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Selected Elements Influencing Pilot Situational Awareness

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Abstract:

The article discusses the influence of pilot's knowledge, skills, experience, as well as the influence of technical and environmental factors on pilot's ability to build a proper Situational Awareness (SA) state during an aviation operational activity. Moreover, the decision-making process and SA process were defined, and their dependence from the perspective of some aspects of abilities presented by pilot as well. Authors' conclusions are based mainly on their own research supported by results of research available in the specialist literature.

Keywords:

Decision-making process, SA, human factor, aviation safety.

1. Introduction

Despite huge changes in aviation technologies, materials, and the level of cockpit ergonomics or aircraft automation systems designed to improve flight safety, human factor still leads to errors of various kinds. No matter what kind of aircraft or aviation will be taken into consideration, errors made by pilot are still the main causes of approximately 70 % of aviation accidents.

Pilot's decision-making can be treated among others as a systematic approach to SA, risk assessment, or stress management. Therefore, it is important to understand how human factor can influence the pilot's decision-making process and how this process can be improved.

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2. Situational Awareness Versus Decision-making Process

Pilot’s ability to make an adequate decision in any situation is the basic condition for maintaining the proper level of aviation safety. Moreover, pilot’s decisions belong to the core transactions and have high influence on the state of an aviation organization and its development ability. Making decisions can be either regarded as a problem-solving, or it can be described as a behavioral reaction to situations in which aviation personnel makes decisions on the basis of aviation procedures, norms, and principles described in emergency procedures, as well as personal knowledge, skills, and experience. It is worth mentioning that pilot’s decisions are often made in unfriendly, unpredictable, and dynamically changeable environment.

Some definitions of decision-making can be found in literature. F.E. Harrison defines decision as “a moment, in an ongoing process of evaluating alternatives for meeting an objective, at which expectations about a particular course of actions impel the decision maker to select that course of action most likely to result in attaining the objective” [1]. From the pilot’s point of view, the right decision should be treated as a key condition of his/her safety activity. In other words, it is very difficult to find out the percentage of pilots’ right decisions as opposed to erroneous ones.

The element which has the high influence on the pilot ability to take a proper decision is his/her state of the SA. Situational Awareness can be treated as a specific database of the aircraft status in a given task environment. More precisely, SA should be treated as the aircraft operator's ability to obtain information relevant to creating a clear mental picture of the aircraft's status at a certain moment from the dynamic mission environment and to anticipating its future changes in a certain time frame – the process of SA. The objective of these actions is to attain a desired state of knowledge – situational awareness state being a basis for decision-making, and allowing the operator to maintain the required safety level during air mission execution.

SA is regarded by some authors as a separated part of the decision-making process, rather than as its integral part [2]. Endsley justifies that view by the fact that even the "excellent" state of SA does not guarantee its correctness. The studies carried out by Endsley in relation to the impact of the human factor on the emergence of undesirable flight-related events show that in 26.6 % of cases examined, flight crews made wrong decisions even though their state of SA was adequate. Likewise, Smith and Hancock [3] expressed the view that the state of the pilot's SA shapes his decision, and the decision has a major impact on the state of the pilot SA, and thus they incline to the view that SA and decision-making should not be combined in one process. Moreover, they point out that, in practice, decisions and SA are not elements of a single process. These opinions fully confirm the pilot's decision-making model. Therefore, according to the above mentioned conclusions, implementing the SA process and attaining the desired state of SA by the pilot is not necessarily tantamount to the implementation of the decision-making process.

So when does the pilot start the implementation of the decision-making process? In the experts’ opinion [2, 4, 5, 6], an impulse for the pilot to commence the process of decision-making is the existence of a significant change in the mission environment, which enforces the comparison of the current status of the aircraft that is determined by a particular state of the pilot's SA with a reference model, specified in the planning stage of an air mission. Therefore, maintaining the desired state of pilot's SA at every stage of mission execution is so important.

