Design of onboard data server for the implementation as a part of onboard avionics equipment using concept of integrated modular avionics

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Abstract. Modern onboard equipment (OBE) includes systems that require onboard storage and processing of large amount of information. At the same time real-time access to data is required. On the samples of national aircrafts, information is most often stored in computers, where the main functions are not data storage, but data processing. Most of the computing resources are spent on running applications. This results in slow processing of requests to a database (DB), which in turn affects the speed of systems that need data from the database or that keep records to the database. The article is devoted to the development of Onboard Data server (ODS) using the concept of integrated modular avionics (IMA) for the onboard avionics equipment of medium-range MS-21 aircraft. ODS is a separate data server computing platform, which provides running of several independent functional applications and carrying out interaction with onboard equipment via AFDX, USB, Ethernet, RS-232 interfaces. The article provides the requirements for the Onboard Data Server, software requirements, architecture, calculation of reliability indicators, four modes of operation: start mode, operating mode, extended control mode and technological mode, describes the algorithm of transition between the modes of operation of the ODS. The use of the ODS will allow reducing the load on the computers of the functional applications of the aircraft systems, simplifying the work of the ground crew interacting with the onboard maintenance system and the aircraft crew, which prepares the flight plan using the navigation data processed on the server.

1. Introduction

Modern onboard avionics equipment includes systems that require onboard storage and processing of large amount of information. At the same it is necessary to provide real-time access to data [1–3].

In particular, such systems include flight management system (FMS) and onboard maintenance system (OMS). The database size of such systems can reach 10 GB.

The processing of such amount of information requires large computing resources. Therefore it is inadvisable to carry it out on the computers with installed functional software (FSW) of aircraft systems.

The purpose of the article is to develop onboard data server (ODS) for the onboard avionics equipment of medium-range MS-21 passenger aircraft with the application of integrated modular avionics concept [4–6].
ODS is aimed at use as a computing platform of the aircraft data server, which provides database storage and maintenance of functions of database management systems with quasi-simultaneous access to databases at the request of functional applications as part of the OBE [7].

Ground crew gets access to the OMS DB, which contains information about all failures onboard for the current flight and 63 previous flights.

Aircraft crew is provided with access to the air navigation database (ANDB), which contains information about airports, departure and arrival schemes, and air routes.

The requirements for the onboard avionics equipment (OAE) of the MS-21 aircraft constitute the initial data for the development of the ODS [8–11].

Technical specification for the development of the server and requirements specification for its architecture were drawn up; ODS architecture development, ODS software requirements and the reliability indicators calculation were carried out during the course of the presented research.

2. Analysis of existing onboard data storage systems

The authors consider the existing analogues of data storage systems of international and national manufacturers, operated on modern aircrafts of civil and transport aviation.

Data storage devices are used on many foreign aircrafts – Boeing, Airbus, Embraer and aircrafts of other companies. Depending on the manufacturer, such devices are either a separate system (Thales), or a part of another system (often of the information system (IS)). These systems have a variety of functions – from onboard network security to storage of the videos from the video surveillance system. But there is a common function inherent in all these systems – it is the storage of large databases and providing real-time access to them. The authors consider the onboard data storage system of the UTC aircraft as a part of the “Network Server System” (NSS).

Network Server System (NSS) is the main component of the information system, which provides support for interfaces and information interaction between different systems of the aircraft. NSS is based on the UTAS-SIS Aircraft Interface Device (AID) platform. AID platform is developed in accordance with ARP 4754A, ARP 4761, RTCA/DO-297, DO-178B/C, DO-254, DO-160G and other standards. Level of the software loaded to AID is not less than E [12–14].

The important functions of the system are as follows:

1. Providing of network security
   - Physical separation of networks where it is possible to limit unwanted cross-connections.
   - Providing hardware and/or software (firewall) separation between different domains.
   - Disabling any non-system important services and communication channels.
   - Limitation of information exchange initiated from "ground" systems.
   - Support for digital signatures for downloaded SW.
   - The use of COTS tools for the detection of system vulnerabilities.
   - Record of logs of successful and unsuccessful network access requests.

