UDC 656.7.086 (45)

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The diagnostics of emotional state deformation in the professional activity of Operators in Air Navigation System

Professional effectiveness, operator professional effectiveness, Human Factor, pilot, air traffic controller, operator of Remotely Piloted Aircraft System, , emotion portrait

Problem statement. Statistics on aviation accidents in recent decades indicates the prominent role of human factors (HF) influence on the total number of aviation accidents, which is about 80%

The flight manual is intended only for the expected conditions of the aircraft (ACTF) operation and does not include the actions of the crew in extreme conditions, encounters which can be reliably avoided by the introduction of operating restrictions and rules, as well as in extreme conditions that occur so rarely, that the requirement to meet the standards of airworthiness in them would lead to a higher level of airworthiness than is necessary and practically grounded [1; 2]. Because of this, in about 20% of the cases, the crew does not have clear instructions for parrying special situations onboard the ACTF. In these circumstances, timely detection of the ACTF crew into a similar situation and the provision of operational assistance by the traffic service authorities are relevant.

According to the documents regulating flight operation and Air Traffic Control, the final decision in the aviation incident accepts pilot-in-command of ACTF. Due to large amount of the ACFT crews taking inappropriate decisions, which is 90% of the causes of aviation accidents in the world for all types of ACFT [1; 2], the responsibility for the timely and adequate advice in emergency situations assigned to an air traffic controller (ATC). For this purpose it is important for ATC to have current information on:

– development of extraordinary situation;
– current emotional state of human-operator (H-O), which manages the ACFT;
– quantitative prognosis for the development of an extraordinary situation taking into account the psychophysiological state of H-O, which operates in extreme conditions.

International Civil Aviation Organization (ICAO) constantly develops the new concepts for decision HF problems and improves proactive, based on the risks evaluation, methods, directed on the farther decrease in the number of aviation events in the world [1; 2].

The problem of increasing the efficiency of Air Navigation system (ANS) (reducing errors, increasing reliability, reducing the reaction time) is an important aspect of preventing various types of incidents and disasters. Joint activity plays of aviation professionals groups an important role during work flight crew and controllers' group. In features of the interaction in groups of aviation specialists the most evident in emergencies. The nature of the ANS H-O work depends on the dynamic properties of the control object and all links included in the system; laws of control, tools of coding information, type of the tasks assigned to the operator: external work conditions, and, finally, the physiological features and capabilities of the operator.

The information about the emotional state of ANS H-O can be used in audits of programs safety LOSA "Line operations Safety Audit", which are used to collect data on the behavior of crew members and situations during a real flight. LOSA is a tool for collecting safety data during normal airline operations [3].

The purpose of the publication is the developments of the automated system for monitoring and diagnostics of the emotional state of ANS's human-operators in professional activity, education etc.

Main part. There are many circulars, documents and reports of ICAO presented famous conceptual models of the HF[1; 2]. According to them, aviation accidents are the result of a combination of active and latent errors. In the center of the model is a person (Liveware - L), the most critical and most flexible component in the system to which other components of the system must be carefully matched. Now the HFs model added new components such as T (Team), C (Culture), TEM (Threat and Error Management), SMS (Safety Management System), CDM (Collaborative Decision Making) if stress and eventual breakdown in the system are to be avoided [1; 7]. Now important are concepts for optimal solutions of aviation specialists such as Performance-Based Approach (PBA), Collaborative Decision Making (CDM), System-Wide Information Sharing and Management (SWIM) by trajectory [4]. An approach, founded on the characteristics (PBA) [2], based on the next three principles: the strong focus on desired/required results; decision making (DM) is driven by those desired/required results; reliance on facts and data for DM. Herein the principle "using facts and data while DM" admits, that tasks shell comply with the widely known in Western management criteria SMART (specific, measurable, achievable, relevant and time-bound). Such a level of accuracy of tasks determination can be achieved only using the way of consistent and structural description of inhomogeneous human, technical, professional, psychological, emotional and organizational factors. Expected benefits of this approach such as:

1) From an airspace user (pilots) safety systems will be perspective, greater equity in airspace access, greater access to timely and meaningful information for decision support, and more autonomy in DM, including conflict management, will provide the opportunity to better deliver business and individual outcomes within an appropriate safety framework.

2) From a service provider (ATM) safety systems will be perspective, including that of aerodrome operators, the ability to operate within an information-rich environment, with real-time data, as well as system trend and predictive data, fused with a range of automated decision-support or DM tools, will enable optimization of services to airspace users.