Incorrect perception and/or selection of data obtained by the pilot makes his/her mental picture of the aircraft in real time, and in a specific future time period, differ from reality, and thus all analyses and decisions made by the pilot on the basis of such a mental picture are subject to high levels of error. These decisions are highly unlikely to facilitate attaining the desired aircraft status as defined by the specific air mission execution plan.

In conclusion, the higher the compliance between the pilot's mental pictures of the aircraft status and both the current and the anticipated aircraft status (state of SA), the higher is the probability that the pilot will make the right decision. In the decision-making process there are obviously a number of factors, more or less dependent on the pilot, which could have an impact on the effectiveness and safety in the context of air mission being executed – the knowledge, skills, experience, level of training, the assets at the pilot's disposal, the state of the weather, the level of flight safety provided by ground services, etc. However, the importance of those factors for the accuracy of pilot's decisions in the event of the low level of SA should be considered secondary. This view is also shared by Endsley who acknowledges that it is possible to make a decision under low SA conditions, but the outcome of such a decision should be seen more as a lucky coincidence rather than the result of the implementation of the decision-making process based on reliable data.

Because of the fact that pilots act in environments characterized by high risk, unpredictability and dynamic changes – environmental factor, aviation organizations and air personnel should have an appropriate approach to issues related to decision-making process, which is a prerequisite to maintain an acceptable safety level in aviation operations. The human factor and the degree of adaptation of the aircraft to the capabilities and limitations of the human factor also have a significant impact on the pilot's possessing the desired level of SA at every stage of air mission execution.

3. Elements Influencing the Quality of Pilot Situational Awareness

Taking into consideration Endsley's definition, the process of SA can be considered from the perspective of its three basic phases: perception of elements in current state of task environment, comprehension of the current aircraft status, and projection of the future aircraft status in a specified future time period [7] (Fig. 1).

Attaining the desired level of situational awareness by the pilot is possible only when the qualitative level being the condition of the proper execution of the subsequent process stages is attained by the operator in all stages of the process (Fig. 1 – continuous connecting line on the left side of the SA stages). If the desired qualitative level is not attained at any stage of the process, in the following stages of the process the pilot has to search for the error that has been committed (Fig. 1- broken line on the right side of the SA stages). As a result, the duration of the process can be much longer.

An analysis of undesirable flight-related events which occurred in the training units of the Polish Air Force Academy (PAFA) in 1974–1984* unequivocally shows that 82 % of the incidents caused by the human factor resulted from errors committed at Level 1 of

* In 1974-1984, there were numerous air accidents and serious incidents in the training units of Polish Air Force, and 79 % of those events were caused primarily by the human factor. Source: PAFA Flight Safety Bulletins covering the period of 1974-1984; results of the author's own studies obtained on the basis of air accident reports and the data included in [9].

the SA process, 11 % of the errors were committed at Level 2, and 7 % were committed at Level 3.

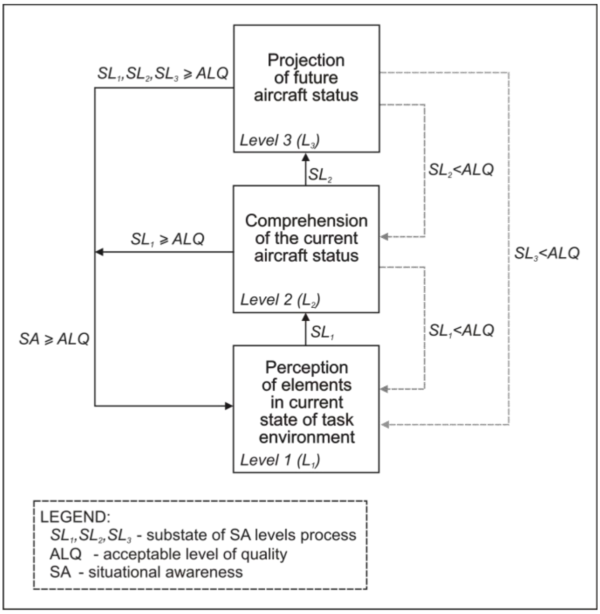

Fig.1 Sub-states of pilot's SA in particular stages of the process and the course of that process. Source: [8]

The following defines three levels of the SA process and identifies key factors that affect the proper course of individual levels of the process, and ultimately the possibility of achieving the desired state of SA by the pilot.

