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RELIABILITY STUDY OF OPERATORS WITHIN A COMPLEX ERGATIC SYSTEM

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Abstract. *The article examines the UAV operator reliability and possibility of transferring the theory of reliability concepts of technical objects to the activities of individuals and groups. Structural information analysis of the human operator activity controlling an UAV has been carried out taking into account the ground complex information structure. An assessment of the reliability criteria of the operator for accuracy and timeliness has been made.*

Key words: *reliability, flight operator, drone.*

Introduction

At the present development stage of the scientific – technological progress, the task of research and development of a theory of human factor (HF) reliability and efficiency within the control systems and systems “man – machine” is put forward. Working out a solution of such a problem is possible provided that a sophisticated system – informational analysis is carried out both in technical point of view and physiological, psychological, and engineering – genetic problems of the human factor.

The present work explores the phenomena and concepts related to reliability of the operator of unmanned aerial vehicles (UAV) and a group of operators (crew) too. A comparison between the technical object theory of reliability and theory of activity of an individual or group has been made. The reliability characteristics of both machines and people have a different nature, dynamics, and change rate over time. It is thought that different comparisons between the UAV characteristics and the pilot have been made already. The technics reliability is described by means of flawless operation distribution functions. The simplest scheme consists of three stages of reliability changes. The first stage is accumulation with increased density of failure probabilities. In the second stage prolonged stabilization of reliability occurs. In the third stage of aging and wearing out, the density of failures increases. It goes without saying that this scheme is well sustained provided standard maintenance and repair is made. As for the human, the stylize reliability curve during his career can qualitatively coincides with the life cycle curve of UAV. However, the quantity and the dynamic variables that affect the human reliability as compared to the machine is an order of magnitude larger [3].

It is well known that the UAV control process appears to be a task intended to highly qualified professionals and, in many respects, it is more complicated than controlling a manned aircraft. Interaction between operator and UAV is different for different systems. In case of unmanned systems with automatic flight and landing route, the operator follows the route, enters the coordinates it in the control system and implements procedures of starting the UAV. During the flight, he did not interfere with the control process. Instead, he solely monitors the flight and, if necessary, introduces additional flight route points or issues the emergency landing command. For unmanned systems with manual flight control, the operator may alter the flight route during the flight and perform various maneuvers, takeoff, and landing too. In the first case, the reliability is based on the reliability of all parts included in Unmanned Aircraft System while in the second case the operator skills are added further, [3].

The human factor influence has to do with the problems that are least opened to an evaluation. It must be noted that modelling the human behavior is difficult. In control systems, the human factor reliability in some cases is treated as efficiency of the system itself since not only does the human process the information, but he also possesses it.

The human activity reliability level is defined as probability of successful completion of the task at a given stage of the system over a given interval of time under certain duration conditions during its implementation. Wherever the human works, errors appear. The errors occur regardless the level of training, qualifications and experience. The human errors are associated with failure to complete tasks, lack of achieving the defined goals, absence or inactivity, [7, 9]. The operator reliability is characterized by the indicators faultlessness, readiness, recoverability, and timeliness.

Reliability of the UAV operator

The study of international experience in the field of air transport justifies critical requirements that the pilot must meet which in turn are related to psychophysical, ergonomic, medical, social, and professional characteristics and eligibility as well in different directions and applications. The initial descriptions were possible based on empirical models, statistical regularities, and plausibility. Modern methods are adopted by fuzzy set theory and fuzzy logic theory, methods of operations research, the principles of situational modeling.

The prakseologic side of human activity is associated with the concepts of efficiency, effectiveness and productivity. As far as activity occurs over time, the non-opportune or a-temporality categories are valid. The size or volume of the result gives the degree of compliance with the target, design, plan and correlates with the terms accuracy and precision of the human actions. Operator's actions can be structured as follows: a) correctness of the actions b) accuracy of the actions c) timeliness (temporality) of the action d) the size or magnitude of the action.

Human activity is structured and organized as a set of unit operations and is based on concepts: valuables, sense, objectives, actions, and operations. Regulatory activities are associated with the rules, standards and regulations. Elementary activities presented as elemental activity unit have spatial – temporal characteristics [10, 12]. Structure of the information activity space in this case includes flight environment of the UAV [11]. This environment encompasses geophysical space, width of the air route, and altitude. The information activity model is described through a Standard Operating Procedure. It is structured on the basis of (in relation to the information search time) decision – making time, time for action (inaction), and time to obtain this result in accordance with the plan of action, [1].

