

Pilot's Situational Awareness and Methods of its Assessment

Iakov Dalinger, Mikhail Smurov, Nikolai Sukhikh and Elena Tsybova*

Saint Petersburg State University of Civil Aviation, ul. Pilotov, 38, Sankt-Petersburg, 196210, Russia;
elena.tsybova@gmail.com

Abstract

Objectives: The objective of this study is to search for the method of redistributing the functions between the pilot and the automatic control system. **Methods:** The study presents theoretical analysis of the principal approaches to the assessment of situational awareness and of the existing methods of its measuring described in both foreign and domestic literature. The review makes it possible to formulate the complex vision of this issue as it is represented in current investigations. **Findings:** Based on the results of the analysis it has been established that notwithstanding the significance of situational awareness within the framework of the flight safety theory, there is no generally adopted opinion on whether it is the process or the result of the pilot's activity. The contradictions in the approaches to situational awareness assessment also lead to the fact that there is no generally accepted method for its measurement. Nevertheless, this study justifies the advisability of the calculation of the degree of the pilot's situational awareness as the quantitative criterion for redistributing the control functions between the pilot and the automation system that takes into account both the complexity of aircraft control systems and the intensity of the pilot's activity. **Applications/Improvements:** The study solves the problem of the redistribution of the functions between pilot and intelligent automatic control system based on the quantitative evaluation of the pilot's IQ and situational awareness.

Keywords: Automatic Control System, Information Content of Recognition, Pilot, Pilot's IQ, Situational Awareness, The Intensity of the Pilot's Activity

1. Introduction

In the complex and dynamic environment where Air-Craft (AC) pilots operate the process of the decision-making is affected by many variables. In such cases not only the purpose of that or another decision is important but also the ability to understand and to analyze the current situation within the short period. Unsurprisingly, over the last three decades the issues of situational awareness and the methods of its assessment have been the urgent subject matters of the investigations. Current importance of this issue in the airborne transportation has also been predetermined by the fast developing information and communication technologies, by the technical progress achieved in the sphere of instrument engineering and Automatic Control Systems (ACS), and also by ever increasing passenger traffic. Navigating a plane the pilot faces a difficult task of

controlling the multilevel systems under the conditions of the dynamically changing environment that makes the pilot's situational awareness one of the key concepts of efficient aircraft handling.

2. Situational Awareness

Situational awareness is the leading paradigm in the area of studying human factor as the source of knowledge and in investigating the effects it produces on the interaction with the environment. Notwithstanding the fact that the term "situational awareness" has been widely discussed in both Russian and foreign literatures no single definitions has been developed so far. Moreover, there are contradictions between different authors as to the proper definition of situational awareness, namely, there is no common understanding of whether situational awareness is a

*Author for correspondence

result^{1,2} or a process^{3,4} of the pilot's activity^{5,6}. However, in this regard many authors⁷⁻¹¹ refer to the definition developed by¹² who maintains that situational awareness is the knowledge of the surrounding things and processes that actually occur; or it is the perception of the elements of the environment at some definite moment and in some definite place, the understanding of their implications and the forecasting of their statuses in the nearest future. Thus, the author¹³ suggests the hierarchical model that splits the concept of situational awareness in three levels:

1. Collecting information from the environment,
2. Compilation of this information to obtain a clear understanding of the current situation, and
3. Using this understanding to forecast future events.

According to¹⁴ situational awareness is neither the result of the activities nor a process, but, primarily, it is the understanding of the situation. Moreover, situational awareness is not the same thing as the knowledge from the long-term memory, inasmuch as situational awareness can be applied to the fast changing situations only, when the conditions change within minutes or even seconds.

Also¹⁵ believes that the pilot's situational awareness possesses three aspects: spatial awareness, system awareness and task awareness. The significance of all these aspects for the pilot is beyond any doubt. The need to understand spatial parameters is associated with the fact that the aircraft moves in three-dimensional space fraught with all kinds of relevant threats. During the flight the pilot has to monitor several continuously changing variables simultaneously, namely: pitch, roll, height, deviation from the route, current position in the direction of travel. The development of ACS is supposed to make navigation easier, as it can take over the functions of monitoring all variables, controlling the flight mode, flight status, etc. Under such conditions the pilots would not have to be continuously aware of all changes unless some emergencies happen (for example, system failure). However, there comes a necessity to understand the system. The interface of the aircraft is equipped with a large number of different system and subsystem status indicators that do not feature sufficient symbolic visualization¹⁶ which makes it difficult for the pilot to understand the system. In the process of aircraft navigation the pilot performs four principal tasks: aircraft control proper, navigation, communication with the crew and with the dispatcher, and system control.

