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SITUATIONAL AWARENESS VS. A PILOT'S DECISION-MAKING PROCESS

ABSTRACT

This article describes the impact of a pilot's situational awareness (SA) on the quality of decisions that are made by him or her. Situational awareness has been defined as a state and as a process. The article also refers to how the situational awareness and the decision-making process interact. The decision-making process and its components have been defined. Based on author's own research as well as conclusions drawn from the subject's literature, the importance of an acceptable SA level for the correct progress of a pilot's decision-making process (and the likelihood of making a good decision) has been pointed out.

Keywords:
safety, aviation, situational awareness, decision process.

INTRODUCTION

Making decisions is an inherent part of human activity. Regardless of the activity area covered by the decision, there is more or less likely risk that our actions will fail. The specific nature of aviation operations makes the pilot (the operator of an aircraft) make decisions in times of high mental stress and under time deficit conditions. And it must be noted that too often the pilot is forced to make decisions that far exceed his or her competence level, and in consequence he or she becomes the victim of others' mistakes or violations. It is often noted in the subject's literature that it's important to train the pilot to make decisions that are part of air operations, including decisions that have to be made in surprising situations. When talking about safety of air operations from the perspective of the pilot (the operator), we usually consider his or her competence, that is to be comprehended as the knowledge, skills, level of training, or experience. These allow to perform specific aviation operations. The author's research point out that the pilot's readiness to perform aviation operations may also be determined through his or her ability to achieve and maintain an acceptable SA state and develop decisions, and through showing an acceptable level of competence to implement these decisions.

SITUATIONAL AWARENESS AS A PROCESS OR STATE

Putting it really simply, situational awareness is a database of its kind with information about the state of an aircraft in a given task environment. It should be looked upon as support of a higher level to avoid threats and/or reduce associated risks while performing an aviation operation. SA may be regarded from three basic perspectives — as a process, as a state, and from the perspective of its place in decision-making process by the pilot.

Execution of the SA process by the pilot is done with the aim to achieve a desirable level of knowledge — SA state, which is essential to define a problem, and then to come to a decision in order to solve it, thus maintaining the required level of safety while carrying out an aviation operation. The SA process is to be regarded from the perspective of three basic stages (Fig. 1):

1. Perceiving information from the task environment. The received data is crucial with regard to the safety and the stage of an operation.
2. Processing the data into a mental model of the aircraft status.
3. Projection of future aircraft status within a given period, while taking into account data from the abstract model of the aircraft (composed in 2nd stage) and the anticipated changes in the environment of aircraft operation.

Achieving a desirable SA state by the pilot is only possible when a desirable quality level (which is the condition for the correct progress of the next process stages) is achieved in all stages of the process. Should the quality level in any stage of the process not be good enough, the pilot is forced to search for the error on subsequent levels of process execution. This makes the process far longer and may be the cause of a short-term or long-term loss of SA. This state is to be regarded as a threat to aviation safety.