3) From a regulator perspective, safety systems will be robust and open, allowing safety not only to be more easily measured and monitored, but also com-

pared and integrated on a global basis, not for its own sake, but as a platform for continuous improvement.

Maximum effectiveness and efficiency of actions can be obtained by activities undertaken in the early phases of any system's life cycle since correcting problems during requirements definition and design is generally the most effective.

To determine the emotional state of operators in the form of phase portraits, it is planned to create training systems that use a monitoring system with industrial organizations aimed to aerospace education development [5-7; 8; 9].

So, Virtual Training and Education system (VTE) consist:

1) Individual VTE for pilots, dispatchers, drones operators, engineering staff, etc. They solve different tasks: normal situations, complication of flight conditions, emergency situations in accordance, for example, with ASSIST (Acknowledge, Separate, Silence, Inform, Support, Time) for ATC, "ASSSIST" (Acknowledge, Separate, Synergetic (Coordinated, Cooperation, Consolidation) Silence, Inform, Support, Time) for Remotely Piloted Aircraft's operator, flight manual (FM) for pilots too.
2) Integrated VTE for collaborative work of pilots, dispatchers, drones operators, engineering staff. They solve different tasks: normal situations, complicating the conditions for flight fulfillment, emergency situations in accordance with ASSIST, ASSSIST, FM, etc.
3) Synchronized systems (Artificial Intelligence System, Decision Support System (DSS), etc.) for inter-decision making in emergency situations, special flight cases for pilots, controllers, drones operators, engineering staff, etc.
4) System for monitoring and diagnosing the emotional state of operator-learners. Determination of the emotional phase portrait of the operator, the diagnosis of deformations of the emotional state in emergency situations, the stability of the system.

Identification of the current emotional state of the operator is based on dispersion analysis obtained from spontaneous models (optimal), emotional and reasonable types of H-O activity [5-7]. Using dispersion analysis for phase portrait of ailerons deviation the mathematical models of spontaneous, emotional and reasonable types of H-O activity have been obtained. To diagnose emotional state of H-O and definition of AES "H-O – ACFT" stability during the emotional experience deformation in the flight extraordinary situation using Nyquist hodograph (with delay) the method of diagnosis of the current emotional state of the pilot in flight has been developed. For example, the calculated limit the dispersion of spontaneous, reasonable and emotional types of H-O ANS activity is shown in Table 1. If the variance takes the value more than defined, indicating changes in the emotional state of the pilot, this requires the relevant consideration.

The authors have presented next stages of the evolution of the HF's models associated with the appearance of new system components and approaches to the diagnosis of operator errors [4; 5]:

1) Professional "*skills*" of human-operators (H-Os); behavior of H-Os and definitional of H-O's errors.
2) Cooperation of H-O's in the "*team*"; interaction of H-O's in the team; error detection of H-O's in the team.

3) Influence of “*culture*” on H-O’s. Safety in the aviation system and error prevention.
4) Safety Management in the aviation system. Safety “*balance”* models and minimization of errors of H-O’s.
5) Optimization in MMS, “*collaborative*” DM and professional effectiveness of H-Os.

Table 1.

Identification of pilot’s emotional state

Type of activity	**Random variable distribution center**		**The calculation of variance**			
T	X_0	Y_0	$M(d^2)$	$M^2(d)$	D	Boundaries D when n = 100
Spontaneous	0,61	0,01	1,62	0,87	0,74	0,60–0,91
Emotional	1,31	-1,25	11,87	10,06	1,81	1,41–2,24
Reasonable	2,11	0,03	4,81	2,67	2,14	1,51–2,32

Estimation of functional stability of H-O is determined by the Nyquist criterion. For the spontaneous (optimal) type of ACFT control, the Nyquist hodograph does not cover the critical point (-1; $j0$) and AES "ATC – Pilot – ACFT" is stable. The Nyquist hodographes with emotional and reasonable control of the ACFT cover the critical point (-1; $j0$) indicating the instability of AES "ATC – Pilot – ACFT" (Fig.1).

Method of diagnosis of the pilot’s current emotional state during the flight

1.Identification of emotional portrait of j-pilot using models of emotional state identification for spontaneous, emotional and reasonable types of H-O activity, obtained by the phase trajectory of ailerons deviation and rudder direction ($F_i=f(D_{ij})$).