In this case the understanding of the task represents the ability of the pilot to prioritize these functions adequately according to the current flight situation¹⁷.

Thus, it can be concluded that under the conditions of automated aircraft navigation the situational awareness of the pilot decreases (there is no necessity to monitor all the variables at every moment)^{18,19} which in turn affects the amount of time available for decision-making in cases of emergency. From the perspectives of the flight safety theory the pilot's situational awareness has to be assessed and measured to avoid any undesired effects.

3. Methods of Situational Awareness Measurement

Insofar as there is no common approach to the assessment of situational awareness, then, correspondingly, there is no single approach to its measurement; therefore, situational awareness is assessed from the perspectives of both the result of the activity and the process. Among the available techniques there are objective (assessment of the result of task performance, index of the task performance process, game simulations, etc.) and subjective (self-evaluation questions, an onlooker ranking of task performance success, etc.) methods of situational awareness assessment^{7,20,21}. According to M. Endsley²², situational awareness assessment should meet the requirements of the criteria as follows: 1. it should measure situational awareness proper without reflecting the parameters of other processes, 2. the assessment method should identify changes in situational awareness caused by the design of the buildings and by the environment of the training sessions, and 3. the method of measurement should not itself change situational awareness.

One of the most popular methods of subjective assessment of situational awareness is represented by SART – situational awareness rating technique²³. The idea is that the respondent is asked to rank his situational awareness on the scale that evaluates attention requirements, attention resources and situational understanding. However, some of the investigations have shown that the results of subjective assessment of situational awareness do not always correspond to the results of objective measurements which can testify of the insufficient reliability of the subjective methods^{24,25}.

To assess situational awareness objectively, the external assessment of knowledge is usually applied. SAGAT

– situation awareness global assessment technique^{22,26} – is based on the development of factual questions that fit in some definite environment and that require the answers that ensure the correct understanding of the situation. One more method is represented by Situation Present Assessment Method (SPAM)^{10,11,27} that implies questioning the respondent in the process of performing the tasks without any interruptions in the activities. The response time and the answers to the questions serve as the assessment of situational awareness. The concept of Distributed Situational Awareness (DSA)²⁸ is one of the situational awareness assessment methods that evaluate not the particular elements of the system, but the interaction between all parts of the system in general (including the operator).

Some authors suggest the QUantitative Assessment of Situation Awareness (QUASA) technique²⁹⁻³² that combines subjective and objective approaches applying questioning on factual knowledge of the current situation and also assuming the evaluation of the degree of operator's confidence in the correctness of his answers.

Given the fact that the pilot's situational awareness affects the promptness of decision-making under critical conditions, one of the most important tasks of the flight safety theory comes to be represented by the redistribution of the control functions between the pilot and ACS. One of the studies³³ suggests the method of quantitative evaluation of the degree of situational awareness than makes it possible to redistribute the functions of control between ACS and the pilot.

In that article the authors introduce the term of “degree of situational awareness” of the pilot which represents the measure of the correlation between the amount of the information on the statuses of the aircraft systems and the capabilities of the operator (the pilot) for controlling the airborne vehicle. Based on the degree of the pilot's situational awareness it becomes possible to identify the rational range of the pilot's activities and the relevant range of the control system operations.

The quantitative value of the degree of situational awareness is to be found based on the dependency as follows below equation 1:

$$SO_i = IQ_\phi \cdot \frac{\sum I_i}{\tau_i} \quad (1)$$

Where SO_i – degree of the pilot's situational awareness in critical situation created by i -aircraft system;

IQ_ϕ – intelligence quotient of ϕ -pilot, where $\phi = 1$ (Pilot in Command), 2 (co-pilot), (the intelligence quo-

tient is determined when the pilot performs the activities associated with some special situations in the flight simulator);

$\sum I_i$ – total information content value of the diagnostics of all units of i -system that created the critical situation;

τ_i – intensity of the algorithm of ϕ -pilot's activity in the process of monitoring, controlling, decision-making and implementing the solution for i -system that created the special situation (a crew member who performs navigation participates as consultant).