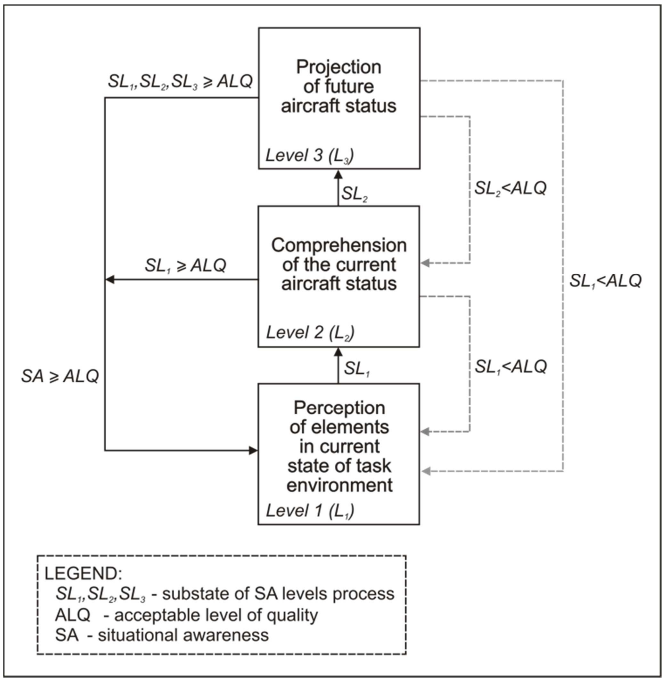

Fig. 1. Sub-states of pilot's situational awareness in particular stages of the process and the course of that process [own study]

Experts' opinions and the analysis of causes of undesirable flight-related events point out that the primary sources of the errors made in the 1st stage of the process (Perceiving information) are:

- the lack of, or restricted access to information;
- not clearly comprehending the information;
- incorrect information that results from a failure of a system (or device) or from a low level of pilot (crew) competence;
- the mistake made while reading the gauge;
- mental loss of information by the pilot or rejection of this information.

In the 2nd stage (Processing data) some of the key factors that influence the creation by the pilot of desirable mental model of the aircraft are:

- pilot's psycho-physical traits;
- level of competence shown by the pilot;
- the quality of information collected from the task environment;
- the dynamics of changes in the task environment.

In the 3rd stage (Projection of future aircraft status in a given period), the key elements are:

- the quality of the mental model of aircraft status that was composed on the 2nd level of the SA process;
- the difference in time between the 'future status in a given period' and the actual time of creation of the mental model of the aircraft status;
- the dynamics of changes in the aviation operation environment — involving the weather, air traffic intensity, technical condition of the aircraft, communication level etc.;
- the scope and the quality of information that is at the pilot's disposal, pertaining to changes in the aviation operation environment.

It must be stressed that the factor which deteriorates the capability to act correctly during the above stages of the SA process is the emergence of a particular situation that forces the pilot to perform actions that are not seen in the Standard Operating Procedures (SOP), with which the pilot is well familiarised.

The term ***state of situational awareness*** usually applies to the influence of SA on the quality of performing aviation operations by the pilot, or for referring to a wide range of factors that have an influence on the loss of SA by the pilot — in case of an undesirable flight-related event, or if the pilot shows a desirable level of SA state — in case of a successful flight. To determine the factors that have an influence on the SA state by the pilot, we must refer to the subareas of situational awareness and the elements that decide upon maintaining a desirable SA state by the pilot, with regard to all subareas that are defined below (Fig. 2.).

1. Geographical Subarea of Situational Awareness (GSSA) — the state of knowledge exhibited by the pilot regarding the current position of the aircraft (geographical coordinates, position relative to terrain points etc.) and its change in a given period. The knowledge is acquired with the help of general navigation and/or radio navigation/satellite navigation, taking into account the wind direction and wind velocity, and the assumed flight parameters. GSSA refers to the following elements that are related to the position of the aircraft (and their usefulness in case of an emergency situation): position of the aircraft relative to natural or artificial landmarks (prominent natural and artificial terrain points); natural topography in the flight area with particular focus on take-off and landing zones; airspace elements within the flight area (routes, restricted zones, dangerous

zones, low-noise zones, military zones, responsibility area limits, country boundaries etc.); operating procedures, incl. STAR[1], SID[2] etc., category of an airfield that is at the pilot's disposal.

