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Investigation of the automation level of designing the software and hardware structure of the on-board equipment integrated modular avionics

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Abstract. This article shows the complexity of the integrated modular avionics design of on-board equipment of large aircraft. A modern image of the integrated modular avionics of on-board equipment is presented on the basis of existing samples. The design process of the software and hardware of the integrated modular avionics of on-board equipment is analysed. The main tasks of its design are listed. The existing and currently used methods for solving design problems of integrated modular avionics of on-board equipment are described. The level of the design automation process is reviewed. Modern means of computer-aided design are presented and their comparative analysis is carried out. An assessment of the existing level of design automation is given. The design stage with the lowest level of automation is defined. Appropriate conclusions are given.

1. Introduction
Large aircraft (LA) have a number of distinctive features in comparison with small classes of aircraft (AC) [1]. This article discusses the complexity of the on-board equipment (OBE) of only large aircraft.

In early AC models, the flight process was controlled by mechanical feedbacks. Later, analogue electronics was developed and a prototype of modern on-board equipment appeared. With the further development of digital technology, avionics has changed again. The result was a decrease in size and weight, reduced energy consumption. Designing digital systems in practice has proven to be a very difficult task. Later a new approach was developed. It was called integrated modular avionics (IMA). According to this approach, numerous individual system processors are replaced by centralized ones, which leads to even greater space savings. The advantage of the IMA is also the principle of open architecture, which greatly simplifies the modernization. The first implementation of this approach was applied on the Airbus A380, Airbus A350 and Boeing 787 [2].

2. IMA OBE design
The basis for the development of the IMA was the ARINC 653 standard. At present, the application of the AFDX (Avionics Full Duplex Ethernet) standard [3] is considered a promising development. For the IMA approach, it was necessary to replace the wired data transmission medium of linear system units (LSU) with virtual connections of the modules inside the central computer. To do so, it was...
necessary to apply AFDX, which was developed by Airbus. The conditional transition from the federated architecture to the IMA is shown in figure 1.

![Transition from federated architecture to IMA.](image)

**Figure 1.** Transition from federated architecture to IMA.

The design of the OBE IMA is difficult because of the need to integrate it with the federated architecture. This is a natural transition process that is impossible to get rid of. As a result, confusion arises, since the IMA can be executed within the subsystem, system, platform. Having considered the architecture of the Airbus A380 and Boeing 787 one can immediately notice the difference. Boeing 787 is a prominent representative of the transition from federated architecture to IMA. It inherits the reception of independent primary data preprocessing. This processing is implemented in the computer hub. In the Airbus A380 IMA, the functions of the primary information processing from sensors into a separate computer are not carried out. An illustrative example of the differences in the architecture of these aircraft is shown in figure 2.

Now it is impossible to completely get rid of autonomous systems. There are a number of well-established complex systems that currently meet functional and design requirements.

The greatest number of difficulties occurs at the final stages of the complex design. It is required to integrate all developed software and hardware components into a single whole. This process is extremely complicated. Integration tasks can be solved using verification and modelling technologies. It is possible to develop computer-aided design tools on their basis.

In its general understanding, an IMA is a set of common hardware and software resources designed to perform certain functions.

![Airbus A380 and Boeing 787 OBE architecture.](image)

**Figure 2.** Airbus A380 and Boeing 787 OBE architecture.
To facilitate the design of the IMA complexes, universal hardware platforms have been developed that provide the ability to create shared computing resources for the software of the complex. The distribution of software applications (SA) by the total computing resources of the platform is the most important design stage. It causes many difficulties and one of the most important is the choice of the data network topology. Key distribution factors are the requirements for reliability and latency of message transmission between recipients and senders. To meet these requirements, AFDX and CAN (Controller area network) switching technologies are most often chosen. AFDX was applied on the abovementioned aircraft. This technology is based on ARINC 664 and has the second name “Part 7 in ARINC 664”. It surpasses most of the previously used switching technologies, including MIL-STD-1553 and most of the ARINC standards.

The main tasks arising in the design of OBE:
- check of the OBE for compliance with the stated requirements;
- verification of individual components of the OBE;
- determining the availability of computing resources to all software providers;
- ensuring consistency between software and hardware.

When performing these tasks, a hierarchical representation of the complex is used. This allows to solve these problems in stages and analyse the response of the complex when making changes. Traditionally, text description of requirements was used, but on the scale of modern aircraft this is impossible. The current architecture of the IMA complex makes it possible to impose requirements on systems and their components, as well as to analyse and verify them. Architectural models (AM) are used to analyse the communication of system components, making it possible to use CAD tools. AM analysis can be performed at any design stage and at any level of abstraction.

3. Engineering support tools for the IMA OBE

To describe the functions of high-level systems, the most appropriate language for designing and analysing architecture is AADL (Architecture Analysis and Design Language) [4]. This language allows to simulate real-time systems. There are several approaches for describing AM. The most commonly used description is in the AADL, but along with it the UML (Unified Modelling Language), in the form of MARTE [5] and SysML profiles is used. Both of these languages are suitable for describing software and hardware models of the OBE.

However, the description of AM by means of AADL makes it possible to automate the following main tasks [6]:
- group analysis of models;
- synthesis of models;
- editing of models.

The purpose of group analysis of models is to identify new properties that were not shown on individual models. For example, signal delays can be detected only by assembling models into the system. As a result of the synthesis of models, one can see the distribution of PP by hardware resources.

For automated execution of these tasks, toolkits for supporting the design of the IMA have been developed. The advantage of such CAD systems is that in the process of modelling it is possible change the system configuration at the software level. It is possible to transform the system on the same IMA platform flexibly. Currently, there are several such CAD systems. The most famous of them [7-10] are as follows: OSATE, Ocarina, STOOD / AADL Inspector, Adele, ASCCS, Capella, MASIW (Russian design).

These CAD systems have a convenient development environment in text and graphic presentation. The most important task, which not all the listed CAD systems can solve, but only MASIW, Ocarina and STOOD/AADL Inspector, is the generation of the allocation of CPU time between applications. This allows to assess the adequacy of hardware to work with PP.
4. Conclusion
As a result of the study, it was found out that the level of automation in designing the structure of software and hardware is not sufficient. Existing CAD systems allow to calculate a number of key parameters of the developed structure. But at the same time the development of the structure is done manually. From the point of view of automation, such a process is not an automated structure development process.

To automate the process of designing software and hardware, it is necessary to implement the process of finding its optimal configuration option using CAD tools.

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