RESEARCH ARTICLE OPEN ACCESS

# Specificity of optimization of performance indicators of technical operation and updating of radio electronic systems of aircraft

Y. Kovalenko, H. Konakhovych, I. Kozlyuk
*Information Security Department, National Aviation University, 03058, Ukraine, Kiev, ave. Lubomir Guzar, 1.*

**ABSTRACT**
The paper analyzes possible variants to construct the system of technical operation and retrofitting of aircraft radio electronic systems. The authors formulate the concept of the basic variant. The determinant classification marks are used to select the basic variants. The concept of derivatives and competing varieties of the basic variant is determined. The classification marks that characterize the properties of electronic system equipment are established.
The article is devoted to solving the problem of identifying optimization performance indicators and updating aircraft radio electronic systems, which is currently an urgent metrological task. The article analyzes the possible variants of construction of the system of technical operation and updating of radio electronic systems of aircraft. In addition, a selection of performance indicators for the construction of the system of technical operation and updating of radio electronic systems of aircraft was conducted. The generalized index of efficiency of the system of technical operation of radio electronic systems of aircraft is substantiated.
The article is devoted to solving the problem of identifying optimization indicators of operational efficiency and updating of radio electronic systems of aircraft, which is currently an urgent metrological task.
The analysis of possible options for the construction of the system of technical operation and updating of radio electronic systems of aircraft is conducted. The concept of the basic variant of construction of the system of technical operation and updating is formulated and the basic variants of construction of the system of technical operation and updating are identified with the help of defining classification features.
The concept of derivatives and competing varieties of the basic variant of construction of the system of technical operation and updating in radio-electronic systems is defined. For this purpose, the classification features characterizing the properties of products of radio-electronic systems, the place of restoration of the product, the place of fixing of the failure of the product and the availability of means of operational control in the organization of maintenance were introduced.
**Keywords:** maintenance; retrofitting; aircraft radio electronic systems; evaluation; effectiveness; basic variants.

Date of Submission: 04-09-2020 Date of Acceptance: 19-09-2020

## I. INTRODUCTION

Effective operation of new aircraft is possible only in accordance with the rules of aircraft equipment certification. The issue of a scientifically based selection of methods intended for technical retrofitting of the radio-electronic systems has been actively analyzed, because these systems are the most expensive and significantly affect the safety and regularity of aircraft flights. This influence is possible only if the costs required for retrofitting are minimized.

**Analysis of recent research and publications**

In order to develop an organizational system for the operation of on-board radio-electronic systems installed in advanced aircraft, it is necessary to solve the following tasks:

to analyze the possible variants how to construct the system of technical operation and retrofitting of radio-electronic systems;

to select efficiency indicators of the system of technical operation and retrofitting and to substantiate a generalized indicator of the efficiency of the system of technical operation.

**Modern approaches to the analysis of nonlinear inertial measuring channels**

The basic variant to construct the system of technical operation and retrofitting is understood as an organization of operational process for the radio electronic systems which perform a certain range of retrofitting operations at the place where failure takes place. With this in mind, it should be noted that the number of operations on technical retrofitting, which are characterized by the states of the graph shown in Figure 1, are constant for each type of the selected basic variant (Konakhovych 2012).