Thus this dependency takes into account the following:

- intelligence level of the members of the crew: the higher it is, the higher is the value of situational awareness; i.e. a professional pilot can make correct decisions even having minimal amount of information at his disposal to maintain control over the aircraft in critical situation;
- total information content value of diagnostics of the system that created the critical situation. With higher level of the information content value the results of the system technical evaluation are more objective; and
- total intensity of the algorithm of the pilot's activity in the process of monitoring, controlling, decision-making and in the implementation of the relevant solution for the critical system. Thereat, the degree of situational awareness will be higher in cases when the intensity of the pilot's activity is lower, because in this case the workload on the pilot is lower, and the probability of mistake or incorrect decision is minimal.

The calculated value of the degree of the pilot's situational awareness SO_i is compared with the criterion of the pilot's intelligence $IQ_{norm\phi}$ that was obtained during the tests in the flight simulator under normal conditions. Two variants are possible:

- 1 variant – $SO_i < IQ_{norm\phi}$, in this case ACS should switch on the automatic pilot system and the crew should take over the functions of monitoring; and
- 2 variant – $SO_i > IQ_{norm\phi}$, in this case ACS engages the crew and controls their activities.

Modern automation systems are quite ready to participate in the process of redistributing the functions of controlling the complex systems based on the quantitative assessment of the criterion calculated according to the mathematical model that is to be developed with the parameters of different nature and that should take into account the complexity of the system which creates the critical situation, as well as the specifics of this particular situation and the workload on the operator.

3.1 Example of Calculating the Degree of Situational Awareness

The suggested methodology has been tested using the example of hypothetical schemes with the initial data as follows:

- IQ = 70, 90, 110, 140;
- $\sum \hat{o}_1 = 0.4$; $\sum \hat{o}_2 = 0.8$; $\sum \hat{o}_3 = 1.6$, i.e. the case considers three systems of different complexity;
- the value of the trouble-free operation of the system elements varied within the range of 0.995...0.96 (the availability of the system elements was assumed to be at $\lambda = \text{const}$ and equal for all elements to 10^{-5} 1/h).

The results of the calculations are shown in Table 1.

Table 1. Results of calculating the degree of situational awareness.

	$\sum I_i$	$\sum \hat{o}_i$	IQ = 70	IQ = 90	IQ = 110	IQ = 140
1	0.49	0.4	86.24	110.88	135.52	172.48
2		0.8	43.12	55.44	67.76	86.24
3		1.6	21.56	27.72	33.88	43.12
4	0.85	0.4	147.84	190.08	232.32	295.68
5		0.8	73.92	95.04	116.16	147.84
6		1.6	36.96	47.52	58.08	73.92
7	1.05	0.4	183.89	236.43	288.97	367.78
8		0.8	91.91	118.17	144.43	183.82
9		1.6	45.92	59.04	72.16	91.84
			a	b	c	d

4. Conclusion

The results of calculating the degree of situational awareness for the aircraft and pilot operation models considered in the framework of this study enable the conclusion as follows: the higher the intelligence of the pilot and the more complex the system, the more readily the pilot takes

over the control in cases when the intensity of the activity is lower than the permissible value (when the intensity is close to the permissible value the degree of situational awareness does not exceed 100, see 9-d); the more complex the system, the higher is the degree of situational awareness (confer 2-b and 8-b); the higher is the intensity of the pilot's activity, the lower is the degree of situational awareness, and then the control ought to be turned over to the automation system (confer 4-c and 5-c). For the options under consideration the value of 150 can be set as the threshold point of the degree of situational awareness; thereat, if $F < 150$ the autopilot system is in operation, and if $F > 150$ then the pilot performs his activities, because only the pilot is capable of controlling the complex systems.

Taking all the aforesaid into consideration it could be maintained that given the strong dependency of the flight safety on the pilot's situational awareness, the implementation of the suggested method of enhancing the functional capabilities of the on-board intelligent ACS will make it possible to resolve the abovementioned problem of the redistribution of the aircraft control functions between the pilot and the ACS.

5. References

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