A SYSTEM OF OPTIMIZING THE HUMAN-MACHINE INTERFACE AT AIRCRAFT[1]

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OVERVIEW

Optimization of human-technical system interface goal is to minimize the human-operator workload. Applying that attitude, one can avoid the quick fatigue of that operator. It allows for effective and long lasting performance of control task, also in the presence of time deficit. The idea of system for optimizing the human operator-military aircraft interface has been presented. That system consists of research-engineering flight simulator used as a testing stand and technology allowing for optimizing that interface.

1. INTRODDUCTION

Modern technology advancements and also the increasing costs of the new systems development, caused the extension of their life cycles. That is easily seen at the military area, in particular in military aviation. The present knowledge on the methods of aircraft technical state evaluation assure that their modernization, driven by the financial reasons, allow for achieving reliable aircraft properly adjusted to the modern battlefield requirements. Those modernizations generally cover replacing the power system and the most often avionics. Introduced then new avionics systems include the new integrated presentation systems, allowing for effective control and operation of integrated devices. Such modernized human operator interface should allow him effective performance of control tasks during normal and abnormal operational conditions, within the whole flight envelope. It requires optimized human operator - technical system interface. Above problem will be presented in that article on the example of pilot - military aircraft interface, and conclusions driven from it apply directly to any system, which can be controlled by the human.

Such an attitude seems to be a standard in the countries performing that kind of programs for their air forces, eg. [1]. [2].. In Poland we had not any big program of that kind. The first one should have been the Mi-24D attack helicopter complex modernization program, being prepared by the four countries exploiting that aircraft. Unfortunately, because of not technology reasons, program wasn't introduced into the life. So in that situation the first substantial modernization program in military aviation is upgrading the avionics systems of multi role helicopter W3-WA "Sokół" by the Air Force Institute Of Technology in Warsaw together with Military Aviation Factory in Łódź, Poland. During performing of that program many problems, also from the Human Factors area, have occurred. They have been solved with the use of accessible at that moment methods. Among others, one could find necessary the methods and tools for optimizing the human interface of that helicopter. An obvious necessity of such methods and tools applying, caused a decision for developing a system of optimizing the human-machine interface applied to military aircraft. That system should take into consideration the latest achievements in that area, and also the local country conditions of performing such programs. The research and development program has been started at the end of 2006 and is planned to complete by the end of year 2008. That article is being presented the baselines of the program and some chosen elements.

2. PROBLEM DEFINITION

One of the initial assumption of the program [3], [4] was dividing the developed system into the two subsystems:

- test stand,
- interface optimization technology.

The first subsystem necessary for development of the human-military aircraft optimization technology is the test stand. The works performed under that

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program goal is to develop such a stand, which is in fact research-engineering flight simulator, dedicated to the human-machine interface (HMI) optimization.

The importance of that kind of stands is well known in aviation world, and introducing the simulation methods into that area is kind of a standard. Up to day it is the best way for achieving such a goal.

Developing the HMI for military aircraft and stand being used for that purpose requires some research at the aviation physiology and psychology and also real time mechtronics systems areas to be performed.

In the area of aviation physiology and psychology the ranges and methods of operator psycho-physiological parameters measurement have to be defined. Those methods should cover the operators of the following types of military aircraft: jet trainer, turbo prop trainer, multi role, medium size helicopter, UAV. Also the methods of operator reaction time and his workload factor measurement have to be developed. They should allow for achieving the normalized and optimized values of data, which can be used as the guidelines by the operator cockpit designers.

In the area of mechtronics subsystems the following modules have to be developed:

- mechanical structure of the operator test stand, which allow for simple modification of the optimized interface, during the research and design works,
- computer system structure. It has to be open architecture type, which in a real time could be able to perform the following tasks: modelling the military aircraft space motion and its on-board systems in both normal and abnormal conditions, control the indicators and gauges on operator stand, read the state of the operator controls with the required frequency, register and store data needed for the next analysis and design works, present on the test stand indicators all data necessary for aircraft control and performing the research and design works,
- mechanical structure and software allowing for effective including the real devices into the aircraft control loop.

The latest accessible technologies and methods have to be applied. At the test stand, which is the key for the whole system, has to be applied the COTS real time systems and software, which assure ability of modification and development of the system in the future. Also the hardware elements should allow for effective changing the software, according to performed researches. Achieving those goals should assure that the whole interface modernization program is being perform at the top level.

