THE PROBLEM OF HUMAN FACTORS IN UNMANNED SYSTEMS

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Summary
With the advent of unmanned systems, the development of ergonomics entered a new stage in the study of human-machine interaction and exacerbated security problems. The requirements for security and reliability of both the systems themselves and their main link, the human operator, have changed. New challenges – new human problems in digital systems. Digitization has allowed the creation of unmanned systems, but has also created an ergonomic contradiction "the growth of automation – the complication of the problem of the human factor". Unmanned aerial systems have unique ergonomic problems associated with the characteristics of the UAV operator and the technical features of the UAVs themselves as complex systems. In this regard, the analysis of the causes of the ongoing manifestations of the human factor phenomenon in the functioning of unmanned systems, as well as the search for ways to reduce them, is relevant. ***The purpose of the work*** is a meta-analysis of the problem of the human factor in complex systems that actively use ICT, using the example of unmanned aerial systems. The article provides a critical look at the problems of the human factor in unmanned aircraft, which are not solved within the framework of existing approaches.

Keywords: Unmanned Aerial Vehicles, human factor, human operator activity, automation, training of UAV operators.

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1. Introduction

The problem of security of complex dynamic systems (CDS) in unpredictable conditions is interdisciplinary and extremely relevant. The use of cyber-physical systems (Industry 4.0) made it necessary to pay special attention to human-machine interaction. The transition to Industry 5.0 directly showed the relationship between the reliability of cyber-physical systems and human-machine communication. The appearance of cobots and the complication of human perception of new robotic systems caused attention and interest in human cognitive capabilities *(Nahavandi, 2019; Industry 5.0, 2019)*. This, in turn, caused the rapid development of the sciences created to solve the problems of human-machine interaction – ergonomics, human factors engineering, engineering psychology, bioengineering, etc.

The technology of the future – unmanned systems – is already actively serving people today. With the advent of unmanned aerial systems (UAS) and unmanned aerial vehicles (UAVs), the development of ergonomics has entered a new stage in the study of human-machine interaction in complex systems. The requirements for security, fault tolerance and reliability of both the systems themselves and their main link, the human operator, have changed. New technological challenges have led to the emergence of new problems related to human activities in digital systems. Digitalization and the growth of automation have allowed significant advances in technology, but also significantly changed the requirements for cognitive abilities and psychophysiological capabilities of a modern person. Today, the difficulties of digital thinking, clip thinking and even "digital autism" are being actively discussed, despite the high level of digital competence even in children. Digitalization has made it possible to create unmanned systems, but has also played a cruel joke and does not yet allow us to get out of the vicious circle of problems "the growth of automation is a manifestation of the human factor phenomenon (HF)". For example, the emergence of unmanned UAS and UAV systems means a new type of activity, a new workplace, new requirements for a human operator, new human factor problems, and hence the need to resolve issues of selection, admission and control of operators.

This is confirmed by statistics: 67% of UAV accidents occurred due to the human factor. It would seem that this is much less than 80-90% of accidents with manned vessels due to crew or dispatcher error. However, for example, today there are about 35 thousand passenger aircraft registered in the world, not counting general aviation. At the same time, the number of UAVs is growing rapidly. For example, in 2010, the US Federal Aviation Administration estimated that by 2020, about 15,000 drones would be used for peaceful purposes. In 2016, it was estimated that there would be up to 550,000 by 2020. According to the NY Times, 2.8 million civilian UAVs were sold in the US in 2016 *(Wikipedia, 2022)*. It is obvious that the number of UAVs is simply not comparable with the number of manned aircraft, which means that the fact that they have accidents due to the human factor needs to be paid attention to. The fact that the percentage of accidents due to the fault of the human factor in unmanned aircraft systems has not decreased much in relation to manned systems is of great concern to security professionals. After all, we are talking about a massive transition to unmanned systems in all areas of human activity. Therefore, it is so important now to analyze the current state and develop future requirements for ensuring the safety and fault tolerance of processes and systems in unmanned systems that use ICT intensively. In this regard, the analysis of the causes of the ongoing manifestations of the phenomenon of the human factor in the functioning of unmanned systems, as well as the search for ways to reduce them, is relevant today. ***The purpose of the work*** is a meta-analysis of the problem of the human factor in complex systems that actively use ICT, using the example of unmanned aerial systems. ***The main motivation*** is to bridge the gap between the theoretical concepts proposed to eliminate human factors problems in the modeling and design of complex systems, and the practical implementation of human activities in unmanned systems, using the example of UAVs. It is necessary to consider the problems that may arise due to the human factor in the operation of UAS in order to move forward in solving these problems.

