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DEVELOPMENT OF FRACAS SYSTEMS FOR AIRBORNE EQUIPMENT WITH AUTOMATED IDENTIFICATION OF SOURCES OF SYSTEMATIC FAILURES

The paper presents a methodology for the development of the electronic structure of airborne avionics in the aspect of dependability assurance in the post-production stages of the life cycle, allowing increasing the efficiency of FRACAS systems by computerized analysis of common cause, aimed at identifying the sources of systematic failures and the development of effective corrective actions.

Keywords: *electronic structure of a product, systematic failure, source of failures, corrective actions.*

The increased requirements of airlines for dependability assurance of aircraft (AC) and its airborne equipment (AE) define the current market of aviation technology (AT). At the placement of contracts for AE supply for modern aircrafts such as the An-148, SSJ-100, Tu-204SM, MS-21, a special focus within after-sales service is given to programs of dependability assurance and regularity of flights. Inability of an AT provider to demonstrate the availability of resources for the implementation of such a program makes its products uncompetitive. On the other hand, there is a continuous increase in the complexity of AE due to the expansion of functional tasks and the range of operating conditions.

In addition, the trend to a reduction of time allowed for the design and technological preparation of AE production is retained, which is determined by increased competition in the market of AE suppliers.

Under these conditions, there is a need to develop new methods and tools that allow:

- to ensure the effective implementation of the program to guarantee the dependability at post-production stages and to demonstrate to an AT consumer the possibility of such an implementation;
- to use the information obtained as a result of the program implementation for design and technological preparation of new AE projects.

Systems implementing the analysis of a report about system failures and corrective actions (FRACAS) can be applied as the most effective ones for the assigned task solution. These are closed-loop systems, which usually include the following stages: failure registration – failure analysis – determining the necessary corrective actions – evaluation of corrective actions' effectiveness. Currently, the market of software systems that implement the principle of FRACAS presents the systems Relex FRACAS (PTC) and FRACAS FavoWeb (ALD) [1, 2].

Although the advantages of using FRACAS systems are obvious, it is difficult to implement an effective system ensuring AE dependability at post-production stages of a life cycle. The problem is that the effectiveness of corrective actions depends on the accuracy and timeliness of determination of failure cause, and it is difficult to formalize the task. In addition, the task of using the results obtained from the use of real data to analyze the dependability of new projects is also difficult for formalization.

As a result, the existing systems represent means to automate the collection of information about failures and dependability assessment (quantitative analysis). Identification of failure causes according to the operation data and use of the obtained information in the new projects (qualitative analysis) still represents a time-consuming process, requiring costly and continuous participation of highly qualified experts.

To determine the performance criteria of FRACAS system, we shall consider the change of AE dependability level at post-production stages. Taking into account the complexity of modern AE and its life cycle, systematic failures are typical at the initial period of AE operation. This leads to reduction of AE dependability in operation by a certain value $\Delta R_н$. The quantity of $\Delta R_н$ depends on the number of types of defects that lead to systematic failures and on the number of AE produced with such defects.

Corrective actions aimed at eliminating the causes of systematic failures are carried out at the detection of discrepancy in dependability of AE during its operation. As a result, under elimination of systematic failures' causes and refinement of products in use, an increase of dependability and bringing its level to the desired one take place. Time to bring dependability to the required level $\Delta t_н$ depends on the time needed for the determination of systematic failures' causes, the time needed for development of effective corrective actions, and the time needed for determining the amount of correction and carrying out improvements.

Often during the AE operation, its modernization is carried out due to expansion of the range of functional tasks. Systematic failures' occurrence and dependability decrease on the value equal to $\Delta R_м$ is also possible at carrying out substantial modernization and bringing it back to the required level needs time $\Delta t_м$.

Thus, the efficiency enhancement of AE dependability can be described by the following criteria:

$$\Delta t_н,\ \Delta t_м \rightarrow min;\ \Delta R_н,\ \Delta R_м \rightarrow min.$$

Change of dependability level at the initial period of operation and after the upgrade is shown in Fig. 1.