Operator's reliability can be defined as the probability of accurately and adequately performing the tasks in accordance with the instructions. Accuracy means implementation in accordance with the standard limitations in time and space. Proper operation a1 is performed within a standard operating procedure in moments of time t_1, t_2, …, t_i with reserve excess $\pm\Delta t$. Proper or normal operation is performed in case of timely detection either a signal or a set of signals by the operator which is/are necessary for action. Next, what follows is correspondence identification of signals according to standard configurations, making a decision, the action itself, obtaining and evaluation of the outcome. The concept of time reserve excess is associated with relevance or importance of the procedure.

(1) $$C(\bar{t}_r) = e^{-\lambda \bar{t}_r} \ ,$$

where $C(\bar{t}_r)$ means importance in terms of content and time constraints whereas $e^{-\lambda \bar{t}_r}$ denotes a continuous stream of events.

Proper operation a_1 within the standard procedure p_s is performed at a time t_1 with reserve excess $\pm\Delta t$. Proper performance of actions is possible in case of early detection of a signal or a set of signals by the operator need for action. What follows is signal identification for conformity to the Standard Operating Procedures, decision-making, action itself and outcome identification, which is determined in the same order. The time of action Ta and the procedure time $T_p = T_a + T_r$ increases with the reaction time T_r.

Accuracy could be determined as a degree of approximation of the actual process parameter value to its nominal value, i.e. as result compliance. The accuracy of operator actions depends on the systematic and random causes. They are determined with confidence $\beta = 0{,}95$.

(2) $$\delta_s = M + 2\sigma_s ,$$

where $M = m_1 + m_2 + \ldots + m_k$ is the systematic error of the system whereas

(3) $$\delta_s = \sqrt{\sigma_1^2 + \sigma_2^2 + \ldots + \sigma_k^2},$$

is the random error standard deviation of the system elements, [4].

As a category, contrary to the accuracy the term imprecision is adopted. Absolute accuracy of the actions is practically unattainable, therefore a total acceptable imprecision and accuracy reserve are determined:

(4) $$\delta_G = D_j - \delta_{\min},$$

where D_j is tolerance limits of the parameter j through D_j whereas δ_{min} is minimum total error by parameter j consisting of imprecision of the device during parameter measurement and parameter estimation imprecision made by the operator and his actions. Accuracy reserve excess is determined by the largest admissible imprecision.

Structural informational analysis of the human operator activity

Proper organization and structure of the ground complexes information panels, the choice and location of manual controls have a significant influence on the operator's perception of the necessary information at all stages along the flight route as well as the ability to react quickly to the situation alteration. The fundamentals of information panels are determined by the indicator and control geometrical positions at certain areas of the visual perception, anthropometric data, peculiarities of human information perception during the flight, human operator dynamic characteristics as a unit in the control systems, and temporal loss of control, [1, 5]. Successful implementation of the operations by human operator (s) during control of the UAV and its systems directly affect flight safety and action effectiveness. At the present time, there is a considerable backlog of experimental statistics based on the recommendations that have been developed for a rational design and operation of information panels for aircraft complexes.

Due to the widespread implementation of computerized control systems, the operator's field perception narrows to the monitor screen(s) (change numeric values, colors and shapes ripple image) in practice as well as audio messages and violations. Operator's control forces are carried out through a choice of set elements displayed on the screen or keyboard keys and functional devices buttons (joystick, trackball, tablets, etc.), thus depriving the operator's motorial action from a significant motive component. Given the particularities of the human operator of an UAV specific activity as a complex dynamic monitoring of continuous parameters and logic elements, it could be said that the intellectual tasks dominate over the perceptual and the motor. It is known that tasks definition of the operator in such a case of automated control systems is reduced practically to the following: timely detection the automated system inability in order to deal with the violations occurring during the process, determination of cause of the fault and making up for the consequences, [6].

The structural scheme of the operator operation within a tracking system is shown in Fig. 1. One could figure out stages of the operator activity during UAV control process within a closed system: detection of signal, mismatching between the assigned motion and state of the controlled object, signal recognition in terms of magnitude and direction, situation assessment and decision making regarding the control method. Moreover, these processes can run simultaneously.