2. The human factor in unmanned aircraft

2.1. Human problems in UAVs

Unmanned aerial vehicles are one of the important technological achievements of our time. The term "Unmanned Aerial Vehicles" (UAV) refers to a component of a broader class of Unmanned Aircraft System (UAS). UAV is a class of aircraft that can fly without the presence of pilots on board *(Hobbs, 2010)*. They are complex functional systems consisting of the UAV itself, a control center with several operators, a communication system and other additional equipment necessary for servicing the UAV.

The growing interest in unmanned aerial vehicles is justified. The main positive differences from controlled ships are: the UAV control system itself; reduced air safety requirements; lack of a number of systems (environmental control, life support systems, etc.); relatively low cost and low operating costs. UAV were originally developed during the 20th century for military missions. As control technologies have improved and costs have come down, their use has expanded to many non-military applications: observation and tactical planning; monitoring (the state of oil and gas pipelines, the state of environmental pollution, protection of large areas with difficult terrain during the day and night, the state of natural resources); crowd management, situation control (concerts, sporting events); payload delivery, firefighting, relocation of objects in a seemingly dangerous environment, remote emergency medical missions; traffic monitoring, remote sensing, aerial photography (precision farming, safety testing and disaster intensity monitoring); police operations (video surveillance, road audit); search and rescue (SAR) operations; intelligent transport, road safety management, unmanned flying taxis and much more.

However, despite the obvious advantages and indisputable advantages, UAV accidents occur even with the death of people. Back in 2001, UAV were thought to be significantly higher than manned aircraft *(Johnson, 2008)*. At the same time, during all the years of existence with the technical improvement of unmanned aerial systems, the number of mechanical failures decreases, and the number of failures due to the human factor remains unacceptably high and competes with those for manned aircraft. *(Johnson, 2008; Kaliardos & Lyall, 2014)*.

Obviously, technology is changing the essence of human-machine interaction. For example, the developer of Autonomous and Unmanned Systems "Lockheed Martin" offers a philosophical idea as a slogan: «The Future of Autonomy Isn't Human-Less». The control of an unmanned aerial vehicle is unique in that it functionally combines the cockpit and the usual office workplace. At the same time, the UAV operator is neither a standard pilot with an extremely high “error cost”, nor an office worker with computer office equipment, whose “error cost” is very relative and depends on the tasks. This leads to misconceptions, cognitive distortions in the perception of information, a shift in emphasis in the workplace, etc. effects.

There is an obvious ***contradiction***: the growing automation and the growing number of autonomous unmanned operations increase the importance of other aspects of human-system interaction. The ergonomic paradox is that with the ever-increasing distance of a person from system control, the role of human-machine interaction only grows, which is confirmed by major incidents. It is in this connection that Bogdanov and Ashby's theory of viability again became relevant and developed; human factor engineering and a risk-based approach, cognitive sciences and technologies began to develop actively.

2.2. Human factors problems associated with digitalizationand automation in UAV

It is known that aircraft, cockpits, human factors manuals and various instructions have been developed and improved over decades as a result of aviation accidents and incidents. Those. The “price” of this knowledge is extremely high. In relation to UAV, such an approach is doomed to failure in advance, since the number of UAV produced and in operation is not comparable to manned vehicles. This means that right now there may be a significant number of potentially dangerous objects controlled by people above us. And here all the typical problems of the human factor begin to appear – accidental and deliberate errors, not-knowing and not-skill; errors of an organizational nature and the consequences of the simplest fatigue or illness of a person. It is clear that predictive risk management is needed rather than incident analysis to develop operating experience (Figure 1).