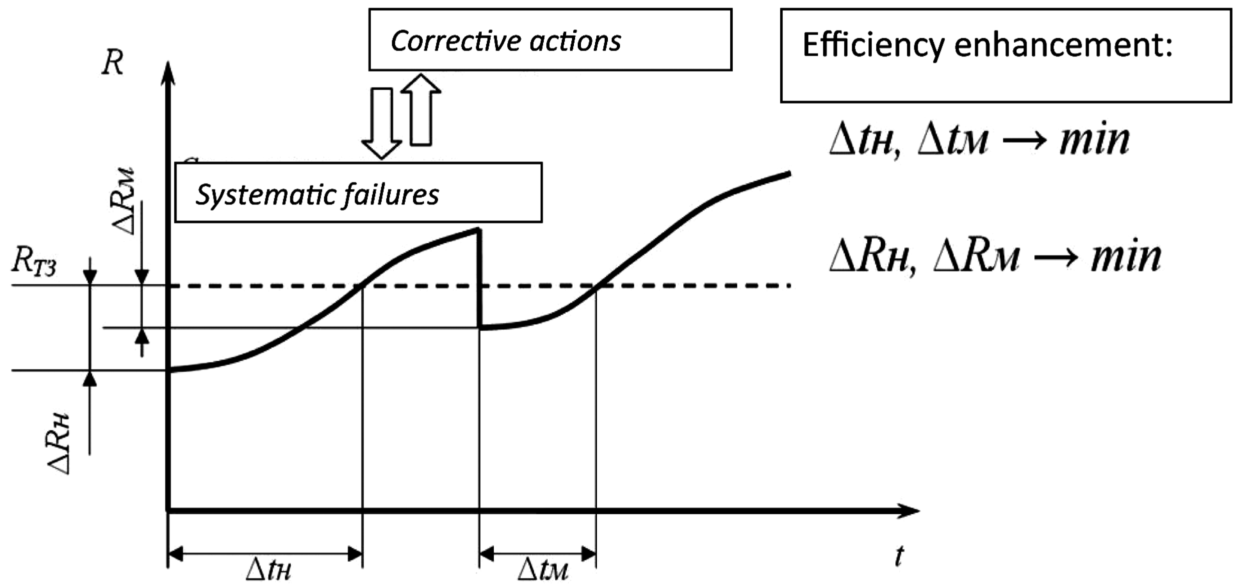
As shown in [3], to solve these problems, it is necessary to develop special-purpose methods and data processing software operating under the control of PDM-system. At the same time, in this aspect it is necessary to solve the problem of developing an electronic product structure (EPS).

To construct the model, we shall rely on the following definitions given in [4].

Failure cause is the circumstances in the process of development, production or use, which has led to a failure.

The systematic failure is the failure definitely caused by a cause, which can only be eliminated by modification of the project or the production process, operating rules and documentation.

From the definitions, it follows that the sources of failures are the processes of development, production and operation. Sources of common cause failures of elements in this process are the general implementations of life cycle processes.



Δtн- refinement time of dependability index to the required level in the initial operation stage
Δtм- refinement time of dependability index to the required level after modernization
ΔRн- the level of discrepancy of dependability index in the initial operation stage
ΔRм- the level of discrepancy of dependability index after modernization
R- dependability index, which statistic assessment depends on the number of failures
t- time

Fig. 1. Performance criteria of AE dependability

Thus, the EPS' purposeful part developed in the aspect of FRACAS system, in addition to data about AE structure and connection of its constituent parts must contain data about significant processes in terms of source of failures.

The structure of AE can be represented by the formula:

$$O = (K, Q, t), \tag{1}$$

where *K* is the set of elements in the system;
Q is a set of connections between the system's elements;
t is the time, to which the description of AE refers.