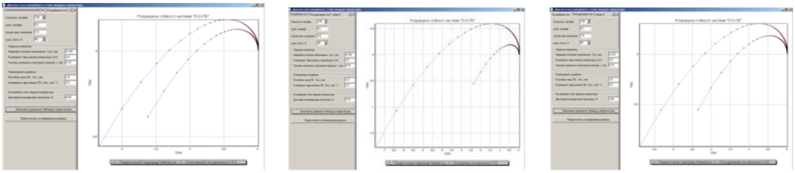
2.Identification of the current emotional state of j-pilot in flight, matching his portrait and emotional limits corresponding variances ($F_{min}=f(D_{min})$, $F_i=f(D_{ij})$, $F_{max}=f(D_{max})$) the type of emotional activity of H-O: $F_{min}=f(D_{min}) < F_i=f(D_{ij}) < F_{max}=f(D_{max})$.

3.Diagnosis of deformations of emotional experience (state) as a transitions to dangerous types of H-O activity (reasonable or emotional): $F_i=f(D_{ij}) > F_{max}=f(D_{max})$, $F_i=f(D_{ij}) < F_{max}=f(D_{max})$.

4.Determination of the type of operational activity in the case of mental deformations of emotional state using models of identification of spontaneous, emotional and reasonable types of H-O activity and determining appropriate variances: $D_i>D_{max}$; $D_i<D_{min}$.

5.Determination of the AES "ATC – Pilot – ACFT" stability using the Nyquist criterion with consideration of the dispersions by operative model of emotional state.

6.Indication of diagnostics results of pilot’s current emotional state in flight using dynamic panel display of digital data encoding.



a *b* *c*

Fig. 1. Calculation of AES "ATC – Pilot – ACFT" stability for: spontaneous (optimal) (a), emotional (b) and reasonable types (c) of H-O activity

A computer program "Diagnosis of the Emotional State of the H-O" has been designed for diagnostic module, which is included in the software complex for evaluation of psychophysiological properties of H-O in the composition of the informational-analytical diagnostic complex (IADC) for the study of the patterns of the ANS's H-O activity. The diagnostic module is intended for operative determination of deformations of the pilot's emotional experience and prevention of its decision in the expected and unexpected conditions of ACTF operation. Particularly important is the monitoring of H-O emotional state in flight emergencies.

Further research should be directed to the solution of problem in prerequisites of emergency situations and preventing catastrophic situations too. Models of flight emergency development and of DM by ANS's H-O in flight emergency will allow predicting the operator's actions with the aid of the informational-analytic and diagnostics complex for research of H-O behaviour in extreme situations. It is necessary to develop modern DSS for H-O of ANS (pilots, ATCs, flight dispatchers, UAV and SMS operators) in flight emergencies and in other situations, to investigate applied tasks of the DM in Socio-Technical Systems (STS) by H-O of aviation system, chemical production, energy, military industry, etc. Research can be applied to airlines seeking to achieve high quality of monitoring by LOSA program, while simulator training for operators. It is planned to define system of indicators of physiological and psychological human comfort from the position of theory of self-organization of complex systems, and to investigate practical usage in the fields of medicine, aviation psychology and design.

In future, we are planning consider other new technology, such as SMART-HOUSE, Smart-home. Developing Intelligent DSSs considering new concepts in aviation (PBA, CDM, FF-ICE, SWIM, SMART, etc.) for different operators and each stage, process, which are problems with using modern information technologies Data Science, Big Data, Data Mining, DM etc. It is necessary to analyze the all factors influencing on the DM of operators in these systems in order to predict the development of the technogenic catastrophe and prevent it with using Intelligent DSSs. Identification of emotional state of operators in dangerous environments, for example in ACFT (passengers), in smart house (persons), in medicine (clients), etc. must include:

– identification of emotional state of pilot / operator (Figure 2*a*);

– identification of emotional state of H-O with using cameras in smart houses, enterprises (Figure 2*b*);

– identification of emotional state of H-O with using devices & GNSS-technology / 5G (Figure 2*c*).

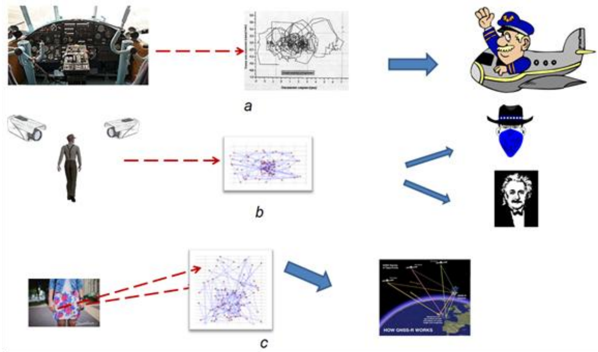


Fig. 2. Identification of emotional state of pilot / operator / H-O

With the development and improvement of technology in modern Intellectual Automated Control System (IACS) the problem effectively monitor the human condition can be solved. This research was first offered to consider human as a control object, human condition monitoring and diagnosis is help and compared to patient's normal state of according to the analysis of phase portraits. So, the system for monitoring the current emotional state of H-O (pilot) and diagnostics strains emotional experience as transitions to dangerous types of H-O (reasonable or emotional) in extreme situations and determining the functional stability of H-O for the prediction of the flight situation were developed by authors [9]. This system (IACS) is proposed to monitor the human condition in medicine, training of athletes, treatment of people and automatic monitoring of individuals who are in dangerous environments, for example in ACFT (passengers), in smart house (persons), in medicine (clients), etc.