2. Optimization of flight parameters. The function helps the crew to fly with the most efficient fuel consumption. AID provides access to avionics data requests.

3. Data download in accordance with ARINC 615. The function provides data download using ARINC 429 interface in accordance with ARINC 615A and ARINC 615 standards.

4. Record of flight parameters. The function provides automatic recording of flight data at specified time intervals. Information is sent to the "ground". If the flight is non-standard, the system increases the frequency of data recording and sending.

Another foreign analogue is Thales Company On-Board Data Server (ODS). In the provided ODS architecture functions are divided among already installed CPIOM MC 21, two LRU secure proxy servers (SPS) and portable maintenance access terminal (PMAT).

CPIOM provides security of critical functions and SPS place functional application. SPS are DAL-D hardware which are in line with DO-254 and managed by operational hypervisor. SPS places sections dedicated to data loading functions, BITE, A664 Ethernet, etc. and a section with built-in Linux, file
server, and SQL database. The SPS is connected to the A664 switch already installed on MS-21 to connect the interface to the avionics and PMAT containing the HMI data loading functions.

Such solutions are offered by Rockwell Collins Company. The Secure Server Router (SSR) system is aimed at files and DB storage, support for applications, ensuring network security, providing wireless communication in the cockpit and with ground systems. It consists of one unit.

The main functions of the system are application support; functional software, database, files download; EFB connection support.

Separate systems were not used on the samples of national aircrafts for databases storage earlier.

On the Sukhoi Superjet 100 aircraft databases were stored and processed each on its own computer. OMS DB – on a multifunctional indicator (MFI), air navigation database (ANDB) – on the FMS calculator.

DB storage and processing requests are not the main function for MFI or for FMS computer. Most of the computing resources are spent on running functional applications. This results in slow processing of requests to a DB, which in turn affects the speed of systems that need data from the DB or that keep records to the DB [15, 16].

3. Scheme of interaction of the ODS with conjugate systems

The characteristics of the developed ODS must meet the requirements of ARINC 624-1 Design guidance for onboard maintenance system and the requirements of the technical specifications for the onboard avionics equipment of MS-21 aircraft [17].

![Figure 1. Scheme of ODS interaction with conjugated systems](image-url)
Figure 2. Algorithm of transition between the ODS operation modes
According to the requirements for the onboard avionics equipment and the requirements of ARINC 624-1, the ODS must provide information exchange with the OMS via the ADN onboard local area network via the AFDX redundant channel in accordance with the ARINC 664 standard.

In addition, for the maintenance purpose, the server must provide information exchange on USB, RS-232, ARINC 600 (Ethernet) and PK technological interfaces. The scheme of ODS interaction with conjugated systems is shown in figure 1 [18]. The server must be provided with four modes of operation: start mode, operating mode, advanced control mode and technological mode.

Start mode is started automatically when the power is supplied. Initialization of the unit equipment, starting control of the equipment and determination of the identification server address in the aircraft network by a combination of input Discrete signals (DS) must be carried out in the mode. After starting control ODS should form “Serviceability signal” DS. The starting mode should last not more than 45 seconds from the moment when the power is supplied.

The extended control mode is started when the interactive mode initialization command is received from the OMS. In this mode, advanced control tests are available to check the satisfactory condition of the unit. ODS must enter the technological mode in case of simultaneous “Technological mode” and “LGS signal” DS during the initialization procedure at startup. The exit from the technological mode is made by switching off the power or by “Manual reset” DS. The algorithm of transition between the ODS operation modes is shown in figure 2.

Figure 3. Developed ODS architecture
4. Development of Onboard Data Server architecture

In accordance with the technical requirements for the avionics system, the ODS hardware should be developed using the concept of integrated modular avionics and in accordance with DO-254 have a design guarantee level not lower than C [19–21].