Therefore, today there is an ergonomic contradiction. Despite: 1) significant developments in aviation ergonomics and engineering psychology, existing approaches to ensuring the safety of aircraft; 2) developed methodological base of human factors engineering to overcome the

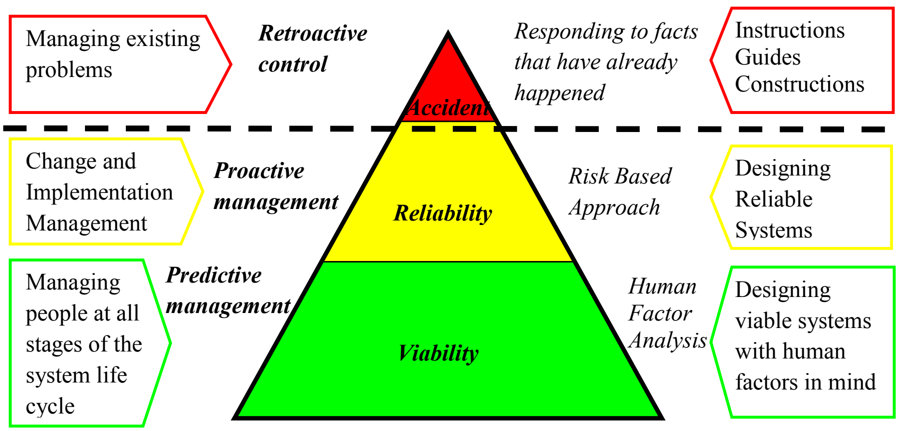

Fig. 1. The iceberg model of security change management for complex systems

problem of human factors; 3) the rapid development of digital ecosystems and the high level of digital competence of people, with the emergence and rapid development of UAS, new challenges (risks, problems, manifestations) associated with human activities in them have appeared.

In our opinion, today still relevant and unresolved aspects of the ergonomic support for the operation of aviation systems, now unmanned, requiring consideration of the human factor, are: human-machine interface (poor interface in UAS is noted by many researchers); regarding UAV operators: training of future operators and selection for the profession; selection of reliable operators to control the UAV; ensuring the reliability of the UAV operator; determination of the current functional state of UAV operators.

3. UAV problems related to the activities of the operator

3.1. Features of human activity in the UAV

The evolution of human activity in aviation systems. During the existence of aircraft, the role of a person in them has undergone significant changes with the growth of automation of control processes. Initially, the role of the pilot consisted of manual control, gradually it changed towards dispatch control and tracking operator activities, then joint functioning in "unmanned" aircraft. Those. the direct human activity of flying an aircraft has evolved from the use of cockpit instruments and manual control, to the monitoring of cockpit instruments that control the aircraft almost automatically, to the use of ground station instruments for remote control of the aircraft *(Hobbs, 2010)*.

Features of the activity of the UAV operator. Unmanned aircraft show a unique set of manifestations of the human factor *(Hobbs, 2010; Johnson, 2008; Kaliardos & Lyall, 2014; Hobbs & Lyall, 2016)*. For example, the pilot of an aircraft physically perceives and processes information in the cockpit. At the same time, the UAV operator mentally perceives and processes information remotely from the control object. The activity of UAV operators is mainly cognitive. They must have a high speed of reaction and thought processes, attention to an unexpected situation. The high rate of accomplishment of UAV operation tasks and the significant duration of missions cause increased stress and overwork. Overload due to multitasking during UAV control tasks can jeopardize task completion and increase chance of mission failure *(Johnson, 2008; Pedersen et al., 2006)*. This worsens the stability and reliability of their activities and leads to personnel leakage. Most often, the problems of the UAV operator's activity are called by researchers: failure to monitor, decreased vigilance, over-reliance on standard values, complacency caused by automation, and a range of problems in obtaining and processing information (increased delay in detecting problems, missing information, distorting information in obtaining and analyzing) *(Hobbs, 2010; Johnson, 2008; Kaliardos & Lyall, 2014; Pedersen et al., 2006; Shneiderman & Plaisant, 2005)*.

The unique ergonomic problems of UAV operators are (Shneiderman & Plaisant, 2005; Sanders & McCormick, 1993; Waraich et al.,2013; Fedota & Parasuraman, 2010):

• decrease in sensory signals (distortion of eye contact with objects (the camera covers a limited field of view, decreased auditory, proprioceptive and olfactory sensations);

• psychological and emotional perception of the control station (they are more like control rooms or office workstations than a traditional cabin);

• unrealistic from the point of view of human physiology, the timing of the mission (for example, more than 24 hours) is accompanied by risks associated with fatigue and then the need to transfer control to another operator, which leads to errors;

• the possibility of an emergency termination of the flight and the destruction of the UAV leads to a number of problems – reassessment of the situation and its role in it, deliberate actions, risks of ground facilities, etc.;

• confidence in automation. Unlike an airplane, a UAV has no manual control at all.