Level 1. Perception of information which comes from mission environment and which is crucial from the point of view of providing safety and execution of a particular phase of air mission.

Obtaining relevant information is a major element of the SA process. Quality and credibility of the information obtained exerts a crucial influence on the remaining phases of the process and also on the ability of an aircraft operator to attain the state of SA that is desirable from the perspective of two most significant elements, i.e. safety and probability of successful mission accomplishment. Depending on the source, the information in question may be divided into data coming from internal environment e.g. from readouts of instruments and systems available in the cockpit, from onboard warning systems, from subjective assessment of the operators' physical and psychological disposition, etc., and data coming from external environment, which include data received via radio from navigation services, the assessment of current weather and terrain conditions, and the data concerning air traffic congestion in the mission area. In data reception and selection, particular attention should be paid to the data which affect the safety of air mission execution. Not only analyses of the causes of undesirable flight-related events, but also pilots' opinions point out to the fact that major causes of information reception errors include the following:

1. Lack or limited availability of information, which may be caused by, among others:
   - technical failure of indicators, systems, installations, etc.;
   - lack of on-board systems relevant from the point of view of the mission accomplishment, such as e.g. aircraft icing warning system;
   - pilot's overestimation of the importance of information which is in fact less important from the perspective of aviation safety;
   - disregarding multi-crew cooperation (MCC) rules, e.g. lack of cooperation between the pilot flying (PF) and the pilot non-flying (PNF) and vice versa;
   - large amount of information received and actions performed by the pilot, particularly under time deficit conditions;
   - crew incapacitation, causing problems with information reception;
   - insufficient knowledge of English aviation phraseology;
   - low level of academic knowledge and/or low level of practical air training.
2. Inability to comprehend information precisely may be caused, among others, by the following factors:
   - individual items of information concerning a certain parameter of the aircraft status, having been received/read from two or more sources, differ significantly;
   - information concerning the status of the aircraft deviate significantly from the accepted standards;
   - measurement units of data read in cockpit are different from those received externally, e.g. the on-board altimeter has a scale graduated in feet and the data received from the air traffic controller (ATC) is in meters (or vice versa);
   - different instruments and systems – data sources for pilots – are applied in cockpits of the same type of aircraft . For example, different instrument scale graduation systems may be used, or warning sounds may be employed instead of warning lights to warn the pilot against a given hazard;
   - ambiguity of the emergency signalling – several installations are connected to one system warning the pilot against an on-board unit or system failure;
   - lack of desired communication level between the pilot flying (PF) and the pilot non-flying (PNF) or between the flight crew and the air traffic service (ATS);
   - poor level of academic knowledge and/or practical air training of the flight crew.
3. Erroneous information may be caused by, among others, the following factors:
   - technical failure of on-board systems or installations, e.g. erroneous instrument readouts resulting from icing or fault of the atmospheric air pressure transmitter;
   - limited perception capabilities of the pilot;
   - false information given to the flight crew by ATS personnel, technical services, aviation weather services, etc.;
   - poor communication between the flight crew and the navigation services personnel;
   - taking erroneous assumptions as correct during flight preparation;
   - erroneous suggestions made by other crew members.
4. Misinterpretation of an instrument readout may be caused, among others, by the following factors:
   - oversight;
   - distraction;

- absent-mindedness;
- necessity to read excessive amount of information in a short period of time;
- poor level of knowledge and/or practical air training of the flight crew – e.g. incorrect interpretation of weather radar indications resulting from the unfamiliarity of the symbols used on the radar scope display;
- being biased by the anticipated information and rejecting the current information provided by navigation services or on-board systems;
- environmental conditions – sunlight, condensation build-up on instrument displays, pilot's incapacitation;
- different instrument scale graduation systems used in different aircraft types.