Among the total set of AE elements, it is possible to single out equivalence classes according to a dependability level (the elements of the same type). Subsets of elements having the same common cause sources can be distinguished from a set of elements having the same dependability level. Thus, alternatives of applications of the same elements in AE with respect to each source of systematic failures are generated.

At the same time, the presence of systematic faults in any source of failures causes a sharp increase of failure rate of one of the application alternatives, and consequently, the presence of statistical estimates' heterogeneity, which can be a criterion of the need for corrective actions of the given process.

Thus, the expression (1) must be completed to the following form

$$O = (K, Q, P, R, t), \tag{2}$$

where the symbol P means process parameters that describe the AE elements in terms of common cause sources, the symbol R presents the parameters defining the actual failure rate of an element or a failure stream parameter.

Evaluation of corrective actions' effectiveness is performed by comparing the dependability of components made without corrective actions, with elements made in view of the corrective actions. For the identification of implemented corrective actions, the expression (2) must be completed as to the following form

$$O = (K, Q, P, R, C, t), \tag{3}$$

where the symbol C is the attribute that defines the indicator of implementation of corrective actions.

Thus, to develop an AE model in the aspect of dependability assurance, it is necessary to determine:
- a list and values of attributes that describe the AE structure;
- a list and values of attributes that characterize the sources of common cause;
- a list and values of attributes for statistical estimations;
- a list and values of attributes that determine the implementation of corrective actions;
- procedure of changing the values of attributes in the life cycle process.

Life cycle processes of AE are the subject of research in terms of the generation of the design decisions in the design of AE and the development of corrective actions and the assessment of their effectiveness during the operation of AE. In the process of AE life cycle, event-trigger and dynamic space is generated, in which the following problems are solved:
- evaluation of new projects of AE during their design according to operation results of analogous products;
- determination of causes of systematic failures, development of corrective actions and assessment of their effectiveness.

The life cycle model of AE in the aspect of dependability assurance is shown in Fig. 2.

The database for the expert system for the analysis of reliability of aircraft airborne information systems [5] and for the expert system for the analysis of dependability of aircraft airborne information systems [6] were developed in 2011.

Their development has taken into account the implementation experience of programs assuring dependability of AE for various purposes, such as:
- integrated information systems of signaling,
- electronic warning systems,
- critical behavior warning systems,
- the complex system of electronic display and signaling,
- alarm signaling systems,
- cockpit interior lighting systems,
- systems for converting analog and discrete information,
- control systems for general air-borne equipment,
- systems of limiting signals, systems of air signals of helicopters,
- onboard information systems of control,
- perception of air data systems that are installed on the following aircrafts: Tu-204, Tu-214, Tu-334, Il-96-300, Il- 96-400, Il-76, Il-114, AN-148, Ka-226, Ka-31 and Ka-32, Ansat etc.

Sources of failure in the design process are selected in accordance with the "Guidelines for the assessment of the correct application of electrical and radio products" used by industrial enterprises in the analysis of causes of electrical and radio products' failures in samples of equipment and in the development of proposals to improve its reliability [7], and also in accordance with qualifying requirements KT-160D, establishing operation conditions and environment for airborne equipment [8].

Sources of failures in the production process are selected according to the basic list of special processes (SP), developed for the aviation industry as a whole, as well as a list of SP formed for specific products of aviation technology [9].