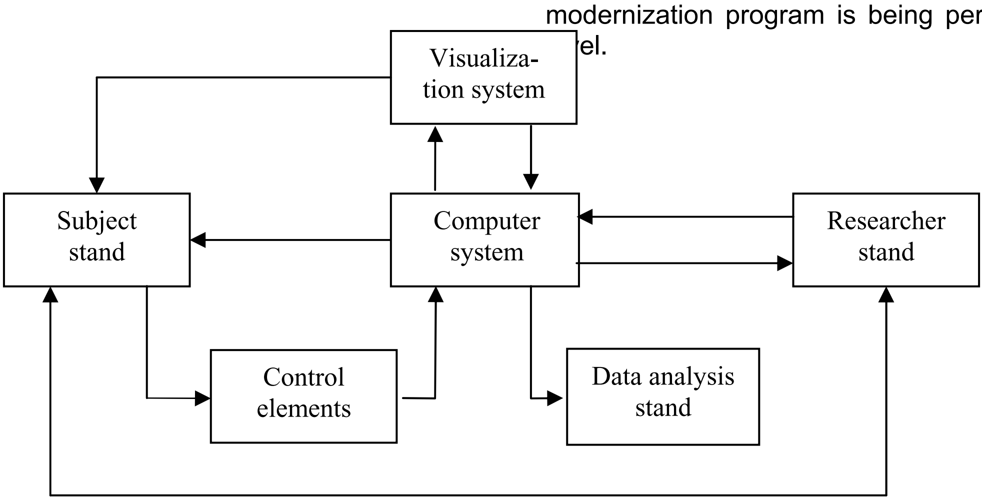

FIG.1. Research engineering simulator structure scheme

3. RESEARCH ENGINEERING SIMULATOR

The structure of the research simulator is being presented in the FIG.1. Blocks presented in the FIG.1 represent the real modules and systems or other crucial system elements, being the parts of the simulator. The arrows show the information transfer within the simulator. Those data are generated and transferred through the different channels Following the functions, hardware and software solutions of the simulator modules will be discussed.

3.1. Computer system

Computer system is the basic module of each simulator. Its open type architecture is caused by the requirements of different types of aircraft cockpits optimization researching and including into the aircraft control loop the real devices. The simulator computer system tasks are the following:

- real time modelling:
    1. motion dynamics of the military aircraft,
    2. on-board systems dynamics,
    3. aircraft environment reacting on the simulated object,
- data transmission between the simulator modules,
- controlling the indicators and gauges at the tested aircraft cockpit,
- reading the state of the controls at the subject stand, with required frequency,
- simulator systems on-line monitoring,
- allowing the preparation and archiving the test scenarios,
- research exercise controlling through the researcher interface.

The computers and data transfer elements are also included in the other test facility stands and visualization system. They will be described in the following paragraphs.

3.2. Visualization system

The visualization system consists of the two following subsystems:

- environment data base generator,
- presentation system.

The module named environment data base generator except the generating of data base including the information necessary for simulated aircraft environment displaying, also assure the following:

- adding or eliminating the environment objects by the researcher,
- generating the information on location of the object or phenomena being the sound source,
- generating the signal transmitted to the presentation subsystem.

The presentation module transforms the signal from the generator into the simulated aircraft environment picture being observed by the subject. In our research simulator the presentation module consists of the three big size plasma displays, located in front of the cockpit of the simulated aircraft. Such solution allows for its easy adoption for the width of the tested cockpit. For example, during the helicopter cockpit optimization we have two side by side seats and then two displays are located in front of the cockpit, and during the airplane tandem located seats cockpit tests one display is located in front and two at the both sides of the cockpit.

3.3. Researcher stand

With the use of that stand researcher can perform all standard functions of simulator instructor stand and also some additional functions connected to research tasks. The following functions the researcher is able to perform:

- turn on and off the simulator and continuous monitoring of its work,
- modifications of performed test conditions,
- registering the required information on performed test,
- on-line observing of the subject activities in the cockpit,
- generating the new scenarios of the tests,
- modifications of simulator visualization system data base,
- communication with the subject stand.

The analysis of above simulator functions allow for defining its structure, hardware equipment and location in the laboratory. For successful performance of majority of above functions the simple stand in form of a desk adopted to comfortable work, with the use of two 20’ monitors, keyboard, mouse and microphone is quite enough. Location of the stand in the laboratory allows for direct observation of the subject, his control actions, cockpit displays and gauges indications. Thanks to such solution we could avoid presenting all those indications in the researcher stand monitors. It has simplified the stand structure and decrease the cost of adopting the stand to the next aircraft cockpit testing.