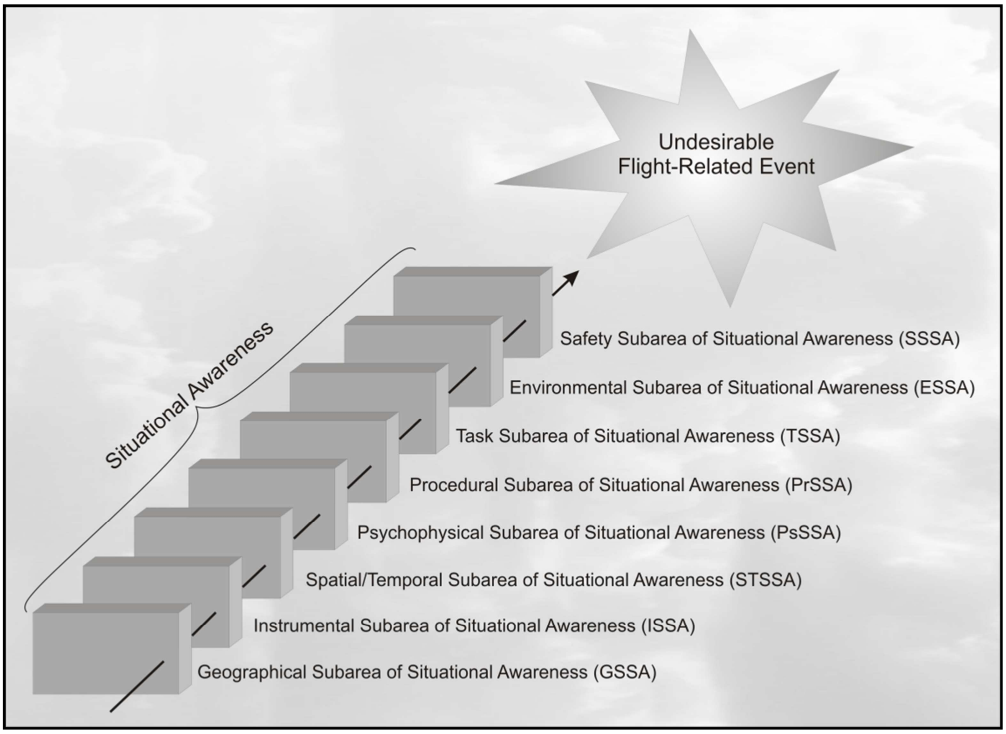

Fig. 2. Subareas of situational awareness and undesirable flight-related event from the perspective of the domino effect model [own study]

2. Instrumental Subarea of Situational Awareness (ISSA) — the state of knowledge exhibited by the pilot regarding the correct readings of flight instruments, incl. navigation/radio navigation instruments, instruments monitoring the technical condition of aircraft devices and systems. The knowledge also comprises the ability to recognize incorrect readings of instruments (and the causes of these) and to properly counteract those problems. ISSA is related to the crew's ability to correctly interpret flight instrument readings, to recognize deviations of readings that are over permissible range (or the lack of readings). In case of problems with

[1] STAR — Standard Instrument Arrival.
[2] SID — Standard Instrument Departure.

instrument readings ISSA also relates to taking actions in order to safely continue the flight, that is using alternate instruments, turning on pressure transmitter heating etc.

3. Spatial/Temporal Subarea of Situational Awareness (STSSA) — the state of knowledge exhibited by the pilot regarding the spatial location of an aircraft relative to the ground in the basic Frame of Reference (X, Y, Z) and the anticipated changes in location in space following changes in the position of control instruments/devices, while taking into account the operating limitations of an aircraft.
4. Psychophysical Subarea of Situational Awareness (PsSSA) — the state of knowledge exhibited by the pilot regarding his/her own psychophysical state, based on his/her own feelings and unusual body behaviour during the flight, and the impact of those changes on the ability to continue an air operation. This also comprises the knowledge of psychophysical state of other crew members (multi crews) and its influence on the operation being performed in the definite future.
5. Procedural Subarea of Situational Awareness (PrSSA) — the state of knowledge exhibited by the pilot regarding the compliance of currently used procedures with those outlined in appropriate aviation regulations (airfield, operational and emergency regulations etc.) and the effects of continuing to use these procedures. Other procedures are possible to apply in the definite future, while taking into account the anticipated changes pertaining to the task environment or technical condition of an aircraft etc.
6. Task Subarea of Situational Awareness (TSSA) — the state of knowledge regarding the correct performing of the operation based on available flight data and the information provided by the flight control staff, while taking into account the previously developed flight plan and the possibility of continuing it given the changes in difficulty that are the result of changes in the task environment and the technical state of the aircraft in the definite future.
7. Environmental Subarea of Situational Awareness (ESSA) — the state of knowledge exhibited by the pilot regarding the task environment parameters — internal environment (aircraft cockpit) and external environment (weather conditions, air traffic intensity etc.) at a particular stage of an air operation, based on flight instruments readings and interpretation of external conditions, messages from flight control staff, incl. their influence on the quality and safety of the flight. It also comprises the state of knowledge regarding changes of flight environment parameters and their influence on the flight in the definite future.