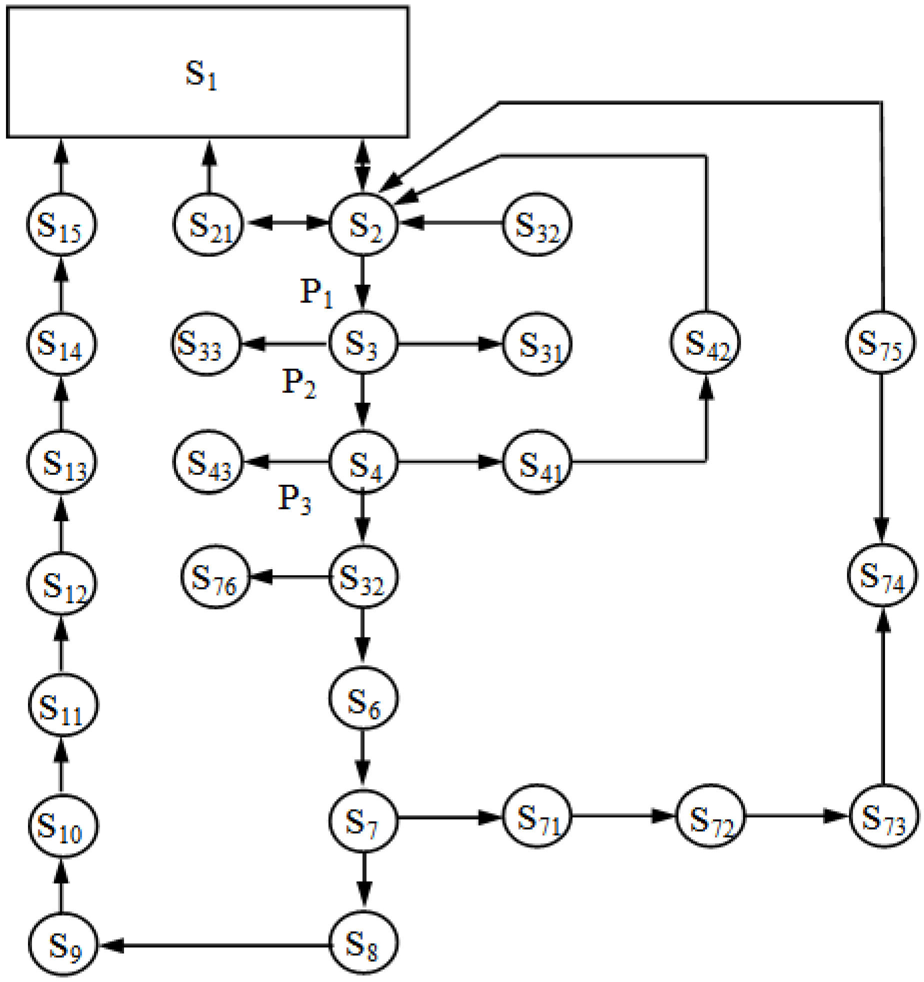


**Fig. 1.** A graph of possible states of the radio electronic system block

The evaluation of the effectiveness of the basic variants for constructing the system of technical operation and retrofitting of electronic systems is carried out with the help of technical and economic efficiency indicators (Konakhovych 2005). Complex reliability indicators are included into the following technical data: readiness coefficient, operational readiness coefficient, technical operation coefficient. The technical and economic indicators include specific average profits and specific average costs.

Considering that one of the basic variants can be applied to radio-electronic systems, the failure of which leads to the refusal to perform the assigned functions (the value of the classification mark), it is necessary to take into account the probability of the normal functioning of these systems (probability of the system to maintain the operational condition), when selecting efficiency indicators.

As for radio-electronic systems with classification marks ($A_1$) to fail-safe during the intended use ($S_1$) advanced requirements are raised, then the reliability index should be used: for systems with a classification mark ($B_1$), (non-renewable system) – a posteriori probability of failure-free operation ($P_A$), but for systems with the mark $\overline{B}_1$ (recoverable with different depths of the system) – the operational probability of failure-free operation $P_E$.

A posteriori probability of failure-free operation ($P_A$) we will call the conditional probability of failure-free operation of the system on the interval ($t_k$,$t$) provided that the results of the operational control at moments the system is recognized as workable.

The operational probability of failure-free operation is understood as the probability of failure-free operation of the system at the interval of use ($t_k$,$t$), contemplating the fact that at moments $\overline{t_k, t}$ the technical operation is carried out, which includes operational control and retrofitting of defective systems.

Consequently, to assess the effectiveness of the basic variants in the structure of the system of technical operation and retrofitting in radio electronic systems, a certain procedure should be carried out according to the "reliability-cost" criterion, which includes two performance indicators. The first one characterizes the reliability of radio electronic systems, and the second one is the costs of technical operation and loss because of the unplanned grounding of aircraft due to the replacement of an easily removable block that has failed.

The expenses intended for technical operation characterize the specific average costs, i.e., the average cost per time unit of use of the system. Moreover, for systems with the mark specific average costs include the cost of control $B_1$, the replacement of an easily removable unit and the loss due to the forced grounding of aircraft. Specific average costs for such systems are marked as $C_H$. In relation to the costs mentioned above, it is also necessary to take into account additional recovery costs. We mark these costs as $C_B$.

