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Use of real-time operating systems in the integrated modular avionics

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Abstract

The foreign real-time operating systems were widely used for the last years in Russia-developed aircraft as well as in the Russian Integrated Modular Avionics (IMA) research projects. But presently the question of their substitution with Russian analogues has arisen. This article provides the requirements of the operating system should satisfy in order to be used in the civil aviation, the analysis of existing foreign and domestic RTOS and some aspects of the operating system development process.

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1. Introduction

Currently one of the high-priority directions for the aviation industry development in Russian Federation is the development of the advanced airborne equipment. Suffice it to say that the percentage of the avionics systems development costs in the total cost of aircraft development can rich 35-40% for civil airplanes and more than 50% for the military projects[1].

Formerly the so-called federative architecture used to be the basic concept of the airborne equipment development. It was not flawless (especially in the integration and certification aspects); to overcome these shortcomings, the alternative concept was contrived. It was designated as "Integrated Modular Avionics" or simply "IMA"[2,3]. It has the following distinctive features:

- Open network architecture, based on the wide usage of standardized and commonly accepted technical solutions and designs.

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• Unified computing board, embodied as the basic construction (cabinet) with a set of the removable electronic modules (central processor modules, memory modules, network switchboard modules).
• Multifunctional computing system, which means that several user applications (including those with different criticality levels) can be run on the same hardware platform, thus providing the functioning of diverse airborne equipment.

The last item causes two consequences:

• Firstly, the division of hardware and software takes place; it becomes possible to use the functional applications with minor modifications in the projects that feature different hardware platforms.
• Secondly, the real-time operating system (RTOS) obtains the prominent place, because it should provide predictability, safety and workability of several functional applications at once.

Internationally the IMA concept was being developed and widely used in the new aircraft since 1990s. The avionics for Airbus A380, Boeing 787, Sukhoi Superjet and some currently in-development aircraft employ the concept of the first-generation IMA. There are several international projects in EU aimed at the advancement of the second-generation IMA (SCARLETT and ASHLEY), in which some dozens of companies all over the Europe are engaged (including GosNIIAS).

These companies have developed several hardware platforms with the basic software; unfortunately too little attention was given to the RTOS development, because one of the already existing systems was supposed to be used. The experience has shown that it's not always possible or appropriate; besides, the conducted IMA research allows us to formulate the principal requirements to such systems and emphasize some aspects of its development.

2. Some requirements for the perspective real-time operating system

The requirements that should be met by the RTOS used in the civil avionics field are listed below:

1) Portability amongst several hardware platforms; it is vital to stick to the policy of reducing the number of architecture - and platform-specific code while designing the RTOS kernel; the software architect should always keep in mind that it might be necessary to modify or completely replace this specific code when transferring the OS to another platform.
2) ARINC 653[4] (API for the avionics' functional applications) support, including:
   a) Part 1 (standard services).
   b) Part 2 (extended services); in particular, file system services and ARINC 429 and ARINC 664 integration.
   c) Part 4 (subset services).
3) Support for the widespread avionics interfaces like ARINC 429, AFDX (ARINC 664), CAN, MIL-STD-1553.
4) Advanced tools: Integrated Development Environment (IDE) with debug and verification tools; the possibility to use the simulator (e.g. open-source QEMU project).
5) Transparent RTOS adaptation to a specific hardware platform (availability of infrastructure required to develop a board support package and drivers).
6) Support of graphical programming interfaces (OpenGL SC/ES and ARINC 661 standards).
7) High performance (compared to the modern foreign RTOS').
8) Safety standards compliance.
9) Multi-core CPUs support.
10) The Possibility of certification according to DO-178C5, including:
   a) High-level requirements development.
   b) Development of low-level specifications', that should be traceable to the high-level requirements.
   c) Documentation development for the software components.
   d) Development of certification kits' for the RTOS and also for the network stack, drivers, the graphical components and the file system.
   e) Software components verification (including formal methods).

Certification support is a key requirement because it affects not only the final product but also the entire life cycle. Certification requires correct development processes, the use of qualified tools, interaction with certification bodies; it also has a significant impact on the conduct of the processes of modernization and refinement of the RTOS.

When the RTOS is created it is necessary to consider prospects of development of the concept of IMA, in particular, make the ground for the network RTOS, enabling the sharing and interaction of several modules, the use of distributed file systems, etc.