5. Mental loss/rejection of information may result, among others, from the following factors:

- disturbances in mission environment;
- stress related to safety hazard during mission accomplishment;
- pilot's incapacitation;
- pilot's limited experience;
- mission complexity exceeding pilot's level of training;
- exceeding physiological capabilities of information perception by the pilot.

Because of the complexity of the factors which affect the pilot in attaining the desired level of receiving information from the mission environment, perception abilities are given much attention in the screening of pilot candidates. The results of the analyses conducted[†] unequivocally point out that perfecting that skill ought to be one of the most significant tasks to be covered within basic training and professional development of pilots. The results of analyses concerning the syllabi of pilot training and professional development courses, including courses involving the use of flight training devices (FTD), show that improving those skills have not been given enough attention. The exceptions to this trend include IFR certification training courses, exercises related to potential on-board emergency situations and, widely popular in civil and national aviation, MCC (Multi Crew Cooperation) and CRM (Crew Resource Management) courses. Regulations concerning such simulator trainings do not take into consideration the fact that the pilot may complete the simulator training using an FNPT II simulator which is equipped with conventional flight controls and navigation instrumentation but his practical air training will involve using the "glass cockpit" instrumentation, where flight parameter values are displayed on an integrated digital Multi-Function Display (MFD). At present, additional familiarization training for pilots intending to fly aircraft equipped with "glass cockpit" is mandatory in only a few countries (e.g. the U.S.). In Polish regulations no consideration is given to the problem of the difference between instrumentation and flight control systems applied in FTDs and in aircraft used in practical air training. That problem is important as some aircraft in the training fleet feature conventional flight controls and instrumentation whereas others are equipped with "glass cockpit". This difference may have a significant influence on pilots' ability to obtain information concerning the aircraft status efficiently and correctly, and, what it involves, to attain the desired state of SA. Experts' opinions suggest that exercises in perceiving aircraft status information from mission environment, with special emphasis

[†] The results of previously quoted analyses concerning the causes of undesirable flight-related events in the training units of the Polish Air Force in 1974-1984.

on recommended practices, (procedures), should be included in basic pilot training[‡]. This does not mean, however, that such exercises should not be covered in professional development training i.e. in CRM courses.

Level 2. Processing the information gathered within the scope of the first level of the SA process into a mental picture of the aircraft status. This picture must be characterized by high credibility and must allow the pilot to assess the compliance of air mission execution with a predetermined plan, while taking into consideration legally-binding safety rules and the assumed results of air mission accomplishment.

Major factors affecting the creation of the desired mental picture of the aircraft by the pilot include, among others:

1. Psychophysiological characteristics of the pilot:
   - level of coping with stress;
   - presented level of spatial visualization skills;
   - ability to remember/store information;
   - ability to create mental pictures;
   - ability to draw mental conclusions.
2. Pilot's competence:
   - level of specialist knowledge;
   - specialist skills;
   - abilities to act in the environment characterized by highly dynamic changes and unpredictability;
   - high level of skills related to the ability to act automatically in the cockpit;
   - the degree of consistency between the crew training level and the degree of mission complexity.
3. Information from mission environment:
   - the amount of information stored in pilot's mental database;
   - information quality – the degree of consistency with the real aircraft status;
   - accuracy of information selection.
4. Status of the mission environment:
   - weather conditions;
   - air traffic congestion;
   - time of day;
   - flight parameters (among others, airspeed, altitude, G-load);
   - cockpit ergonomics;
   - level of aircraft automation.

As it was mentioned above, major factors affecting the creation of the desired mental picture of the aircraft by the pilot include his knowledge and specialist experience. Inexperienced pilots interpret the information coming from the environment correctly, but they have a poor ability to create a highly credible and detailed mental picture of the aircraft status. An additional element that intensifies such a tendency in

[‡] By referring to basic training the authors mean the training up to the CPL (Commercial Pilot License) level with IFR (Instrumental Flight Rules) and ME (Multi Engine) ratings (approx. 200 hours practical flying time) in civil aviation and up to Class 3 (approx. 200 hours practical flying time) in military aviation.

this group of pilots is their lack of such experiences which would enable them to quickly notice deficiencies and to make the appropriate correction in the information database within an acceptable time frame. Other elements adversely influencing that state are: lack of certainty in relation to correct interpretation of information which is new from the point of view of the pilot's experience; state of confusion which the pilot experiences when facing the necessity to solve such dilemmas in a short period of time, and also potential failures in eliminating discrepancies which are caused by contradictory data or which emerge as a result of the improper cooperation within the flight crew.

