The study of the aircraft functional appearance design

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Abstract. The paper investigated the technical specification as the main document describing the major functions performed by the aircraft. The functional appearance of the on-board equipment complex is revealed in the first approximation. A range of tasks related only to solving problems of navigation and aircraft control is highlighted. The possibility of decomposition of functions depending on their degree of complexity is presented. The process of selecting existing systems to perform the required functions is investigated. The possibility of automating the process of designing a functional appearance based on existing systems is described. The system selection process has been formalized to enable the use of computer-aided design systems in order to shorten the design of the functional appearance of the upper level and minimize the functional inadequacy or redundancy of the complex.

1. Introduction
The development of a new aircraft (AC) is a complex and long process. The main two tasks in the development of a new aircraft are the development of functional and technical requirements for the fuselage and on-board equipment (OBE). The main document containing all these requirements is the technical task (TT) or tactical and technical task (TTT). In turn, the requirements contained in the TT are also limited by the clear requirements contained in the aviation regulations [1] and supply contracts [2].

On the basis of these requirements, technical requirements (TR) for the OBE, the aircraft body and the power plant are formed. There are requirements for the OBE on the structure of the complex, interfaces and additional functionality. Functionality is the capabilities of the aircraft, which can be provided by software and hardware, for example, functions: autopilot, takeoff, landing, display, alarm, etc.

Along with the requirements for the functional and constructive avionic, a key factor for suppliers is the use of commercially available components, which greatly reduces the cost of the product and the development time of the complex.

Summarizing the requirements for the OBE, we can distinguish two main tasks that are priorities for any avionics complex. These are the tasks of navigation. These tasks can be implemented by a set of various functions. Exploring as an example, the CID-80 system of the C-80 aircraft [3] can be distinguished by a clear separation according to the functionality aimed at solving two main tasks:
- performance of flight control and autopilot functions in accordance with a given route;
- control of radio systems;
- providing the crew with all the necessary information during the flight;
- control of technical serviceability of avionics.

However, when developing a complex from the very beginning, there is no clear idea about the division or combination of functions in one device. Functional description requires to rely on the TT requirements. As practice shows, the initial TT is poorly formalized and represents the primary appearance of the object. It causes the problem of decomposing upper volume functions into simpler ones.

2. Function decomposition
Decomposition of the primary functions imposed on the OBE in accordance with the TT is a complex process. The most common approach for solving such problems is a systematic approach. The purpose of applying a systematic approach to the decomposition of functions is to achieve such a complexity of a function that can be provided with existing equipment or development work on the development of new necessary equipment in a reasonable time and resources.

Therefore, the process of decomposition of functions is abstract and its result is very much dependent on the developer. Still, the key points that bring clarity to this process are the condition that there are complexes, systems, subsystems, and separate equipment that has already been developed and performs specific functions. This makes it possible to use the principle of mixed design [4]. As a result, when setting the task of developing a new complex that fulfils the requirements described in the TTT, we obtain a functional-constructive model of the complex (FCMC). An example of such FCMC is shown in figure 1.

Figure 1. Functional constructive complex model.
As it can be seen from figure 1, the fundamental point is the availability of ready-made systems and devices, “Of the shelf”. At its core, the design of OBE look is a synthesis of avionics, i.e. it is the process of combining elements in various variations. When performing a synthesis task, the most common methods belong to the combinatorial-logical class [5]. But the key point in the application of such methods is a clear limitation of the object's TTT requirements. Taking into account the large variety of existing ready-made solutions, it will be limited only to the criterion in terms of functionality. Hence it causes the task of describing the requirements for the list of criteria [6] according to which systems are selected. These criteria can be:

- weight;
- dimensions;
- lifetime;
- reliability;
- power usage;
- maintenance cost, etc.

The list of requirements can be very wide, and the set of these criteria may vary among different systems. It is necessary to limit the number of criteria by which the selection of systems will be made.

To select the most important of them, one can use the approach of expert assessments so that all non-essential criteria do not participate in the system selection process. The most suitable for solving this problem is the scoring method, described in detail in [7].

The essence of this method is to evaluate each criterion on a certain scale, for example, the most important criterion has a weighting factor of 100, and less important one has just 40. So one need to set the weight for each criterion. Then the formula for calculating the weight (importance) of the system is applied. Thus, the process of selecting the optimal systems existing in the avionics market is ensured.

3. Construction of the primary appearance of the complex

Based on the above, the task of designing the primary appearance of the aircraft OBE arises on the basis of the requirements presented in the TT and the use of ready-made solutions. Combining these tasks, a functional-systems approach (FSA) is proposed. The main feature of this approach is the possibility of designing the top level of the OBE. In addition to providing a solution to the main problem, the FSA makes it possible to identify subfunctions formed by the proposed set of systems.

In the next stages of the complex design, this will allow to make optimization of the OBE composition. The purpose of optimization is the elimination of unclaimed functions, as well as the definition of requirements for new systems that implement the missing functionality.

The selection of such a clear boundary between the functionality and the system allows for the integration of non-complex additional functions on the hardware of the equipment used.

Current trends in avionics are aimed at striving to make the OBE multifunctional. The implementation of such an idea is the concept of integrated modular avionics (IMA). This concept is based on component redundancy, exceeding the minimum required composition, due to the requirements of the complex [8].

Since the use of such an approach requires the processing of a significant amount of data, the use of computers significantly improves the overall performance of this approach, and reduces the design time. Thus, it is advisable to create a computer-aided design (CAD) system that allows processing a large flow of data at high speeds and providing the OBE developer with the desired result.

4. CAD usage

For the implementation of the FSA, CAD tools require detailed formalization of the entire design process and the creation of a library of objects with which the CAD system will operate.

CAD is a complex technical system (TS). When designing a vehicle, one of two key tasks is solved [9]. Based on the above, we will focus on the task in which we need to define a mathematical model, which is a transition function, using the well-known information vector and output vector. Formalizing
the FSP, here the input and output sources of information are the functions of the OBE and systems, and the transition function is a structure designed by a computer.

At its core, designing a structure is a process. Nowadays, in practice, the IDEF0 model is often used to describe processes. Each block of the IDEF0 model expresses a process, as a function or set of functions, that performs Outputs from a set of Inputs using the specified mechanisms. The outputs of some functions become Inputs for others. This concept is called “Process Functions”, and it is a convenient basis for describing the elements of the development process [10].

Creating a library of objects requires a high structuring of object criteria and methods for their storage, use and updating.

5. Conclusion
When developing new avionics complexes, a huge amount of resources is spent. To minimize these costs, the principle of studying the shortcomings of the old facility and introducing technological innovations to eliminate them in the new facility is most widely applied.

Taking into account many options for the implementation of the functional decomposition of the AC complex functions, and the large market for avionics equipment we shall get a difficult task of designing OBE functional instrument cluster. The proposed FSA applied in CAD allows to speed up the process significantly, as well to meet the requirements of the TT and the customer as more accurately and fully.

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