8. Safety Subarea of Situational Awareness (SSSA) — the state of knowledge exhibited by the pilot regarding the safety level while performing an air operation, based on information from the task environment (collected in real time) and the likelihood of maintaining the desirable safety level of the flight in the definite future.

To sum up, the state of SA exhibited by the pilot comprises the whole knowledge which pertains to the state of an aircraft in specific task environment conditions, with particular focus on the assumed state of an aircraft (that was specified during the operation planning stage) and the acceptable safety level while performing an air operation. SA subareas are of particular importance when regarded from the perspective of the requirements for the pilot. Meeting those requirements should allow to achieve the desirable SA state at each stage of an air operation. They may also be used when investigating causes of unwelcome flight-related events. To say, that at the time of an accident the pilot exhibited a low SA level, is not good enough to effectively prevent accidents from happening again. Whereas to say, that the pilot exhibited a low SA level in the Geographical Subarea (due to insufficient level of knowledge regarding the flight area and the procedure to execute in case of the loss of geographical orientation), allows to take appropriate actions to prevent such situations from happening in the future.

THE IMPACT OF SITUATIONAL AWARENESS ON DECISION-MAKING PROCESS

Making a decision boils down to carrying out by the pilot the process of selection of the method to further pursue the activities in order to resolve a specific problem, related to the operation. As a rule, the problem is defined through:

- determining the difference between the assumed aircraft state at a given operation stage and the actual state;
- determining the difference between the actual aircraft state at a given operation stage and the state determined by the change in the method of carrying out the task; this change usually results from changes in the anticipated state of task environment — weather conditions, psychophysical state of the pilot, technical condition of the aircraft etc.

According to George P. Huber making a decision must be distinguished from making a choice and solving a problem [4]. He believes that making a choice involves a limited scope of activities that are related to a set of options. Making a choice is regarded as one of the elements of decision-making process. Whereas solving a problem is to be regarded in terms of a broad scope of activities aimed at searching and implementing actions that lead to correction of the task situation which has deviated from what was assumed or forced. In the first place a problem must be defined, and then a solution found and decision made, regarding further actions. Having assumed that defining a problem is the basis for effective decisions, and using the decision model adhered to by the pilot — operator (Fig. 3), we are then able to define the role of SA state with focus on the correct decision. The decision is likely to make the aircraft revert to a desirable state (determined by the stage and environment conditions), through changing flight parameters and maintaining safety standards.