3.4. Subject stand

The subject stand is the key module of the research flight simulator. There are elements of other modules and subsystems of the simulator, located here. They are the following: presentation subsystem, human-operator psychophysiological parameters measuring system, measuring and controlling elements of computer system. On that stand the subject need to perform all standard functions of the simulated military aircraft operator. Moreover, the stand has to assure performing the tasks, coming out of the research program [3]:

- replicate, **in the way proper to interface research**, the modernized or designed military aircraft cockpit,
- assure the ability of connecting the devices for measuring the tested subject psychophysiological parameters, and their integrating with the simulator operating system,
- allow for including into the tested cockpit or interface the real element of the designed system,
- allow for including into the aircraft control loop the real elements and modules,
- replicate the visual and aural noises, similar to the real ones, acting during the real flights on the aircraft operator,
- assure the registration and storage of the required data from the performed tests, and also their processing for the next analysis,
- allow for performing the designing works and researches on optimization of the many different types of the military aircraft.

The block shown in the FIG1., which in fact is the integral part of the subject stand, is the "control elements". With their use, the subject is able to control the simulated aircraft in the way very similar to the real cockpit. In the research simulator cockpit those control elements are not necessary to be the detail replicas of the real ones, but need to act in the same way after the same subject control motions, as in the real aircraft. If necessary for the research reasons, those control elements could be replaced with the real ones.

The subject stand includes also the apparatuses for the subject psychophysiological parameters measurement. Those devices, although physically are located in that stand, are controlled by the independent computer systems. Data registered by them are transmitted thorough the researcher stand to the data analysis stand.

3.5. Data analysis stand

Data analysis stand allows for performing the following tasks:

- connecting the medical measurement and control apparatuses with the aim of reading the registered data and their next analysis,
- performing additional tests and psychophysiological parameters measurements before and after the main test task completing,
- presentation of the test results in the form of the multimedia presentation or printed version,
- archiving the data from the performed tests.

Moreover it can perform the function of additional stand for test preparation in the form of:

- preparation and modification of scenarios of test tasks in the way proper to the research of the defined interface of designed or modernised military aircraft,
- the scenario presentation in the form of mission planning, which need to be performed by the subject.

Taking into consideration all above factors, the structure, hardware and software configuration, and location of that stand in the laboratory have been defined. The hardware and software requirements are rather standard, but what is important it needs to be located in the separate room from the simulator. That room takes also the function of the briefing and debriefing room for the tested subjects.

4. INTERFACE OPTIMIZATION TECHNOLOGY

The military aircraft HMI optimization technology can be presented in the following steps:

1. defining the critical tasks for the researched aircraft,
2. choosing no more than a few critical tasks, the most suitable for the performed research

goal,

3. testing the critical tasks performance with the participation of the operators, for the researched interface,

4. analysis of the data registered during the tests performed on the simulator and drawing the conclusions,

5. eventual repeating the steps 3 and 4, for the other modified interfaces, up to achieving the acceptable results,

6. integration of such optimized interface into the real military aircraft board and next testing it in the real operation conditions.

4.1. Critical task choosing

Describing the task as critical was taken according to the standard MIL-STD-1478, where the task is critical when:

- mistake during its performance (according to the system requirements) makes negative influence on the system reliability, its effectiveness, efficiency, safety or costs,
- forcing the state, in which the system operator acts on the limit of his abilities and as a result may restrict, delay or disturb the mission performance.

The particularly important for our purpose is the above second item.

The methods of critical task or tasks choosing were adopted in the way, allowing the tasks chosen for optimization researches were the best from the interface designer point of view [5]. Because one, single method does not guarantee such a solution, the package of the three methods were adopted. They are the following:

- based on the CASE logic method,
- the authors method of critical task choosing,
- empirical method.

The process of the critical tasks choosing using the above methods is being presented in the FIG.2.

4.2. Testing of the critical tasks performance

Testing of the critical tasks performance with the purpose of optimization of the HMI for the military aircraft is in fact the determination of operator cognitive workload during the control process [4]. Optimizing tests are in their core, the ergonomics tests of that optimized interface. They base on the psychical and psychophysiological workload measurement for each interface version.