The reverse side of automation. The constant improvement and automation of the CDS is accompanied by an increase in the number of information sources (sensors, gauges, etc.), which gives rise to an even greater variety: a) information flows of a different nature; b) how they are processed; c) types of visualization and means of modeling and analysis. Therefore, despite the significant efforts of developers of complex systems, nowhere is the phenomenon of automation manifested to a greater extent than in unmanned aerial systems and UAV control! The increase in automation is associated with: increased mental workload, loss of awareness of the situation, and even deterioration in skills. Automation generates operator confidence and acceptance, as well as complacency. It is complacency due to automation that has been noted by Parasuraman et al. as a contributing factor to many aircraft accidents that reduces system reliability *(Fedota, John R. & Parasuraman, 2010; Reiman. et al., 2021)*. At the same time, increasing the level of automation does not lead to a decrease in the workload or an increase in UAV productivity *(Parasuraman & Mehta, 2013)*.

In addition, new problems of human-machine interaction are emerging. So, if the 4th industrial revolution (Industry 4.0) is the introduction into human life and individual optimization through the use of ICT (information and communication technologies), then the 5th industrial revolution is the optimization of society through the integration of cyberspace and physical space *(Reiman et al., 2021; Mygal et al., 2021)*. While the main challenge in Industry 4.0 is automation, Industry 5.0 involves synergy between humans and autonomous machines. And a person will have to work together with robots and perform activities on a par with them. Cobots will notice, understand and feel not only the person, but also the goals and expectations of the human operator. As, for example, the created An Intuitive End-to-End Human-UAV Interaction System, in which the UAV can be controlled by a person's natural postures. Those. The 5th industrial revolution is the fusion of the physical world and its three main elements – smart devices, smart systems and smart automation *(Reiman et al., 2021;*

Mygal et al., 2021). However, the human intellect, human cognitive abilities and psycho-physiological capabilities will be at the center of all interconnections, as shown in our works *(Mygal et al., 2021; Protasenko & Mygal, 2021; Mygal et al., 2022)*.

3.2. The human factor in unmanned systems as a consequence of the non-transdisciplinarity of education

Education problem. Safety of technologies and equipment, safety of human activity in this environment – a sign of the highest human qualification, which is present in all stages of the life cycle of any technology or system. The ability to prevent risks and minimize the possible negative consequences of the human factor is one of the most important professional skills today. Apparently, today there is a contradiction between the educational sectors and the needs of society: the need to ensure the security of complex systems (transport, energy, etc.) is trying to solve without the primary link – training specialists who will ensure security, understanding the nature of the human factor .

That is, errors in the design of unmanned systems, not taking into account the psychophysiological and cognitive specifics of the human operator in the development of the interface and their technical qualities and capabilities, are the basis for creating a safety problem in UAV. Therefore, today in the design and operation of complex systems, which include UAV, it is necessary to take into account the individual capabilities and limitations of man as the main link in the system, which then makes decisions in the management process *(Mygal & Protasenko, 2020)* (see fig. 2).