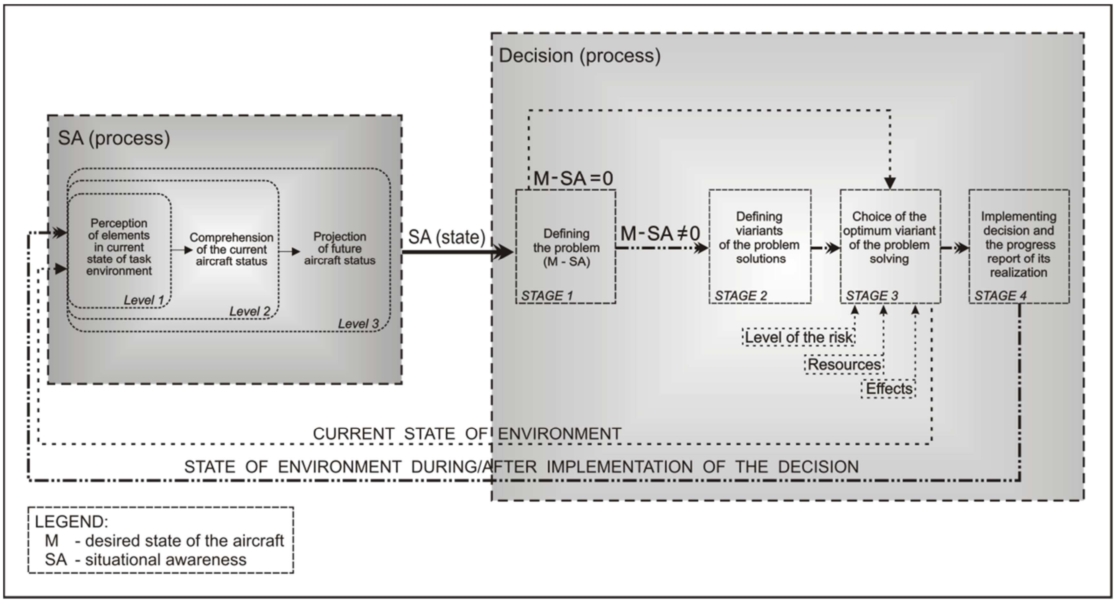

Fig. 3. Decision-making process to be used by the pilot-operator with acknowledgement of additional element — situational awareness [1, 4]

As mentioned above, SA is a database of its kind with information of the state of an aircraft in a given task environment. This information is key to perform a decision-making process, which comprises four basic stages:

Stage I. Defining the problem — diagnosing the difference in the state of an aircraft while taking into account the desirable state of the aircraft (determined during the preparation stage) — flight parameters at individual stages of air operation, which allow to achieve the goal of the operation while taking into account the requirements imposed by the state of task environment and the states of the aircraft that result from the state of SA by the pilot — mental models of the state of the aircraft that determine its actual state and the state anticipated in the definite future. If the models of the state of the aircraft that are the result of the carrying out of SA process are concurrent with the model of the desirable state ($M - SA \approx 0$) at a level which allows to achieve the operation's objectives, further actions by the pilot are tantamount to regular diagnosing the state of the aircraft. This process is repeated until the desired state of the aircraft is different from the actual state of the aircraft, and the difference is large enough to be a threat to the operation, and/or may be the cause of violation of the safety rules that are binding during the operation ($M - SA \neq 0$). According to G.P. Huber's theory this difference may be regarded as the problem that needs to be resolved in subsequent stages of decision-making process.

Stage II. Determining variant solutions to a problem — working out several variants of a solution increases the likelihood of coming to a decision that will allow to achieve a goal in minimum time and to optimally use resources that are at the pilot's disposal. These elements are particularly important from the point of view of carrying out an operation. They are implemented with high dynamics of change having been taken into account. It is to be noted that the pilot-operator's capability to determine variant solutions to a problem is largely dependent on his/her experience and level of expertise.

Stage III. Selection of an optimal variant of a problem solution — the pilot estimates each variant solution, keeping in mind the anticipated level of their effectiveness and risk. The effectiveness of respective variants can be graded using one of the two criteria:

— the perspective of the goal to be achieved/resources that are at the pilot's disposal;
— the likelihood that this variant will solve the problem.

On the one hand, some variants may be deemed to be quite effective, but limited resources that are at the pilot's disposal will mean that the pilot will have to reject those variants at the estimation stage. On the other hand, despite the availability of full resources that are needed to implement a variant, the low level of its effectiveness will force the pilot to reject it. When variant solutions have been preselected, the pilot's task is now to estimate the individual risk of each of themWhen considering risk management in process approach, we are presented with six basic stages:

- Threat identification
- Risk assessment
- Minimising risk
- Making a decision
- Implementing a decision
- Supervision and the monitoring of changes [5].