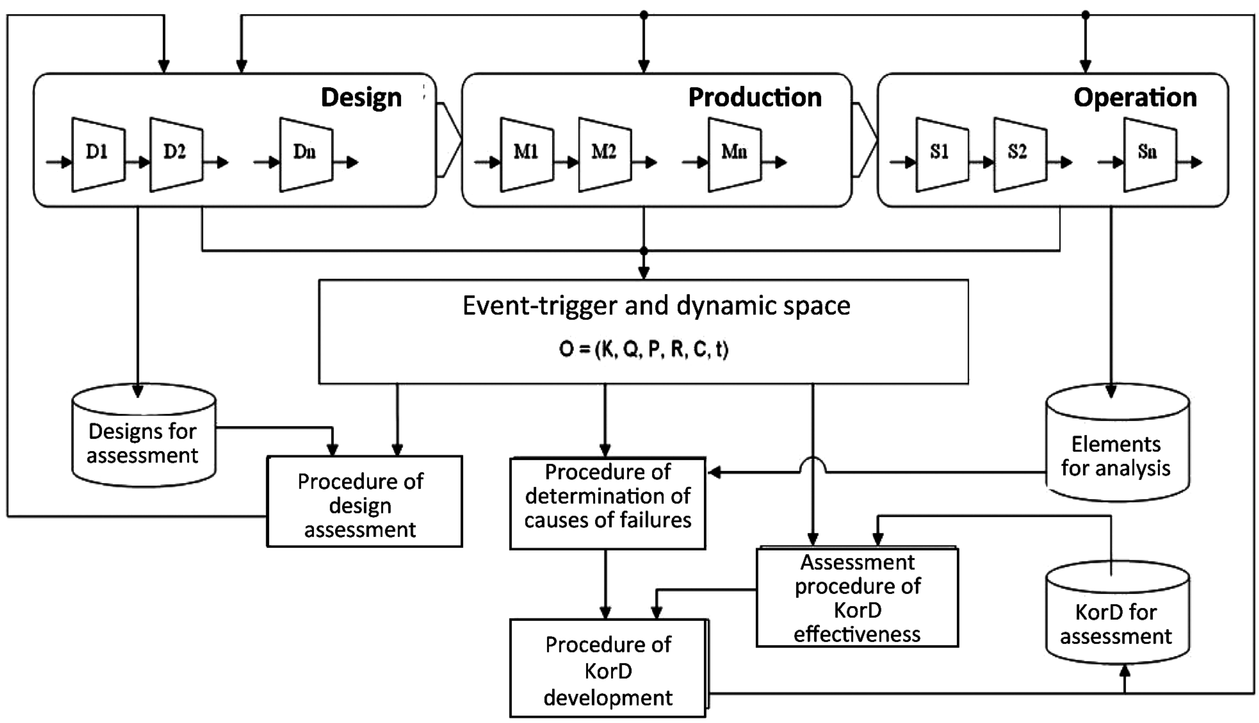


Fig. 2. The life cycle model of AE in terms of dependability assurance

Since the basic list of processes is generated from the point of view of the enterprise-developer and manufacturer of AE, detailing of the post-production stage onto processes has been carried out with less level. In this case, a set of processes implemented within an enterprise was generated for the model, such as the installation on the aircraft, operation, repairs, which are treated as separate processes.

The appearance of the interface part of the module for identification of sources of systematic failures and performance assessment of corrective actions are presented in Fig. 3.

The upper part of the screen contains information about the analyzed element or AE unit and considered process.

In the right part of the screen, there is a field of alternative applications. Applications are shown in the form of a graph whose vertices correspond to the elements analyzed, and nodes – to subsets of elements distributed by source of common cause.

On the left side of the screen, there is a diagram field. Each column of the diagram is a statistical assessment of dependability of one of the applications with the confidence limits of indicator. The columns of the diagram, statistical estimates of which are heterogeneous, are highlighted in color.