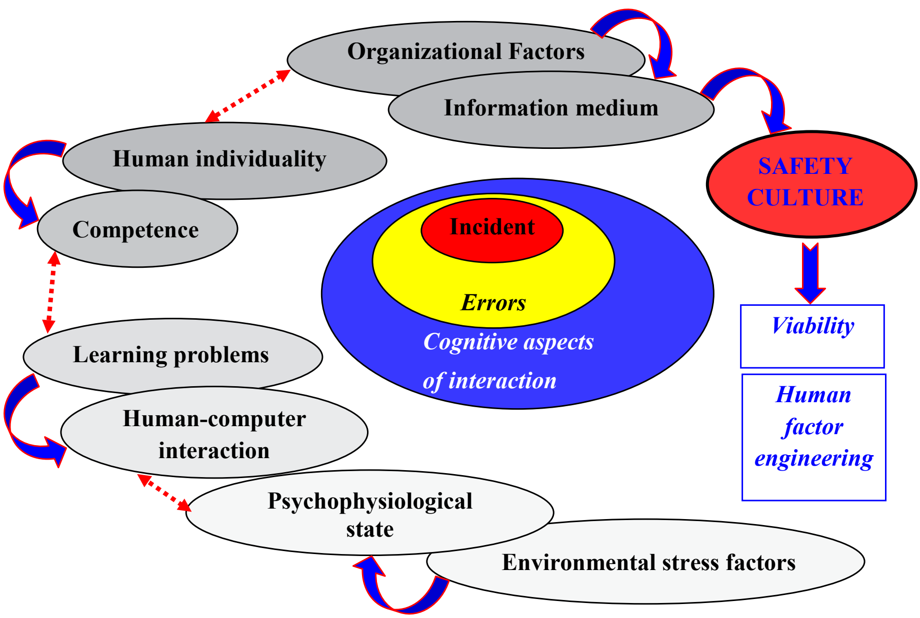

Fig. 2. Interdisciplinarity in the learning of specialists – taking into account modern challenges

Convergent combination of engineering sciences, information technologies, psychology, bioengineering, neuro- and cognitive sciences allow to create conditions for ensuring safety, reliability and stability of complex human-machine systems designed and operated *(Advancing Research, 2013; Nachreiner, 1996; Roco, 2002, Lee et al., 2017)*.

Considerable attention should be paid to the development of ergonomic thinking in everyone whose activities relate to the life cycle of a complex system – developers and service providers, operators and managers. Because it is a system of individual views on the development of complex human-machine systems and the role of man in them; it is an understanding of complex processes of human-machine interaction; ability to predict risks in these systems and plan the development of systems with prior consideration of these risks. After all, ergonomic thinking for the specialist of today, and especially the future, along with environmental and critical thinking is a sign of education, is the foundation of highly qualified specialist *(Protasenko O. & Mygal, 2021; Mygal & Protasenko, 2020; Mygal et al., 2022)*.

The problem of training UAV operators has several aspects, since even today the use of drones in the workplace raises a number of concerns. The advent of smart learning interfaces has exacerbated the problem of understanding human nature. The ability to control unmanned systems has become available to a wide range of specialists who do not have key knowledge to ensure the safe control of UAV – about the perception and processing of information by a person, operator errors, the psychology of behavior in extreme situations and the ergonomic properties of systems. Many disciplines of the cognitive and ergonomic direction in the leading universities of the world are designed to give future specialists knowledge in the field of human-machine interaction. It is only necessary to realize that without such knowledge, high-quality technical education is impossible. It is the transdisciplinarity of the education of specialists – from developers to performers and operators of digital systems, that makes it possible to reduce these risks of human-machine interaction *(Rigolot, 2022; Mygal et al., 2021)*.

There are also legal issues. It is obvious that companies providing commercial services using UAV are starting to appear. Accordingly, it is necessary to hire drone pilots or train personnel to fly and ensure their safety, as well as the safety of the population in the territories where missions are planned. The commercial use of drones is fairly new and it is likely that there is a shortage of skilled operators. It may be attractive for HR agencies to create specialized staff. But at the same time, there are a fairly large number of former pilots and people with experience in managing automated systems. The use of drones, like other new technologies, may have more significant impacts than initially thought, and companies providing such services should be aware of this. However, the process of verification and admission of operators remains unanswered; issues of certification of their activities and control; issues of privacy and access to private airspace, as in the case of delivery; and, of course, issues of security and accountability for the results of missions. Attention should be focused primarily on safety, and then on new jobs that will potentially be created for operators of unmanned aerial vehicles. That is why training should be focused on the features of human-machine interaction, and only then on the technical side of the process.

4. Conclusions

It must be recognized that with the advent and rapid development of unmanned aerial systems, new challenges (risks, problems, manifestations) associated with human activities in them have appeared. In unmanned systems, the problem of the human factor exists and manifests itself quite acutely. Unmanned aerial systems have unique ergonomic problems associated with the peculiarities of the UAV operator and the technical features of the UAV themselves as complex systems. Today, important aspects of ergonomic support for the operation of unmanned aerial systems have become aggravated, requiring consideration of the characteristics of the human factor in the design, operation and training of operators.

There is also an urgent need to introduce ergonomics as a mandatory discipline for engineers – designers of complex systems. It is the development of ergonomic thinking in future engineers that should be given considerable attention, because it is a system of individual views on the development of complex human-machine systems and the role of man in them; it is an understanding of complex processes of human-machine interaction; ability to predict risks in these systems and plan the development of systems with prior consideration of these risks. After all, ergonomic thinking for the engineer of the present, and even more so of the future, along with environmental and critical thinking is a sign of education and high qualification of the specialist.

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