In addition, when the consequences of a system failure can be estimated economically, as an indicator of efficiency, it is necessary to use an economic indicator in the form of specific average costs. Indicator of specific average costs, which will be marked $V$ as in the future, can be applied in assessing the effectiveness of the strategy for products having the classification mark $A_2$.

This indicator includes the costs of technical operation, losses due to the presence of the system in a state of latent refusal during the flight of an aircraft and the loss due to exceeding the time of replacement of the rejected unit in the radio-electronic system suspended for a long time.

The above-mentioned performance indicators may only be used in cases where the indication is given in advance as, which characterizes the presence of a certain type of ground vehicle operational control and, accordingly, an exchange fund, where no varying can occur. However, in a comparative analysis of the basic variants for constructing a system for technical operation and retrofitting in radio electronic systems and their varieties, it is necessary to have indicators that take into account not only the characteristics of control and recovery operations, but also the composition of the ground vehicle operational control and exchange fund (logistics). Therefore, as an economic efficiency indicator of the system of technical operation and retrofitting in radio electronic systems, we will use the following costs, which represent the sum of the cost of the system of technical operation and update and standard profit:

, (1)

$$B = X_E + E_H K$$

where $C_E$ – the cost of operating the system during the year; $E_H$ – specific investments in ground-based operational control and exchange fund; K – normative coefficient of efficiency of capital investments.

The cost of operation of the electronic system during the year should include the annual operating costs of the system, depreciation of the land resources of the operational control and the exchange fund, as well as for the variant of upgrading the kits that include electric rotor materials and printed circuit boards.

The costs for the variant are as follows. As the variant does not foresee the use of ground control equipment in maintenance, the investment will only be associated with the exchange fund of the units of the radio electronic system in the organization of maintenance.

Investments into an exchange fund are determined by the formula:

, (2)

$$K_{\hat{I}\hat{O}}^{(\hat{I})} = \sum_{i=1}^{m} Z_i \Phi_i / \theta_i$$

where $m$ –the number of units of the electronic system; $Z_з$ – purchase price of -type block; $F_i$ – the number of -type blocks in the exchange fund of the maintenance organization; $q_i$ – the number of seats for -type blocks of the same type throughout the aircraft's assigned fleet. If the system consists of blocks of the same type, then formula (2) transforms into the following:

. (3)

The cost of operating the system is easy to determine, knowing the specific average costs per hour of flight for one system (block radio-electronic system).

Specific average costs are determined by counting the graph depicted in Fig. 1, as follows:

$$\hat{E}_{\hat{I}\hat{O}} = \grave{o}\,\ddot{O}F / q \quad , \qquad (4)$$

$$C_{\acute{Y}}^{W1}(t_n) = \frac{1}{t_n}[C_{S2}t_{S2} + P_1(C_{S3}t_{S3} + aC_{S31}\Delta t_{S31} + C_{S32}t_{S32}) + P_2 C_{S33}]$$

where $t_n$ – the duration of the flight of the aircraft; $C_{S2}$ – average costs per time unit to efficiency control using built-in control systems; $C_{S3}$ – average costs per time unit to dismantle the unit from the aircraft; $C_{S32}$ – average costs per time unit for unit installation on board an aircraft; $C_{S31}$ – average costs per time unit due to a simple aircraft associated with replacement of the failed unit; $C_{S33}$ – average costs of retrofitting the failed block; $P_1$ – the probability of a solution to embedded control systems for dismantling the block; $P_2$ – the probability of sending a block in its absence in the exchange fund of the organization of technical maintenance;

$$a = \begin{cases} 0,\ at\ \Delta t_{S31} > t_C,\ where\ t_C\text{ - } parking\ time\ in\ the\ AP; \\ 1,\ at\ \Delta t_{S31} \le t_C. \end{cases}$$

Thus, the cost of operation of the radio electronic system unit during the year is determined from the expression