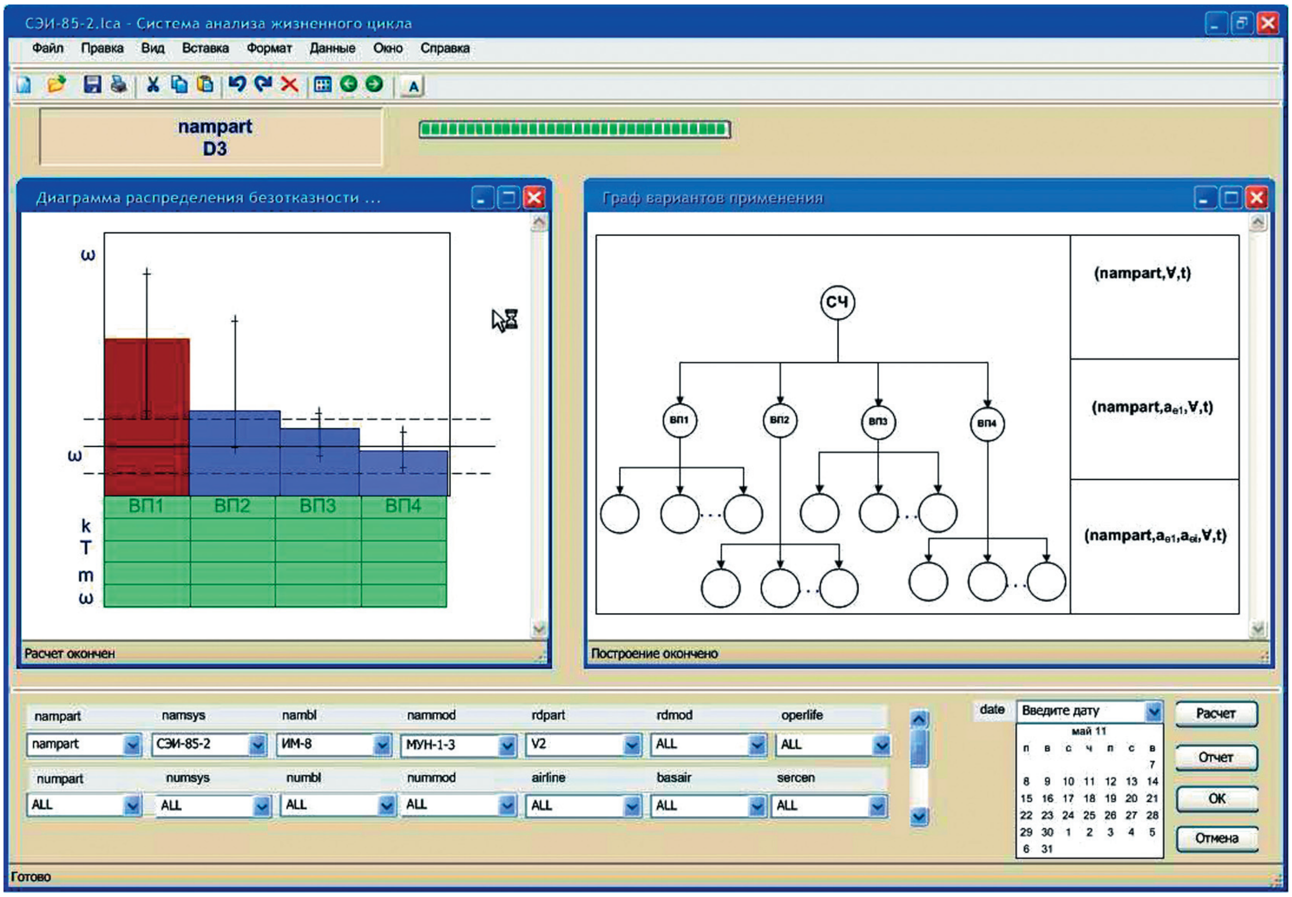


Fig. 3. The interface part of the module for identification of sources of systematic failures

At the bottom part of the screen, there is a constructor, which allows making changes in the tuple, by which application options are generated. This allows the expert, if necessary, to intervene in the process of analysis to implement his strategies.

The possibility to change the date of the relevance of the model for analysis is also provided. This allows us to analyze the dynamics of dependability level.

Conclusion

The paper developed the electronic structure of AE in terms of the analysis of information about failures and development of corrective actions. Besides the model of AE in the aspect of FRACAS system was constructed, which allows an event-trigger and dynamic space of attributes of life cycle processes to solve the problems of determining the sources of systematic failures and the subsequent development of corrective actions and the assessment of their effectiveness.

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