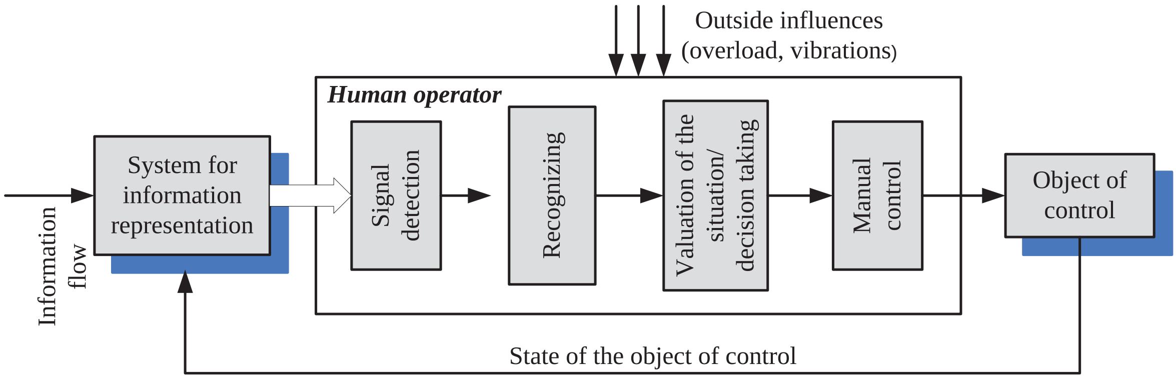

Fig. 1. An UAV control system chart with an operator.

In some cases, a simplified transfer function is utilized in terms of both mismatching magnitude φ and control force ψ, [8].

(5) $$\varphi = \varphi(\psi, k, \tau, \pi),$$

where k is an operator gain coefficient, τ is a constant time delay during information perception (0.25 s), π is a constant time delay of the motorial reaction (0.125 s), and φ is the Laplace's operator.

In order to assess the operator's reliability (error-free operation) and precision of operation objectively, special computer imitation stands and simulators are created, [2, 5]. Recent studies in the theory of reliability of technical facilities and the reliability of people activities show that there is a correlation between concepts of reliability, quality, safety, and also accuracy, relevance, and timeliness. Table 1 shows conceptual content of reliability modern structure of the individual.

Table 1. Structure of the concept for reliability of the operator of flying machine

Operator's reliability R_p	**Reliability properties**	**Conditions and states**	**Events**
Psychic reliability $R_{p\psi}$	**Flawlessness**. Aptitude for a flawless activity	Desynchronizing, tiredness and stress	Errors
Physiologic reliability $R_{p\phi}$	**Fitness for work**. Capacity for work during entire activity cycle	Tiredness, illness	Absent-mindedness, dozing
Demographic reliability $R_{p\Delta}$	**Working capacity**. Labor efficiency, health fitness	Age, sicknesses	Traumas

The operator's properties could be described as follows:

(6) $$R_p = \{R_{p\psi}, R_{p\phi}, R_{p\Delta}\},$$

where complex relationships are possible, i.e. either $R_\psi \Rightarrow R_\phi \Rightarrow R_\Delta$ or $(R_\phi \Rightarrow R_\Delta) \Rightarrow R\psi$. Stress results in chronic fatigue and even health deterioration that in turn increases the error in the operator's operation.

If one considers the reliability of a complex ergatic complex, the individual operator reliability is described as the probability of working out a solution correctly of the following problem:

(7) $$P_n = m / N$$

where "m" is the number of the problems solved correctly whereas "N" is the total number of problems. In accordance with the reliability theory methods, in order to perform a flight P_n safely and effectively, the operator reliability value should be P_{ho} and defined as follows:

(8) $$P_{ho} > P_i / \prod_{i-1}^{n} P_i(T_n),$$

where $P_i(T_n)$ is system technical unit reliability during the flight.

The possibility of transferring the reliability theory of technical objects and its application to the operator activity could be illustrated by means of various approaches and methods. For example, flawless property of the technical object is equivalent to the **method of error minimization**. This method directly affects the source of errors by means of either reducing or excluding factors that cause them. Examples of such methods are improvement of technologies and aircraft maintenance and improving ergonomics of the control panels as well. Duplicating a technical object is equivalent to the **method of capturing human error**. The method assumes that the error already turned up and it is not necessary to "capture" it prior to onset of adverse effects thereof. Examples of such methods are various checks of both structure of the UAV and the human's capabilities.

Conclusions

Reliability and efficiency of the man – machine systems have to do with the particular important features. Not only is the Man – Operator reliability within the Operator – UAV systems determined by psycho – physiological endurance regarding harsh loads but the human intellectual properties to make up for a variety of distorted informational processes during interaction with technology is also important. The development of these systems require more research to be carried out on the processes of information perception, processing, and storage by human as well as decision making mechanisms in different cases, psycho – physiological factor impact on reliability and effectiveness of such systems.

In the article hereby, the UAV operator reliability has been investigated as well as possibility of transferring the theory of reliability of technical objects concepts to individual and group activity. A structural – informational analysis of the man – operator activity has been carried out during controlling an UAV rendering into account the informational structure of a ground aeronautical facility. The criteria of operator reliability have been estimated in terms of accuracy and timeliness.

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