3. Some aspects of the RTOS design and development processes

The Russian RTOS development is a complex task. Previously we have listed the principal technical requirements for such system, including the necessity of its certification according to DO-178C. At the moment there are very few totally domestic DO-178 certified projects (including DO-178B); one of the successful examples is a remote data concentrator EIU-100 produced by UIMDB JSC (Ulyanovsk), that was successfully certified together with the SSJ-100 aircraft.

The little number of the certified projects can be partly explained by the fact that trying to comply even to the previous version of this standard (DO-178B) results in a massive increase of development costs [8]. Coupled with a minor capacity of the civil avionics market in Russia, it leads to the reluctance of the developers to invest to the certification processes. One of the possible solutions here would be the state financial support for the development of the most critical software.

Absence of the established DO-178 processes in Russia implies that before the RTOS development begins we have to carry out an excessive preparatory work: organize one or several groups of developers, define the regulations for the project, pick (or develop from scratch) the necessary qualified tools. The regulations should specify the kind of artifacts the developers should amass in the course of RTOS development. This experience might be priceless for the functional application projects in the future; one might say that the RTOS development might pave the road for the appropriate development culture and the certification in the international bodies.

The second important question that should be tackled as soon as possible – is a licensing policy of the end product. It seems appropriate for the advancement of the aviation industry (and possibly some other fields) to make the crucial parts of RTOS together with the certification documents available at least for the aviation companies and their subcontractors.

Let's make a brief overview of some RTOS development aspects for the civil aircraft.

1) The development of the RTOS concept and architecture RTOS should become one of the main tasks at the early stages of its development. Special attention should be paid to the multicore problem as well as the support of multiple hardware platforms. The ideas should be widely discussed by the industry. It seems undesirable to set this task to the single company that already might have its own solutions, so the role of the independent company that coordinates several developers becomes vital.
2) Special attention in developing the hardware-independent RTOS should be paid to the concept of unified components that would allow the modularity and continuous use of technologies. It might also lead to the significant cost reduction for developing and modernization of the on-board equipment. This concept would ease the development and renewal of functional IMA applications. The example of this concept is the FACE program (Future Airborne Capability Environment)[9] of FACE Consortium, that pursues the development of open standard for the avionics components.
3) It's necessary to conduct a close examination of the RTOS available at the global market. Despite them being widespread in avionics, they are not flawless, which is often caused by some peculiarities of their development. These flaws should be taken in account for the new RTOS design and development.
4) Developing the new technology it's important to conduct a study and analysis on perspective technologies such as formal methods, formal verification and modeling, integration tools that comply to the DO-297. Some companies already work on these tasks in the scope of the Russian IMA program. E.g. ISP RAS (Moscow) works on the software verification problems and it also develops the Integrated development environment (IDE) for the avionics design and integration stages (named MASIW) [10]
5) It's necessary to interact with companies that have already worked on the certifiable RTOS. The information from this interaction should be summarized and systematized, and the recommendations for reducing risks connected to the creation of the new software product should be elaborated.
6) The perspective Russian RTOS is supposed to have a long support and operation period, so it's important to conduct a research on the upcoming hardware boards that might be used for the RTOS.
7) The process of making the RTOS should be interconnected with a technological environment development, including tools for the software development and lifecycle support (i.e. system engineering tools).
8) Based on the market requirements analysis the concept of the end product is supposed to be developed. It should answer the several questions, including its commercial viability, lifecycle duration and its competitiveness. It's also important to define the form of the end product (single product or a line of products) and whether the RTOS

will be present at the markets outside the avionics – e.g. space, nuclear energy, railroads, automotive, medicine, automated control systems, communication etc).

4. Conclusion

The real-time operating system is one of the key components of the on-board equipment that complies the IMA concept. The RTOS is very important for the applications to function and interact with each other in a determinate, safe and secure way; moreover, the RTOS are likely to become even more prominent in the upcoming years due to the constant growth of the computing power of the avionics hardware.

It's possible for the new Russian on-board equipment to be based on the foreign RTOS, as it was previously. But based on the experience we can now conclude that it's not always advisable and acceptable. On the other hand, the current Russian RTOS's do not satisfy the necessary requirements. So the question of the perspective RTOS development becomes very important.

RTOS development is a complex task; in order to do it properly it's necessary to integrate science and industry, obtain the State support, take in account the experience of the foreign RTOS developers, conclude the necessary scientific research and organize the whole process of design and development.

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