Conclusion

The proposed method of monitoring and diagnostics pilot's emotional state in flight can have a significant interest for airlines seeking to achieve high quality monitoring within the program LOSA. It is proposed for usage within LOSA safety audits in order to create the database of crews' operations in real flights. Also, this method can be applied during operators' simulation training.

The IACS of monitoring and diagnosis of the human condition that is being treated has been proposed. IACS has been built with the help of dynamic modelling principles, the algorithm of human psycho-emotional diagnosing and monitoring through IACS system has been provided. IACS subsystems have been formalized in the form of transmission functions and algorithm of modeling, analysis and synthesis by methods of IACS automatic control theory has been developed. An example of IACS modelling by analysis of the influence of the time constants and coefficients on the stability and reliability of the system, including and humans has been represented. Therefore, as a CO it is proposed to consider the human, for whom applying diagnosis and monitoring of human condition in comparison to its normal state by the analysis of phase portraits, it is possible to develop methods for adjusting and improving the human condition. In case of presentation IACS as STS it is possible to diagnose, monitor and control of the human condition during the performance of professional activities; the system of monitoring the emotional condition of operator caused by environmental influences (occurrence of a non-standard in-flight situation, accident, psycho-emotional stress) with the definition of relevant stability has been offered.

Monitoring of current emotional state of H-O and diagnostics deformations of emotional experience in the forms of transitions to dangerous types of H-O activities (reasonable or emotional) in extreme situations and determining the functional stability of H-O will allow timely prevent the development of flight situation towards worsening. It is planned to use this techniques to identify emotional portrait of portable devices users in the future. Portable personal device is coded by phase portraits corresponding to the emotional state of the user. Timely detecting changes in phase portrait will allow diagnosing deformations of the user's emotional state.

References

1. International Civil Aviation Organization. (2005). *Global Air Traffic Management Operational Concept*. Doc. ICAO 9854-AN/458. Canada, Montreal: Author.

2. International Civil Aviation Organization. (2015). *Manual of Remoted Piloted Aircraft Systems (RPAS)*. Doc. ICAO 10019-AN/507. Canada, Montreal: Author.

3. Federal Aviation Administration. (2004). LOSA Advisory Circular. USA, Texas: The University of Texas. Human Factors Research Project.

4. International Civil Aviation Organization. (2002). Line Operations Safety Audit (LOSA) (1st Ed.). Doc. ICAO 9803-AN/761. Canada, Montreal: Author.

5. Shmelova, T., Sikirda, Yu., Rizun, N., Abdel-Badeeh M., Salem, & Kovalyov Yu. (2018). *Socio-Technical Decision Support in Air Navigation Systems: Emerging Research and Opportunities*. USA, Hershey: IGI Global.

6. Shmelova, T., Sikirda, Yu., & Kovaliov, Yu. (2017). *Decision Making by Remotely Piloted Aircraft System's Operator*. In Proceedings of IEEE 4th International Conference: Actual Problems of Unmanned Aerial Vehicles Developments (APPUAVD). Kyiv, NAU. – P. 92-99.

7. Kharchenko, V., Shmelova, T., & Sikirda, Y. *Decision-Making in Socio-Technical Systems*: monograph. Kyiv: NAU, 2016

8. *Sterenharz A, Degtyarev A., Novykov A., Ventzkovsky O., Polyakov N., & Petrenko A. Experience and Future Prospects For International Cooperation Of Universities With Industrial Organizations Aimed To Aerospace Education Development //* In Materials of Tempus European Program 62nd International Astronautical Congress, Cape Town, South Africa, 2011

9. Shmelova, T., Kovalyov, Yu., Sechko, O., Shostak, V., & Vasyliev, M. *Intellectual Automated Control of Human State Monitoring Systems:* In Proceedings of the 7th World Congress „Aviation in the XXIst century. Safety in Aviation And Space Technologies". Kyiv: NAU, 2016, 5.21-3.5.25.