4E
	SIGNIFICANT 3	3A	3B	3C	3D	3E
	MINOR 2	2A	2B	2C	2D	2E
	INSIGNIFICANT 1	1A	1B	1C	1D	1E

Risk probability	Risk severity				
	Catastrophic A	Hazardous B	Major C	Minor D	Negligible E
Frequent 5	5A	5B	5C	5D	5E
Occasional 4	4A	4B	4C	4D	4E
Remote 3	3A	3B	3C	3D	3E
Improbable 2	2A	2B	2C	2D	2E
Extremely improbable 1	1A	1B	1C	1D	1E

Fig. 8. Risk assessment matrix – original project design and Polish version.

The likelihood estimation of the occurrence of risks related to human errors is generally a more subjective parameter (it should be taken into account that even when equipment is evaluated, failures caused by human error (e.g. incorrect technical service procedures) are possible). Once the likelihood evaluation has been completed for all hazards identified, the results of the evaluation, along with the rationales, should be recorded in a hazard register.

V. Risk assessment is based on the assumption that risk acceptability depends on the likelihood of occurrence as well as gravity of consequences, whereby the criteria used in the assessment of acceptability are always two-dimensional. Acceptability is usually based on a comparison with the gravity of consequences/likelihood model. Risk assessment matrix was used to determine the likelihood and gravity during the SHERPA project involving the implementation of satellite techniques to RNAV GNSS approaches (Fig. 8).

Risk assessment includes a sphere between acceptable and unacceptable risk level, for which the decision on the acceptance is not clear-cut. Such risks belong to a third category, i.e. they can be tolerated after being reduced to the lowest rational level. If a risk has been assigned the lowest level, attempts at its mitigation will be undertaken and those mitigation measured deemed feasible will be implemented.

VI. Risk mitigation measures are undertaken when a particular risk fails to meet predefined acceptance levels. The identification of appropriate risk mitigation measures requires a good understanding of the hazard and its facilitators since an efficient measure will lead to a modification of one or more of the facilitating factors. Achieving the desired level of risk reduction entails the introduction of one or more mitigation measures. Possible approaches include: verification of system design, modification of operational procedures, changing the number of employees assigned, training of personnel who will deal with hazards.

The SHERPA project involved the implementation of satellite techniques to RNAV GNSS approaches as well as the application of appropriate risk mitigation procedures (Fig. 9).

Risk probability	Risk severity				
	Catastrophic A	Hazardous B	Major C	Minor D	Negligible E
Frequent 5	5A	5B	5C	5D	5E
Occasional 4	4A	4B	4C	4D	4E
Remote 3	3A	3B	3C	3D	3E
Improbable 2	2A	2B	2C	2D	2E
Extremely improbable 1	1A	1B	1C	1D	1E

Fig. 9. Schematic representation of risk mitigation.

VII. Preparation of safety assessment documentation is the final stage consisting in documenting the results of the safety assessment as well as arguments and evidence proving that the risk related to the implementation or change in the system has been eliminated or subjected to appropriate control, thereby being reduced to a tolerable level. Aside from the description of the safety assessment results, the documentation should contain a summary of the methods used, hazards identified and measures of risk mitigation necessary for meeting risk assessment criteria. The documentation must also contain a hazard register. Additionally, it should be sufficiently detailed as to allow the reader to infer about the decisions taken and how the risk classification (as acceptable or tolerable) has been substantiated. Finally, the documentation should include the names of personnel involved in the assessment process.

Conclusions

The last years saw an increasing understanding of the mechanism of aviation accidents and incidents. In the context of the causes of error, the focus has been shifted from technical factors (the 1970s) to human factors, although some experts attempt to distinguish a separate group of factors – organizational (however, the factors in this group are also human-related). People play a key role for the functioning of maintenance staff and airport services. They perform various duties indispensable for safe and effective airport operation. Occasionally, an employee may be unable to complete the tasks assigned to him/her in a proper and timely manner. Such failure may lead to numerous adverse effects, including damage to aviation equipment, injuries, delay of flights or damage to any equipment within employee's operating area. Within this context, human factor is an indispensable component of every safety case.

Acknowledging the importance of the issues discussed above, President of the Civil Aviation Authority enacted a Human Factor (H) Ordinance No. 3 on 22 February 2005, in which the groups of causes of aviation incidents and accidents, related to flying personnel, but also technical, environmental and organizational areas, have been specified. For example, cause H2 may be a consequence of training shortages (02) or the lack of standards, controls and audits (03). Similarly, cause H5 may result from safety management gaps (01) or the lack of standards, controls and audits (03). The groups of causes include:

H1 – deliberate actions
H2 – lack of qualifications
H3 – operational errors
H4 – communication errors
H5 – procedural errors
H6 – inability to carry out activities due to physical or psycho-physical incapacitation.

Sources of figures and tables

Fig. 1: www.baaa-acro.com/result-histogram-crash-page
Fig. 2: www.dynamicflight.com/avcfibook/instruction_techniques
Fig. 3: www.avhf.com
Fig. 4: ICAO: Podręcznik zarządzania bezpieczeństwem, Doc 9859 AN /460, Montreal 2006, s. 10.
Fig. 5: Truszyński O., Biernacki M.: Skalowanie udziału czynnika ludzkiego w wypadkach lotniczych, „Polski Przegląd Medycyny Lotniczej" 2010, nr 1 tom 16, s. 28.
Figs. 6–9: authors
Tabs. 1–6: authors

Translation Rafał Wierzchosławski

Bibliography

1. Fellner A.: Polish National Scenario Report, Doc. SHERPA-PANSA-NSR-D21EP, Issue 01-00, 2013, p.79
2. ICAO: Podręcznik zarządzania bezpieczeństwem, Doc 9859 AN /460, Montreal 2006, p.10.
3. APV SBAS Approach – Concept of Operations, CONOPS 1 28/01/2009.
4. EUROCONTROL: Safety Assessment Methodology Guidance Material on Planning and Conducting FHA Sessions, SAF.ET1.ST03.1000-MAN-01-01-03-A
5. Jong H.: Guidelines for the Identification of Hazards – How to make unimaginable hazards imaginable? NLR-CR-2004-094, EUROCONTROL 2004.
6. Klich E.: Using the James Reason Theory in air Events Study, "Journal of KONBiN" 2008, Vol. 4(7), p. 20.
7. Truszyński O., Biernacki M.: Skalowanie udziału czynnika ludzkiego w wypadkach lotniczych, "Polski Przegląd Medycyny Lotniczej" 2010, Vol. 1(16), p. 28.
8. Kałużna E., Fellner A., Metody uwzględnienia czynnika ludzkiego w zarządzaniu bezpieczeństwem systemu transportu lotniczego, „Prace Naukowe Politechniki Warszawskiej" 2014, Vol. 103.
9. Reber A.S., Reber E.: Słownik psychologii, Scholar, Warszawa 2000.
10. Makarowski R.: Ryzyko i stres w lotnictwie sportowym, Difin, Warszawa 2010, p. 190.
11. www.avhf.com
12. www.baaa-acro.com/result-histogram-crash-page
13. www.dynamicflight.com/avcfibook/instruction_techniques
14. The Bureau of Aircraft Accidents Archives in Geneva.