What is worse, in certain situations such a state may cause the flight crew to gradually fall into a state of apathy. Experienced pilots on the other hand, being over-accustomed to certain solutions that proved to be right in the past, tend to exclude other solutions even though their perception of the information coming from the environment is correct. The reason for that is their subconscious rejection of contradictory information which may influence the change of the previously created and accepted mental picture of the aircraft status. Like in the former case, such a situation occurs most frequently when the process of SA is executed in a dynamically changing mission environment. Pilots particularly often encounter such situations during the take-off and landing approach. Because of traffic congestion in the vicinity of airports and, what it involves, very limited time for decision-making, 85 % of all undesirable flight-related events in civil aviation occur in those flight phases [8].

Level 3. The determination of the anticipated changes of the aircraft status in a specified future time period, taking into consideration the data from the abstract mental picture of the aircraft status, created in Level 2, and from the anticipated changes in the mission environment. The probability of committing an error at this level is dependent on, among others, the factors which stipulate the creation of the aircraft status mental picture at Level 2 of the situation awareness process, and, furthermore, on:

- the quality of the mental picture of the aircraft status created at Level 2 of the situation awareness process;
- the time difference between the "specified future time period" and the real time of creating the mental picture of the aircraft status;
- the dynamics of changes in the mission environment, concerning weather phenomena, air traffic intensity, technical condition of the aircraft, quality of communication, etc.;
- the scope and quality of information at the pilot's disposal, concerning the changes in the mission environment.

It ought to be stressed that the factor which intensifies the pilot’s inability to act at the levels of SA presented above may be the presence of a situation which the pilot has never encountered before, and which forces the pilot to take non-routine actions, not included in the described and previously practiced standard operational procedures (SOP). The proof of that are the results of studies conducted by a NASA research team who used the data from the Aviation Safety Reporting System (ASRS).

Using the descriptors "emergency" and "abnormal"[§], the team selected 107 safety reports from operational flights and analysed them. The results of the studies clearly point out that in the event of a situation classified as "emergency" aircrews reacted

[§] Emergency = emergency situations described in Pilot's Operating Handbooks (POH) and practiced regularly in simulator flights – textbook emergency; abnormal = emergency situations not described in Pilot's Operating Handbooks (POH) – non-textbook emergency.

correctly in 19 of 22 cases (86 %), whereas in the event of a situation classified as "abnormal" only in 6 cases of 85 (7 %) [10].

Regardless of the factors presented above, which may affect the quality of the SA process executed by the pilot, having certain skills is a condition necessary for the pilot to achieve the desired state of SA. The most significant of the desired pilot skills, which facilitate attaining the desired state of SA, were identified taking into consideration the conclusions that may be drawn from the analyses described in this chapter, particularly those related to the definition of the state and the process of SA. The skills in question include among others:

1. Perception ability – the ability to receive the signals from the dynamically changing mission environment at an acceptable quality level during the execution of the SA process. Pilot's capability of creating a relevant, highly reliable mental database is a major condition ensuring the correctness of subsequent phases of the situation awareness process and, consequently, also of its state.
2. The ability to select the relevant signals from those received from the mission environment at the desired level, which is determined by the intensity of changes in that environment. Selective reception of signals from the mission environment is important for the operator in the creation of such a mental picture of the aircraft status that has a required level of reliability. Failing to apply the principle of selective reception of mission environment signals may lead to the loss of the crew's ability to create the mental picture of the aircraft status with required level of reliability, or may significantly limit that ability, particularly under conditions of heavy workload and time deficit. As a result of that, the crew may lose the ability to attain the desired state of SA.
3. The ability to maintain high degree of objectivity at the subsequent levels of SA process. This means that decisions made by the flight crew in the SA process should be based on knowledge, skills and experience, as well as on procedures, standards and rules that are currently in effect. Routine in decision-making should be regarded as secondary.
4. The ability of the flight crew to create a mental picture of the aircraft status on the basis of the mental database created in the process of SA. Within the SA process, the flight crew ought to be able to create a coherent and reliable mental picture of the aircraft status at a given stage of air mission execution. That picture is the basis for determining the degree of consistency between the mission as planned and the mission that is actually executed. Furthermore, it facilitates the determination of the aircraft status in a specified future time period while taking into consideration the anticipated changes in the mission environment.
5. The ability to determine the changes of the aircraft status on the basis of its actual state and the anticipated dynamics of changes in the mission environment in a specified future time period. The changes in the aircraft status are anticipated on the basis of the current knowledge, skills and the information received by the flight crew from the mission environment. The degree of prediction accuracy is particularly important in the aspect of mission execution safety.
6. The ability to analyse the complex interactions within the system operator-aircraft-mission environment (O-AC-ME). That ability is the response to high complexity of

SA. It facilitates the determination of the influence of interactions between particular elements of the aviation system (O-AC-ME)**.

7. The ability to store mental pictures of the aircraft status which are created in particular stages of mission execution so that they may be effectively used in later stages thereof. The ability to re-enact major stages of an air mission execution by describing mental statuses of the aircraft is a major element facilitating the identification of errors committed so far and of their sources. Those pictures also constitute a "template" for creating subsequent mental pictures of the aircraft status as a result of the execution of subsequent SA processes. Moreover, they make valuable contribution to pilot's experience, and enable the pilot to master his skills and maintain flying currency and, consequently, to execute air missions more effectively.
8. The ability to carry out the SA process cyclically in order to incorporate the changes taking place in the mission environment into the previously created mental picture of the aircraft status. Maintaining the desired state of SA requires from the pilot taking, constantly and sequentially, actions related to subsequent SA processes. The dynamics of recurrence and the degree of complexity of that process is dependent on the scope and the dynamics of changes within the mission environment.
9. The ability to maintain the desired level of mental/motor activity at all stages of air mission accomplishment. The dynamics of changes in the complex mission environment forces the pilot-operator to maintain high level of mental/motor activity, which allows full and reliable perception of the signals concerning the aircraft status. This ability is expressed as the knowledge and the skills of the flight crew owing to which the syndromes and hazards concerning the limitation of the pilot's mental and/or physical capabilities may be recognized and effectively prevented. Such hazards may occur as a result of such factors as intolerable G-load, hypoxia, health deterioration, etc.
10. The adaptive ability understood to be the ability of the pilot to adapt to the dynamically changing mission environment. Adaptation may be defined in this case as adapting the relevant features of the operator (knowledge, behaviour, skills, etc.) to conditions and restrictions imposed on him by the mission environment.

The above-mentioned list probably does not exhaust the whole set of the desired pilot abilities which are necessary in attaining the desired state of SA. Lack or poor level of any of the above-mentioned abilities may exert a decisive influence on the pilot's attaining the desired state of SA. Taking into account the significance of the SA state in the pilot's decision-making process, the above mentioned abilities ought to be regarded as critical in relation to the quality and, what it involves, the safety level of mission execution.

4. Conclusion

The SA process poses particularly high requirements relative to the competence of the pilot acting in the mission environment characterized by highly dynamic changes and relatively high level of unpredictability. The correct course of the SA process is influenced by numerous factors related to the pilot and the personnel responsible for the

** The abbreviations represent, respectively: operator, aircraft, mission environment.

execution of air missions, the aircraft, and the mission environment. It is still the human being, however, who plays the crucial role in this system and who faces particularly high requirements imposed on him by the SA process with regard to his abilities and competence. As a result of that process, the pilot attains a certain state of SA, which is crucial to safety and correctness of decision-making process and finally, air mission execution.

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