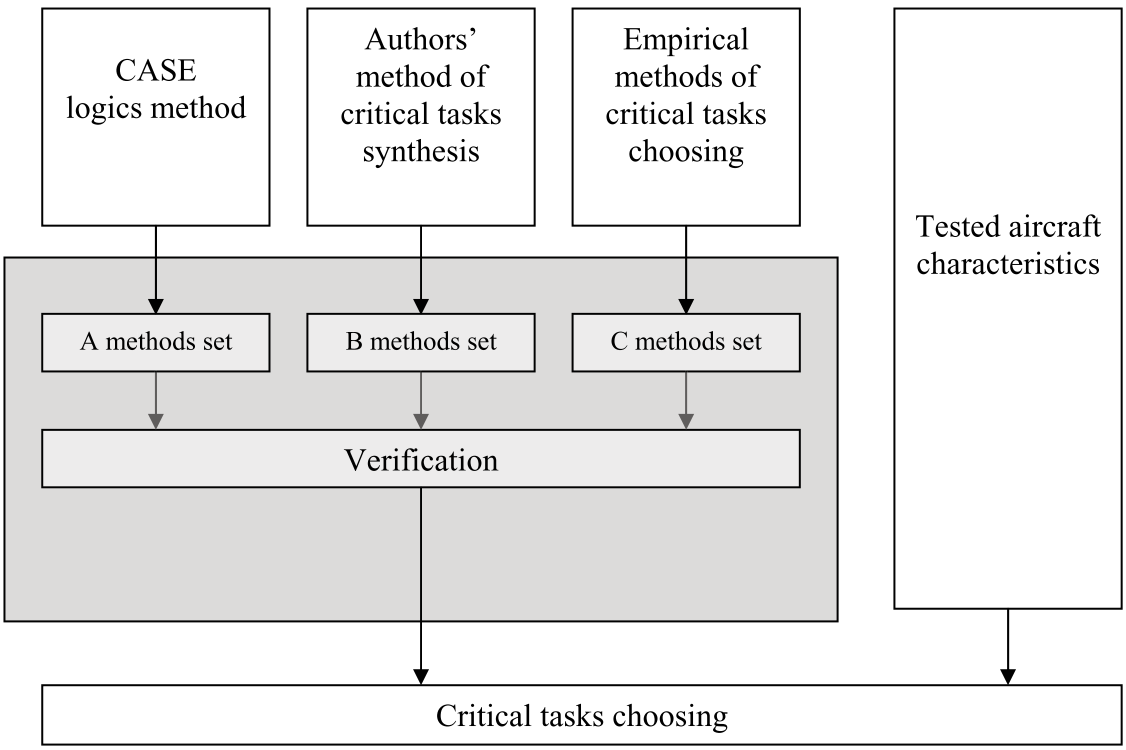

FIG.2. Choosing and verification of the critical task choosing methods

As the theoretical basis of the cognitive workload psychological analysis of the military aircraft operator, the situational awareness concept was adopted. According to the basic assumptions of that concept, the following factors have the substantial influence on the operator activity:

- perception,
- memory,
- understanding,
- foreseeing the future aviation situation (3 dimensional).

As the basic research method the parallel tasks analysis was taken. Generally speaking, one can say, that human operator has limited attention capability. In the case, when the principal task requires the extended effort, the secondary task can use only the remnant, smaller part of that capability. Then that secondary task is being performed slower, worse and in the more schematic way, because of the decreasing level of the conscious attention engaged in its performance.

The situational awareness of the military aircraft operator is influenced by the several factors. Among them the most important are the following:

- perception – conditioned by the visual attention,
- short time visual memory – where the information on location and moving of the objects in the space surrounding the simulated aircraft, is stored,
- thinking processes.

The basic research assumption is, that even at the similar level of task performance by the operator with the use of different interfaces, the better is that one which causes smaller cognitive workload. So the better interface is that one, which absorbs less capabilities engaged in the operational awareness. Then even with the similar levels of primary tasks performance, the levels of secondary tasks performance will be possibly the highest. That assumption is the basis for the performed researches, design of the research simulator and next development of the military aircraft operators interfaces optimization technology.

The final step of the interface optimization will be performed on board of the real aircraft, where some of the operator workload measurements methods used at the simulator also will be adopted.

5. SUMMARY

The research engineering flight simulator at the moment of writing that text is on the stage of final engineering, integrating and initial company testing. One can state, that assumed areas of system functionalities were achieved. In the very next time the optimization researches of the example military aircraft interface will be performed.

6. REFERENCES

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