AEROSPACE SYSTEMS FOR MONITORING AND CONTROL

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STRUCTURE AND REQUIREMENTS FOR A UNIVERSAL TRAINING DEVICE FOR UNMANNED AIRCRAFT COMPLEXES

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Abstract. The problems of personnel training for the operation of unmanned aerial vehicles have been updated. The differences between the skills and abilities of personnel for manned and unmanned aircraft are highlighted.
The widespread types of flight simulators are considered, their features are given. The basic schemes of application of linear and nonlinear mathematical models of formation (formalization) of knowledge, abilities and skills of the personnel taking into account absence / presence of updating of the information in the course of training are substantiated.
The basic modes of operation of USL, the universal simulator for training are specified. Emphasis is placed on the fact that USL is a partial case of an automated training management system (ACS), and a block diagram of training with it is given. The tasks that can be solved on a universal simulator and the requirements for software and hardware, automated workplace, digital sound, general software, peripherals, data exchange, digital video, user interface and web-based automated instructions are discussed in detail. The functions and structure of the universal simulator for training unmanned aircraft complex are presented.

Keywords: training of personnel for operation of unmanned aerial vehicles; types of aviation simulators; knowledge, skills and abilities of staff; automated control system; functions and structure of the universal simulator for learning.

Accepted terms and abbreviations

AGR - AICC Guidelines and Recommendations;
AICC - Aviation Industry CBT Committee;
ATA - Air Transport Association;
ACS - Automated control system;
AT – Aircraft Transport;
UAC - Unmanned aircraft complex;
UAV - Unmanned Aerial Vehicle ;
BITE - Built-in Test;
CBT - Computer Based Training;
CMI - Computer-Managed Instruction;
FAA - Federal Aviation Administration;
JAA - Joint Aviation Administration;
LRU - Line Replaceable Unit;
AWP - Automated workplace;
ATC- Automated training course;
ATL- Automated training lecture;
ETS - Engineering and technical staff;
IETG- Interactive Electronic Technical Guide;
TTA - Technical teaching aids;
TD – Technical documentation;
PC - Personal computer;
USL - Universal simulator for learning;
RP - Remote pilot;
GCS - Ground control station.

Introduction. The issue of training approved personnel for unmanned aerial vehicles (UAVs) is one of the factors that determine their successful practical application. It is known that the risks of aviation events due to the «human factor» are significant and their elimination during the operation of equipment on air transport is given considerable attention [1].

It is also proven that the use of technical teaching aids (TTA) to develop professional skills of specialists in various fields, including high-risk (drivers, operators of risky technological processes, etc.), can reduce training time to the desired level. In the context of civil aviation, obtaining professional skills becomes cheaper and more efficient in the presence of appropriate TTA, in particular simulators [2].

In general, the flight simulator is defined as TTA, designed for the training of flight crew in the ground in accordance with the algorithms of its activities on the aircraft, support training and flight training [3].

Currently, there are the following types of flight simulators: Flight Procedures Training Device, tactical simulators (Full Mission Simulator) and complex simulators (Full flight simulator).

Flight Procedures Training Device is designed for the crew to practice flight preparation procedures. This type of simulator is the simplest and is not designed to master piloting skills. It does not have a visualization system and is not equipped with physical models of controls; they are simulated using touch monitors (except in some cases).

Tactical simulators (Full mission simulator) are designed to practice group combat missions of a military nature. They combine disparate simulators - aviation, tank, artillery, etc. and are integrated into a single network using the HLA interface, which is performed according to the standard for distributed simulation, used in the construction of simulations for large purposes by combining several simulations.

It should be noted that complex flight simulators are also equipped with mobility systems, visualization devices, etc. This type of simulator includes complex simulators (Full flight simulator). They are designed to ensure the training of crews in the full scope of their functional responsibilities for the flight operation of a specific type of aircraft [4].

Formulation of the problem. Despite the in-depth elaboration by developers and educational organizations on the subject of training and the simulator itself, it should be noted that this statement fully applies to manned aircraft, or to the so-called man-machine systems in which a person is directly on board the vehicle. In the case of unmanned systems, namely unmanned aircraft or helicopters and their complexes, the development and construction of the simulator should be considered from another angle, namely, from the standpoint of the absence of a person on board, which creates a number of problems in training qualified aviation personnel.