Only the 1st, 2nd and 3rd stages are carried out at this stage of decision-making process:identification of threats that emerge from choosing a variant of a problem solution (Stage I) — involves using the appropriate identification techniques used to determine existing or potential threats;

— risk assessment (Stage II) — boils down to using quantitative and/or qualitative risk measures in order to determine the likelihood or risk and the effects resulting from it;

— minimising risk (Stage II) — boils down to the assessment of possibilities for total risk elimination or the reduction of it to an acceptable level (which allows to pursue an air operation while maintaining the assumed safety parameters.

It must be stressed that there are rules for the pilot to adhere to while estimating risk during the process of selecting the optimal variant solution. These include:

1. Do not accept unnecessary risk. While making decisions, tasks should always be carried out at the minimum level of risk. Only acceptable risk may be agreed to, that is inherent to the task. The acceptable risk level is not to be tantamount to the notion of hazard.
2. Accept the risk if benefits are greater than costs. There must always be the calculation of profitability of the risk to be taken in the light of expected benefits. Risk is always associated with the potential to obtain some benefits, and the greater the gain, the greater the risk. The objective of the risk management process is not to eliminate the risk but to reduce it to such an extent, so as to make the acceptable losses minimal.

3. Take risky decisions on a suitable level. By making a decision on a suitable level it is possible to clearly indicate the person responsible for it. The suitable level means that the risk-laden decision makers are responsible for the task to be carried out and are given sufficient means to reduce the risk or eliminate threats. This rule is of particular importance in case of crews comprising of several members.
4. Plan to anticipate the risk and handle it in a competent way The key factor to choose such an approach is the time.

When choosing the best available method of handling specific risk that is connected to a specific variant solution, the pilot should plan to meet the requirements of implementing the solution and take into account the specific nature of air operations.

Stage IV. Implementing decision and assessment of its effects. Having implemented the decision the pilot should keep on watching the situation. Is everything going according to the plan? What is happening in the task environment as a result of implementing the decision? Does the decision bring desirable effects? Do changes in the task environment affect implementing the decision? The pilot should not forget about the necessity of further identifying potential risks and any uncertainties that are connected with the decision being implemented. One should not regard the implementation process as something that is done automatically. In case of any disturbances emerging, e.g. significant changes in the task environment, one should take corrective action or abandon implementing the variant solution. Therefore making decisions by the pilot is to be looked upon as a continuous process, which is done regularly at each stage of performing an air operation. As a rule, the intensity of running decision cycles is directly associated with the dynamics of changes in the task environment and/or the magnitude of the problem that results from the difference in the assumed and the actual states of the aircraft at a given stage of an air operation.

Situational awareness is regarded by some researchers as an element that is separate from decision-making process and not as an integral part of decision--making process [2]. This approach is justified by Endelsey, by saying that even the perfect SA state does not ensure that the SA is completely true. The results of research done by him (regarding the influence of human factor on the emergence of undesirable aviation incidents) point out that 26.6% of the crews exhibited the desirable SA state, and nevertheless made wrong decisions. Smith and Handcock [6] are of similar opinion, stating that the pilot's SA state has the impact on his/her decision which in turn is key in forming the pilot's SA state. This means that they should not be regarded as one process. What is more, the authors say that decisions and SA do not usually go together as elements of one process. In light of the above findings, carrying out the SA process and achieving a specific SA state by the pilot is not necessarily tantamount to performing the decision process. The question is: when does the pilot start performing the decision process? In experts' opinion [2, 4, 7], the impulse to start a decision process by the pilot is the occurring of a significant change in the task environment, which forces the pilot to compare the current state of the aircraft (determined by the state of SA) with the reference model outlined during the planning stage of an air operation. That is why it is so important to maintain the desirable state of SA by the pilot at each stage of air operation. Wrong reception and/or selection of data by the pilot causes the mental image of the aircraft projected in real time and the definite future not to be in agreement with the actual state of affairs, thus rendering all analyses and subsequent decisions highly erroneous. These decisions are very likely to have an impact on the desirable state of the aircraft, determined by an air operation plan.