. (5)

$$\tilde{N}_{\AA}^{W1} = \tilde{N}_{\AA}^{W1}(t_n)(\grave{O}_{\acute{I}\acute{I}}) + \AA_{\hat{I}\hat{O}}\hat{E}_{\hat{I}\hat{O}}^{W1}$$

When organizing the system of technical operation and retrofitting during the year, the costs of operation of the radio-electronic system unit given to the variant are determined from the expression:

. (6)

$$\hat{A}^{W1} = \tilde{N}_{\AA}^{W1} + \left(\AA_{\hat{I}\hat{O}} + \AA_{\acute{I}}\right)\hat{E}_{\hat{I}\hat{O}}^{W1}$$

Let's determine the cost for the variant . This variant is characterized by the presence in the organization of maintenance of ground-based facilities of operational control of the first level, which allows the control of units

dismantled from the aircraft of the electronic system. Investments into the system of technical exploitation and retrofitting in radio electronic systems built according to the variant , will include the value of an exchange fund and investments in terrestrial facilities of operational control of the first level. The main purpose of ground-based facilities of operational control is to prevent mistakes when sending operational units to the factory-manufacturer or aircraft repair factory.
Let's denote investments in ground control facilities of the first level necessary for control of this type of system. Then the value

$$\hat{E}_1^{(1)} = \grave{o}\,\hat{E}_1 / \sum_{i=1}^{\grave{o}} q_i \qquad (7)$$

determines the specific investments in ground facilities of operational control of the first level in terms of one block of system on board the aircraft, and the value

$$\hat{E}_1^{(\grave{o})} = \grave{o}^{\,2}\hat{E}_1 / \sum_{i=1}^{\grave{o}} q_i \qquad (8)$$

is equal to the specific capital investment in ground-based facilities of operational control in the settlement on one system, consisting of blocks.
If $q_i = q\left(i = \overline{1,m}\right)$, it is quite obvious that specific investments in ground-based facilities of operational control of the first level are

$$\hat{E}_1^{(m)} = \grave{o}\,\hat{E}\, / \,q \qquad (9)$$

Specific investments in the exchange fund and land resources of operational control of type 1 are determined by the formula

$$K = K_{\hat{I}\,\hat{O}}^{W2} + K_1^{(m)} \qquad (10)$$

Turning to the graph depicted in Fig. 1, we will determine the specific average costs when organizing the system of technical maintenance and upgrading in electronic systems in accordance with the variant :

$$C_E^{W2}(t_n) = \frac{1}{t_n}[C_{S2}t_{S2} + \text{Đ}_1(\tilde{N}_{S3}t_{S3} + \tilde{N}_{S4}t_{S4} + \tilde{N}_{S42}t_{S42} + \grave{a}\tilde{N}_{S41}t_{41}) + \text{Đ}_3\tilde{N}_{S43}], \qquad (11)$$

where $C_{S4}$ – average costs per time unit to work performance with the help of ground-based operational control of type 1 on a dismantled unit; $C_{S42} = C_{S32}; C_{S41} = C_{S31};$ $P_3$ – the probability of sending the unit to an upgrade after the performance check using ground facilities (control of type 1); $C_{S43} = C_{S33};$ $t_{S41}$ – the average time of an emergency delivery of the block in case of its absence in the exchange fund of the maintenance organization.
The costs of operation of the radio-electronic system unit during the year when organizing the system of technical operation and retrofitting are given to the variant are determined from the expression:

$$B^{W2} = C_E^{W2}(t_n)(T_{\ddot{I}\acute{I}}) + (\mathring{A}_{\acute{I}} + \mathring{A}_{\hat{I}\hat{O}})\hat{E}^{(0)}_{\hat{I}\hat{O}} + (\mathring{A}_{\acute{I}} + \mathring{A}_{\grave{A}})\hat{E}_1^{(\grave{o})} \quad . \quad (12)$$

Let's turn to the definition of costs in the system of technical operation and retrofitting in radio electronic systems, constructed in accordance with the basic variant. This variant is characterized by the presence in the organization of maintenance of ground-based facilities of operational control of the first and second levels. Blocks of the electronic system in this case are restored in the organization of technical servicing by replacing the structural-replacement units that refused, and structural-replacement units are restored to the manufacturer or aircraft repair.