The first problem is that UAV piloting is associated with a lack of physical communication between the pilot and the object, as is the case in the pilot system, which eliminates the use of the vestibular apparatus and other components of the pilot sensations, including vibration, temperature factor, odors, etc. The only thing left for a person to «arm» is the visual and auditory communication with the object. Therefore, from a psychological point of view, the flight occurs qualitatively when the pilot first simulates each action in the imagination, and then influencing the control lever, forcing the UAV to perform operations.

The second problem is that stereotypically UAV are perceived as something remote, not real. The real belief that this is not the case, at least in terms of piloting, comes after the first loss of a valuable product.

The third problem is the level of psychological readiness of the future remote pilot (RP) for such activities. Practical experience shows that not all applicants are fully aware of the complexity of future work, especially in terms of psychological stress on them and therefore, without realizing it, may experience significant difficulties up to stress [5].

The fourth problem is the team work of the UAV remote crew to obtain the final result, namely the performance of the flight task, with clearly regulated responsibilities of each member.

In this case, the RP (crew commander) must perform important work on the organization of crew members for quality and timely performance of the task.

Problem solving. It is known that the universal UAV simulator can solve the following tasks:

– selection of the area of location of the complex with UAV and topogeodesic binding of the GCS to the area;

– flight planning and automated development of UAV flight programs;

– monitoring the efficiency of GCS and UAV equipment with modeling of possible failures and abnormal situations;

– interaction with procedural simulators of UAV control of different types (short-range, short and medium range);

– processing of information received from the UAV;

– reception and preliminary processing of species information;

– coordinate binding of the obtained species information to digital cartographic information;

– decryption of images with the selection of areas of interest in the image;

– detection and recognition of single and group objects;

– interaction with the client as well as the formation of reporting documents, etc.

Linear and nonlinear mathematical models that reflect both outdated and constantly updated training materials can serve as a theoretical basis for the development of algorithms for constructing CNT installations. An example of a linear model that can be used to solve problems of formation of knowledge, skills and abilities of the crew (without taking into account the speed of their update) is given in Fig.1.

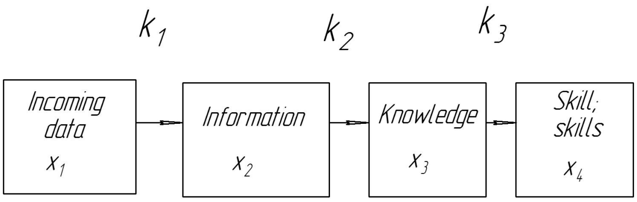

Fig. 1. Scheme of formation of knowledge, skill and skills without access to external sources (training materials are not updated)

In General, the formation process is described by the following system of equations:

$$\frac{(dx_1)}{dt} = -k_1 x_1$$

$$\frac{(dx_2)}{dt} = k_1 x_1 - k_2 x_2$$

$$\frac{(dx_3)}{dt} = k_2 x_2 - k_3 x_3$$

$$\frac{(dx_4)}{dt} = k_3 x_3$$

where x1, x2, x3, x4 – appropriate amounts of data, information, knowledge and skills. The values of k1, k2 and k3 mean the rate of formation of indicators at a certain stage. When using nonlinear models, two-way interactions between components can be taken into account x1, x2, x3, x4. Systems of equations for nonlinear models can be solved using the Lotki or Volterra methods [6].

Since the simulator, which is essentially a learning ACS, it must work in the modes of theoretical and educational learning, as well as in the mode of training.

The mode of theoretical training provides for the acquisition of knowledge by studying the educational material by cadets, prepared by the teacher, with the control of the degree of mastering the material. The training material can be in text, graphic, audio or video format. The degree of detail is determined taking into account the time allocated for training and the level of preparation of the cadet with the possibility of adjusting the curriculum, depending on the results of knowledge control. The results of knowledge control are displayed on the screen of the cadet monitor and the supervisor, as well as on the documentation device.

Initial training mode and learning mode. In these modes, the formation of skills is provided by step-by-step testing of operations.

At the same time, they show the correct execution of operations, instruct on the necessary actions, give hints and warning signals in case of incorrect actions. The degree of complexity of the completed tasks is determined taking into account the time allocated for training and the level of training of the distance pilot with the possibility of adjusting the training plan depending on the results of control of his knowledge. In the mode of direct training the skills of independent solution of problems on practical application of UAC are instilled.