In conclusion, the more concurrent the mental image of the aircraft is with the actual state and the state in the definite future (the state of SA), the higher the likelihood of making the right decision by the pilot. Obviously, there are many factors in decision-making process that are more or less closely dependent on the pilot, that may affect the effectiveness of the decision and the safety level of an air operation — knowledge, skills, experience, training and resources that are at the pilot's disposal, as well as atmospheric conditions, activities of flight control staff etc. However, these factors are of secondary importance for the appropriateness of pilot's decisions if the pilot exhibits a low level of SA. Endelsey is also of this opinion. He believes that it is possible to make a right decision when the SA level is low, but this is to be regarded as good luck, rather than the result of a decision process based on dependable data.

CONCLUSION

The unpredictability, the dynamics of changes and the high risk inherent to a task environment that the pilot is in means that proper approach, exhibited by aviation organizations and flight control staff to issues related to situational awareness, is key to maintaining an acceptable safety level. The analysis of causes of undesirable flight-related events as well as conclusions drawn from the subject's literature [5] point out that it is the human factor and the adaptation of an aircraft to its capabilities and limitations, that have the primary impact on exhibiting the desirable state of SA by the pilot at each stage of an air operation. The author specified two basic areas that have an impact on preparations on the pilot's part, and on ensuring the conditions for performing an air operation are desirable. The first area comprises organizational and technical aspects of aviation activity. The second one comprises the activities related to preparing the pilot (education and training) to perform air operations. Ensuring high standards in the areas of: organizations' activities related to aviation safety; recruitment and selection of pilots; basic education, performance improvement training and practical training of pilots; and proper cockpit adaptation to the pilot's abilities and limitations is key to providing the pilot with knowledge, skills and opportunities for skills improvement. These are essential for achieving a desirable state of situational awareness.

REFERENCES

[1] Bryant J. D., Lichach F. M. J., Hollands J. G., Baranski J. V., Modeling situational awareness in an organizational context: Military Command and Control, [in:] S. Bandury, S. Tremblay, A cognitive approach to situational awareness: theory and application, Ashgate, Burlington 2004.

[2] Endelsey M. R., A taxonomy of situational awareness errors, [in:] R. Fuller, N. Johnston, N. McDonalds (eds.), Human factors in aviation operations, Ashgate, England 1995.

[3] FAA, System Safety Handbook, Chapter 15: Operational Risk Management, Available on http://www.faa.gov/regulations_policies/handbooks_manuals/aviation/risk_managemant/ss_handbook/media/Chap15_1200.pdf (12.09.2013).

[4] James A., Stoner F., Wankel Ch., Governance (in Polish), PWE, Warszawa 1997.

[5] Kozuba J., Kowalczyk P., Risk management — a crucial safety element in aviation, Vojenske Reflexie, 2012, Vol. VII, No. 2.

[6] Smith K., Hancock P. A., Situational awareness is adaptive, externally directed consciousness, [in:] R. D. Gilson, J. M. Koonce (eds.), Situational awareness in complex system, Embry-Riddle Aeronautical University Press, Florida 1994.

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STRESZCZENIE

W artykule opisano wpływ świadomości sytuacyjnej pilota (SA) na jakość podejmowanych przez niego decyzji. Świadomość sytuacyjna została zdefiniowana jak stan i proces. Artykuł odnosi się również do tego, jak świadomość sytuacyjna oraz proces podejmowania decyzji oddziałują na siebie wzajemnie. Zdefiniowano proces podejmowania decyzji i jego komponenty. Przedstawiono również, na podstawie badań autora i wniosków wyprowadzonych z literatury tematu, znaczenie dopuszczalnego poziomu świadomości sytuacyjnej pilota dla poprawnego przebiegu procesu podejmowania decyzji i prawdopodobieństwa podjęcia poprawnej decyzji.