The developed ODS architecture is shown in figure 3. CIM-3U-3 on the basis of Freescale P1010 processor with the PowerPC architecture with the installed VxWorks-653 RTOS is selected as a computing-interface module. This module has the following characteristics: RAM 256 Mbytes with error correction; ROM NOR FLASH 64 Mbytes; ROM NAND FLASH 64 Mbytes; ROM nvRAM 256 Kbytes; set of interfaces: PCIe 2.5 Gbps, AFDX (ARINC 664) x2, Ethernet (ARINC 646), RS-232 x2, 8 input DSs, 2 output DSs, 10 configurational DSs, I2C, JTAG; power supply +12 V, +3.3 V, 27 V; power consumption 7 W.

MMM-3 is chosen as a memory module, which meets all the requirements. The main characteristics of the module: PCIe interface; storage capacity 256 Gbytes SSD; power supply +12 V, +3.3 V; power consumption not more than 15 W.

5. Calculation of reliability indicators

The ODS must have type and size 1 MCU in accordance with the ARINC 600 standard. The unit size must be not more than 197 mm in height, 30 mm in width, 365 mm in length. Its weight must be not more than 3 kg.

LED indicators of serviceability, voltage and secondary power supply indicators, besides, Ethernet and RS-232 connections, “Manual reset” and “Technological mode” input DSs must be on the front panel of the ODS. A carrying handle must be provided on the front panel side.

Basing on the proposed architecture of the system, it is possible to assume that the CIM-3U-3, MMM-3, SPSM-25, cross-board are connected in series. Failure of one of them leads to the unit failure. The failure rate of the product at the serial connection of the elements is calculated by the formula:

$$\lambda_{\text{product}} = \sum \lambda_{\text{ser}}.$$  \hspace{1cm} (1)

where $\lambda_{\text{ser}}$ – total rate of failure of elements connected in series.

The failure rate of the module is calculated by the formula:

$$\lambda_{\text{element}} = \frac{1}{T_\text{c}}.$$ \hspace{1cm} (2)

Since the failure of the indication board does not lead to ODS malfunction, it is possible not to take it into account when calculating the reliability of the unit.

As a result of the calculations, the total intensity of the block:

$$\lambda_{\text{product}} = 1.1 \cdot 10^{-6} \text{ 1/h}.$$  \hspace{1cm} (3)

The probability of failure-free operation of the unit within one hour:

$$P(t) = e^{-\lambda_{\text{product}}t} = 0.999998$$ \hspace{1cm} (4)

The probability of the unit failure within one hour:

$$Q(t) = 1 - P(t) = 2 \cdot 10^{-6}$$ \hspace{1cm} (5)

The average time before unit failure or malfunction:

$$T_\text{c} = \frac{1}{\lambda_{\text{product}}} = 90909 \text{h}.$$ \hspace{1cm} (6)

Taking into account the double loaded redundancy of the unit, the reliability calculation is presented below.

The probability of failure-free operation of the system:

$$P(t)_p = 1 - (1 - e^{-\lambda_{\text{product}}t})^2 = 0.999999$$ \hspace{1cm} (7)

The probability of the system failure within one hour:

$$Q(t)_p = 1 - P(t)_p = 1 \cdot 10^{-6}$$ \hspace{1cm} (8)

The average time before system failure or malfunction:
Т_{\text{average}} = T_c \sum_{i=0}^{n} \frac{1}{i+1} = 1.5 \cdot T_c = 136363.5h, \quad (8)

which exceeds the required value of 40 000 h more than 3 times.

The calculation of the ODS reliability indicators showed the compliance of the calculated and required characteristics.

6. Conclusion

Based on the analysis of the existing data storage systems, requirements of aviation standards and technical specifications for the on-board avionics equipment, requirements for the development of the Onboard Data Server of the MS-21 aircraft are formulated, top-level requirements for the ODS software are developed, the architecture of the ODS unit is designed, the ODS reliability analysis is performed. The reliability analysis confirmed the compliance of the requirements of the developed unit with the requirements of the Technical specification.

The use of the ODS will allow simplifying the work of the ground crew interacting with the onboard maintenance system and the aircraft crew, which prepares the flight plan using the navigation data processed on the server.

Units of this type have not previously been used on the samples of national aircrafts, and previous solutions lose to the proposed one by a number of parameters, so it is advisable to design ODS.

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