Training mode. In this mode the consolidation of skills of the independent decision of problems of the cadet on practical application of a complex of UAV is provided. All operations are performed by members of the remote crew without prompts and warning signals. The control results are also displayed on the screen of the cadet monitor and the trainer monitor, as well as on the documentation device [7].

The educational ACS as a whole should ensure the implementation of the required high-quality training program in a timely manner, at the request of the customer. In the process of acquiring knowledge and developing skills and abilities, appropriate control is carried out and, if necessary, correction (impact) on the cadet in order to emphasize the shortcomings and make recommendations for their elimination. A diagram of the process of organizing training for specialists using training ACS is shown in Figure 2.

As can be seen from the diagram, the training ACS should provide the learning process by performing training planning functions with appropriate methodological support and control function. Also, this scheme demonstrates the main advantage of the training ACS - a significant intensification of the educational process over the usual learning process; in a single circuit are the results of control and corrective action. In addition, it is also known that the use of simulators reduces the risks of the so-called human factor at the stage of crew training.

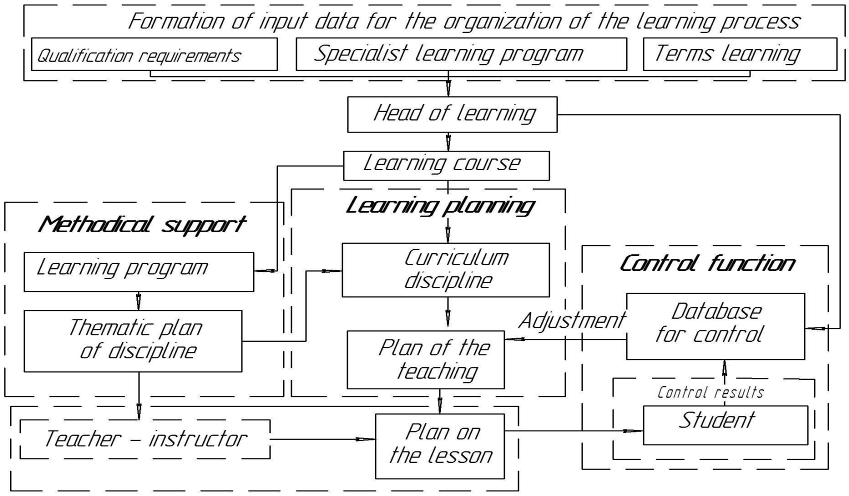

Fig. 2. Block diagram of training with the help of training ACS

Formation of partial technical and software requirements for USL. Since the USL must provide training for certified and approved by the aviation authorities specialists, its hardware and software in general and in detail must meet the requirements applicable in modern civil aviation for training systems. In particular, it is necessary to ensure compliance with the requirements for:

– software and hardware;
– automated workplaces;
– digital audio equipment;
– general software;
– peripheral devices;
– data exchange;
– digital video;
– user interface;
– web-based automated instructions.

These requirements are formed taking into account the regulatory, operational, technical and reference documentation and recommendations of the International Committee on Aviation Computer Training (AICC) [8].

In particular, the automated workplace (AWP) should consist of a personal computer, monitor, operating system and peripherals; requirements for workstation hardware are set out in document «AGR002» from AICC. The document contains recommendations for the selection of workstations for training in the aviation industry. Recommendations guide the operator (developer) of the simulator on the choice:

– processor the automated workplace;
– clock frequency;
– tires;
– power supply parameters;
– operating system;
– random access memory (RAM);
– CD-ROM;
– graphics adapter;
– monitor;
– manipulator (mouse);
– keyboards;
– digital sound system;
– network devices.

For digital audio and video adapters, recommendations are given in documents «AGR003» and «AGR008», respectively. Additionally, audio materials are regulated by documents «AUD001-A», «AUD002» and «AUD003». Particular attention is paid to the ability of educational software that has audio data to play on different PCs with different sound cards.

Requirements for general software (operating system, network software) are set out in document «AGR 004». It provides recommendations for the operating system of automated training courses for the aviation industry, the results of the analysis of the main operating systems recommended for use by the organization AISS.

Requirements for peripherals are set out in document «AGR 005», which provides recommendations for interoperability of video cards, solid state drives and input devices.