Let's $K_2$ denote investments in ground level facilities of operational control of level 2. The value $K_2$ is determined as follows:

, (13)

$$\hat{E}_2 = \hat{E}_2^{\grave{A}} / N_1$$

where $K_2^A$ – total investments in ground level facilities of operational control of the second level (purchase price plus the cost of space for the placement of ground control facilities); $N_1$ – the number of types of systems controlled by ground-based facilities of operational control.

The value $K_2^{(m)}$ determines specific investments in ground facilities of operational control per one system consisting of $m$ blocks.

(14)

$$K_2^{(m)} = m^2 K_2 / \sum_{i=1}^{m} q_i$$

If the system blocks have the same type, i.e. $q_i = q\left(i = \overline{1,m}\right)$, then specific investments in ground facilities of operational control are determined by the formula

. (15)

$$\hat{E}_2^{(m)} = \grave{o}\,\hat{E}_2 / q$$

For the variant $W_3$, the acquisition of an exchange fund is typical at the level of blocks and structural-replacement units. Therefore, specific investments in the exchange fund will be determined by the formula:

, (16)

$$\hat{E}^{(1)}_{\hat{I}\hat{O}} = \sum_{i=1}^{\grave{o}} Z_i F_i / q_i + \sum_{i=1}^{\grave{o}} \sum_{j=1}^{n_i} Z^{\mathring{A}}_{i,j} / q^E_{i,j}$$

where $n_i$ – he number of types of structurally $i$-replaceable units in -type system block; $Z^E_{i,j}$ – purchase price of structural-replacement units of $j$-type in $i$ -type block; $F^E_{i,j}$ – the number of structurally-replaceable units of $j$ -type in $i$-type block in the exchange fund of the technical facility; $q^E_{i,j}$ – the number of structurally-replaceable units of $j$ -type in the whole number of $i$ -type block in a maintenance organization.

If the system consists of blocks of the same type, then formula (16) becomes as follows:

$$\hat{E}^{(1)}_{\hat{I}\hat{O}} = \grave{o}\,(Z\,F\,/\,q + \sum_{j=1}^{n_0} Z_j^E F_J^E \,/\, q_j^E) \quad (17)$$

where $n_0$ – the number of types of structurally-replaceable units in any of the same type of system units; $Z_j^E$ – purchase price of structural-replacement units of $j$ -type; $F_J^E$ – the number of structurally-replaceable units of $j$ -type in an exchange fund for maintenance; $q_j^E$ – the number of structurally-replaceable units of $j$ -type in the whole number of the same type blocks.

Using the graph depicted in Fig. 1, we will determine the specific average costs when organizing the system of technical operation and upgrade in radio-electronic systems in accordance with the variant:

$$C_E^{W3}(t_n) = \frac{1}{t_n}[C_{S2}t_{S2} + P_1(\tilde{N}_{S3}t_{S3} + \tilde{N}_{S4}t_{S4} + \tilde{N}_{S75}t_{S75} + \grave{a}\tilde{N}_{S41}\Delta t_{S41}) + Đ_3\sum_{i=5}^{7} C_{Si}t_{Si} + \sum_{j=1}^{4} C_{S7j}t_{S7j} + P_4\tilde{N}_{S76}], \quad (18)$$

where $C_{S5}$ – average cost per time unit to efficiency control with ground-based operational control of type 2; $C_{S6}$ – average cost per time unit for a partial disassembly of the block; $C_{S7}$ – the average cost per time unit to search for structurally-replaced units that have failed; $C_{S71}$ – average cost per time unit to substitute structurally-replaced units that have failed; $C_{S72}$ – average cost per time unit to construct a block; $C_{S73}$ – average cost per time unit on the setting and adjustment of the block; $C_{S74}$ – average cost per time unit to efficiency control with the help of ground-based operational control of type 1; $P_4$ – the probability of sending for the renewal of the structural-replacement units refused, after controlling the operational capacity with the ground-based facilities of operational control of type 2; $\Delta t_{S41}$ – the average time of an emergency delivery of a structural unit in the event of its absence in the exchange fund of the maintenance organization.

The content of the generalized indicator of evaluation of efficiency of system of technical operation is opened by means of the following categories. The most objective indicator, which characterizes the efficiency of operation of electronic systems, should be considered an indicator that takes into account the ratio of income generated by the aircraft with the installed electronic systems to the cost of its maintenance

$$F = D / C_{s0}, \quad (19)$$

where $D$ - average annual income of aircraft; $C_{s0}$ - average annual operating costs of aircraft during the year.

Consider in more detail the components included in the expression $F = D / C_{s0}$,

taking into account the specifics of the functioning of electronic systems and the losses of the aviation company from the flight delay. It is known that electronic systems are directly involved in the control of aircraft flight. Therefore, failure or loss of quality of some systems can lead to flight errors or departure to the second lap during landing. All this is associated with additional fuel consumption. Identified through $\Delta S$ additional flight hours of aircraft not related to the delivery of passengers to the destination, and through $V_{\tilde{N}\text{Đ}}$ - the average flight speed of aircraft, we obtain (20) and (21):

$$D = d(T - \frac{\Delta S}{V_{\tilde{N}\text{Đ}}}), \qquad (20),$$

$$D = d(T - \frac{\Delta S}{V_{CP}}) - (Z_1 + Z_2) - 3_{\acute{Y}}, \qquad (21)$$

where *d* - profits from aircraft during the flight; *T* - flight hours of aircraft planned for the year, taking into account the peculiarities of the schedule and fuel consumption. Additional (non-production) flight hours of aircraft are determined by two factors. The first of them is associated with the loss of quality *i*-th system, which is involved in the formation of the optimal flight route of aircraft. The second factor is related to the forced landing of aircraft due to the failure of electronic systems, which are not included in the list of permitted faults to continue the flight.

**Results of the mathematical modeling**

Thus, the expression for $\Delta S$ (20) can be written as follows (22):

$$\Delta S = \sum_{i=0}^{N} \beta_i W[S_n(t_n)\Delta\phi_i]t_n + \sum_{j=0}^{n} [(1+\alpha j) - P_j(t)]S_B(t_n), \qquad (22)$$

where *N* – the number of types of electronic systems involved in the management of the flight path of aircraft; $\beta_i$ - unconditional probability of failure detection (quality loss) *i*-th electronic systems; $W\left[S_n(t_n)\Delta\phi_i\right]$ - scale factor, which characterizes the degree of deviation from the optimal flight trajectory with the loss of quality of the *i*-th system by the amount $\Delta\phi_i$; $t_n$ - flight time; *α* – unconditional probability of erroneous failure *j* -th electronic systems of systems; *n* - the number of electronic systems that are included in the class of unacceptable failures to continue the flight; $S_B(t_n)$ - the distance of the aircraft to the nearest place of forced landing. We can calculate the probability of transitions and states, the latter have the following meaning:

$$Z_1 = h\left\{\sum_{j=0}^{m}\left[1 - P_j(t)\right](1 - P^j_{\hat{I}\hat{O}})\left[P_{\hat{I}\ddot{I}}t_{B,j} + (1 - P_{\hat{I}\ddot{I}})t_{\ddot{a}}\right]\right\}, \qquad (23)$$

$P_0(t)$ - the probability of finding all electronic systems in a working sled;

$P_i(t)$ - probability of efficiency ι–th electronic systems from the class of the list of allowed malfunctions;

$P_j(t)$ - probability of efficiency *j*-th electronic systems from the class list of permitted faults;

$\text{Đ}^j_{\hat{I}\hat{O}}$ - the probability of having a transit airport *j*-th required system;

$t_{B,j}$ - recovery time *j*-th systems at the transit airport;

$t_{\ddot{a},j}$ - time of delivery of electronic systems from the base airport to the transit airport;

$t_{\hat{A}}$ - recovery time of electronic systems at the base airport;

$Đ_{\hat{I}\,\hat{O}}$ - the probability of having the required type of electronic systems in the base airport equipment;

$Đ_{\hat{I}\,\ddot{I}}$ - the probability that the transit airport will have service personnel required for recovery *j*-th electronic systems.