Requirements for data exchange are set out in the document «AGR 007», which contains recommendations for text, graphics, animation, sound, logic and format elements of automated training courses.

The user interface is regulated in the document «AGR 009», which presents the functional requirements for the user interface and its graphical visualization.

Web-oriented automated instructions are considered in the work of Nuriev and others and should be built on a spiral principle [9].

In addition, the requirements for web-based materials are regulated by the AISS document «AGR 010».

Universal simulator for learning functions. USL computing equipment must ensure the performance of the following tasks:

– automated planning of the educational process by the instructor, including calendar planning and formation of individual training sessions for each cadet;

– group training;

– management of interactive group process of training of engineering and technical personnel (remote pilots);

– conducting group classes using a multimedia projection system;

– individual training;

– individual theoretical training of each cadet;

– automated remote control by the instructor of actions of cadets in the current training session;

– automated multilevel test control of cadets' knowledge;

– automated analysis of learning outcomes (statistics) for the purpose decision support by a training instructor process, taking into account the individual characteristics of different categories cadets and the dynamics of their learning process;

– formation and maintenance of a database of students containing a complete information on the learning history of each registered USL user;

– output of educational and service material on the printing device.

Structurally universal training simulator is a set of software and hardware based on a local computing environment (PC), which operates in the system «client-server». It should include:

– hardware;

– general software;

– special software;

– set of documentation.

The hardware of the universal training simulator should include:

– automated workplace of the instructor (on the basis of the personal computer);

– automated operator's workplace (based on PC);

– local area network with cluster organization;

– demonstration equipment (multimedia projector and screen);

– auxiliary equipment (cables, etc.);

– server.

The automated workplace of the instructor should provide:

– registration of cadets and delimitation of access to USL;

– configuration of networked specialized automated initial courses (ANC) for the current training session;

– management of ANC operating modes;

– remote control over the actions of cadets in the current session;

– transmission over the network of circular and selective directives by the cadet;

– reception on a network of signals of a call of the instructor;

– management of video projection complex;

– interactive access to the database server;

– documenting information about the course and results of training;

– management of USL network resources;

– access to electronic operating documentation.

The cadet's automated workplace must provide:

– registration of the cadet for the current session;

– functioning in the modes of training and control of knowledge in accordance with the requirements of the USL scenarios;

– reception on a network of directives of the instructor who teaches;

– transmission of the instructor's call signal over the network;

– automatic configuration of ANC by instructor commands;

– exchange of information with the database server;

– display of learning outcomes in the current session;

– access to electronic operational and regulatory documentation. [10].

The general software is configured as follows (example):

– operating system for the operator's workstation (Windows 10 Professional);

– office software package (Office Professional 2019).

Special software must meet the following requirements:

– hierarchical principle of construction;

– navigation in the documentation on the hierarchical tree;

– hypertext implementation of links available in the source documentation;

– the ability to quickly search for information by keywords;

– the ability to view individual elements of documentation;

– support for interactive drawing elements.

In general, the program should consist of the following modules:

– electronic version of TD and regulatory documentation with a software shell for searching and presenting information;

– software module of the instructor;

– software module for cadets;

– modules of management of processes of registration, training and control of knowledge;

– module of operative changes in the software complex and printing of documents from the complex.

Modes and logic of the software package. The main menu of the program should have the following modes of operation: «Specialization», «TD», «Test», «Instructor» and «Parameters».

«Specialization» mode - contains procedures for entering user data (registration) and statistics of his training (each user has access only to his personal statistics); review of materials related to the procedure of UAC and its systems, technology of maintenance of UAC, its systems and units (depending on the declared specialization) by means of multimedia means.

«TD» mode is a database containing operational, technical and regulatory documentation.

The «Test» mode is the most complex, and is designed to control the knowledge of aviation personnel when passing tests and exams. The control questions of the examination ticket are formed by the random number generator. It must be possible to answer the questions in any order with a preview of the contents of the entire ticket. The user is asked to choose the correct answer from several options, or follow the sequence in the right order. The time set individually for each question limits the duration of the answers. During testing, it is possible at any time to interrupt the work on the program and get the results of the control task, which can be viewed, printed and written to the database.

«Instructor» mode. It should be available only to those who are included in the list of instructors or examiners. In this mode, USL allows:

– provide access to statistics of other users (cadets);

– organize group classes;

– arrange abnormal situations in the training process for users in accordance with their specialty and qualifications;

– to analyze the actions of cadets, to carry out current control of mastering the programs and passing the established tests and exams.

«Parametrs» mode – available only to the system administrator and protected from other users. It should allow to implement:

– program settings according to hardware;

– updating the program and information base;

– connection of additional modules;

– making changes and additions.

Conclusions

In the context of civil aviation, obtaining professional skills becomes cheaper and more efficient provided that appropriate simulators are available.

Aviation simulator is defined as technical teaching aids, designed for professional training of flight crew in the ground in accordance with the algorithms of its activities on the aircraft, support and training, flight training and training; accordingly, he must work in the modes of theoretical and learning, as well as in the mode of practical training.

Theoretical basis for the development of algorithms for building the architecture of a universal training simulator can be linear and nonlinear mathematical models that reflect both outdated (non-renewable) and constantly updated training materials.

From a practical point of view, there are procedural simulators (Flight Procedures Training Device), tactical simulators (Full Mission Simulator) and complex simulators (Full flight simulator). The developed USL can be attributed to complex simulators (Full flight simulator) without the use of mobility system but with the preservation of all other functions to ensure the training of remote crew and engineering and technical personnel of UAC.

A universal training simulator should be a set of software and hardware based on a local computing environment that operates in a «client-server» architecture. Structurally, the USL should include hardware, general software, special software and a set of relevant operating documentation.

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Структура та вимоги до універсального навчального тренажера для безпілотних авіаційних комплексів

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Актуалізовано проблеми підготовки персоналу для експлуатації безпілотних авіаційних комплексів. Виокремлено відмінності між вміннями та навичками персоналу для пілотованих та безпілотних повітряних суден. Розглянуто розповсюджені типи авіаційних тренажерів, подано їх особливості. Обгрунтовані основні схеми застосування лінійних та нелінійних математичних моделей формування (формалізації) знань, вмінь та навичок персоналу з врахуванням відсутності/присутності поновлення інформації у процесі навчання. Вказані головні режими роботи УНТ - універсального начального тренажера. Акцентована увага на тому, що УНТ є частковим випадком навчальної автоматизованої системи управління (АСУ) та подана блок – схема підготовки фахівців за її допомогою. Детально розглядаються завдання, що можуть вирішуватися на універсальному тренажері та вимоги щодо програмно-апаратних засобів, автоматизованих робочих місць, цифрового звуку, загального програмного забезпечення, периферійних пристроїв, обміну даними, цифрового відео, інтерфейсу користувача та веб орієнтованих автоматизованих інструкцій. Подано функції та структуру універсального начального тренажера для безпілотних авіаційних комплексів.

Ключові слова: *підготовка персоналу для експлуатації безпілотних авіаційних комплексів; типи авіаційних тренажерів; знання, вміння та навички персоналу; автоматизована система управління; функції та структуру універсального начального тренажера.*

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Структура и требования к универсальному учебному тренажеру для беспилотных авиационных комплексов

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Актуализированы проблемы подготовки персонала для эксплуатации беспилотных авиационных комплексов. Выделены различия между умениями и навыками персонала для пилотируемых и беспилотных воздушных судов. Рассмотрены распространенные типы авиационных тренажеров и приведены их особенности. Обоснованы основные схемы применения линейных и нелинейных математических моделей формирования (формализации) знаний, умений и навыков персонала с учетом отсутствия / присутствия обновления информации в процессе обучения. Указанные главные режимы работы УУТ - универсального учебного тренажера. Акцентировано внимание на том, что УУТ является частным случаем учебной автоматизированной системы управления (АСУ) и представлена блок - схема подготовки специалистов с ее помощью. Подробно рассматриваются задачи, которые могут решаться на универсальном тренажере и требования по программно-аппаратных средствах, автоматизированных рабочих мест, цифрового звука, общего программного обеспечения, периферийных устройств, обмена данными, цифрового видео, интерфейса и веб ориентированных автоматизированных инструкций. Подано функции и структуру универсального учебного тренажера для беспилотных авиационных комплексов.

Ключевые слова: *подготовка персонала для эксплуатации беспилотных авиационных комплексов; типы авиационных тренажеров; знания, умения и навыки персонала; автоматизированная система управления; функции и структуру универсального учебного тренажера.*

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