Losses due to flight delays at the base airport are determined from the following expression

$$Z_2 = h\left\{\sum_{i=1}^{N}\left[1 - P_0(t)\right](1 - P_{\hat{I}\,\hat{O}})t_B\right\}. \qquad (24)$$

Therefore, the average annual costs of an aviation enterprise according to (21) are determined from the expression

$$Ç_0 = d\frac{\Delta S}{V} + Z_1 + Z_2 + Ç_{Ý} \ . \qquad (25)$$

In the expression (25) component *З*<sub></sub>

$З_Э$ characterizes the costs of the aviation company for the acquisition. These costs are determined from the expression

$$Ç_{Ý} = K_0\sum_{i=1}^{N}C_i + \sum_{i=1}^{N}Ç_i^{\grave{O}\hat{I}\,\grave{E}Đ} + \sum_{i=1}^{N}Ç_i^{\hat{I}\,\hat{O}} + \sum_{i=1}^{N}Ç_i^{Đ\hat{E}} + \tilde{N}_{\tilde{A}\tilde{N}\grave{I}} \ , + \tilde{N}_{\hat{I}\,\ddot{I}} \qquad (26)$$

where $C_i$ - cost *i*-th electronic systems installed on aircraft; $K_0$ - regulatory rate of return of aircraft; $Ç_i^{\grave{O}\hat{I}\,\grave{E}Đ}$ - the average costs for maintenance and repair are given *i*-th systems; $Ç_i^{\hat{I}\,\hat{O}}$ - average annual costs for the acquisition of fixed assets *i*-th systems; $Ç_i^{Đ\hat{E}}$ - average annual costs for the purchase of repair kits by the company that carries out repairs for the year; $\tilde{N}_{\hat{I}\,\ddot{I}}$ - salaries of flight technicians.

The average annual profit of aircraft is determined by the formula

$$D = dT - Ç_0 \qquad (27)$$

Substituting formula (26) into expression (18), we obtain

$$F = \frac{dT}{Ç_0} - 1 \qquad (28)$$

Analysis of expression (28) allows us to conclude that the efficiency increases from –1 до + $\infty$ when changing the raid of aircraft (T) ot 0 до + $\infty$ . At $T = Ç_0 / d$ indicator *F=0*.

Therefore, it follows that inequality must be satisfied

$$T > Ç_0 / d \ . \qquad (29)$$

If the inequality is not satisfied and the flight time $T < Ç_0 / d$ , then the operation of aircraft with electronic systems installed on it is unprofitable.

The above expressions allow us to identify the main areas of improving the efficiency of electronic systems. The first area of research is related to the development of a scientifically sound list of permissible faults with which departure outside the base airport is allowed. For this purpose it is necessary: to group on a functional sign all products of radio electronic system of aircraft; to analyze the characteristics of the operation of products and the degree of influence of external conditions on their performance; to calculate the reliability of products; determine the target functions of the products under consideration and the list of failures that cause them to fail; build with the help of Markov chains mathematical models that describe the process of occurrence for each event at all stages of the flight, taking into account the season and day, the complexity of the route and the meteorological conditions on the route; similarly assess the conditional probabilities of getting into special situations as a consequence of each functional failure; assess the probability of getting into a special situation in the implementation of each calculated case for all functional failures of electronic systems.

Based on the results of research in this area, a scientifically sound list of permissible faults is formed, which allows to ensure flight safety and eliminate a reasonable increase $Z_1$ in expression (25).

The second area of research is related to the choice and justification of means of operational control. Practice shows that the correct choice of means of operational control mostly depends on the cost of maintenance and other non-production components (component $\Delta S$ in expression (25).

Operational control means include on-board embedded control systems and ground operational control means. On-board built-in control systems and ground-based means of operational control must form a single complex that ensures the performance of standard work in the operation of products of electronic systems. This complex should provide the possibility of information on the results of control between the built-in control systems and ground means of operational control.

The general design of the complex of means of operational control of electronic systems products should ensure the structural compatibility of the means of control in the complex and their elements with each other, unification of overall, adjusting, connecting dimensions of devices and their detachable connections, as well as information, metrological and operational compatibility.

The set of means of operational control should provide protection against damage from the effects of reboots, as well as from improper connection. Errors of service personnel with control bodies should not lead to failure of both products of electronic systems, and means of control.

At carrying out repair and restoration works and control of working capacity of the dismantled by the decision of the built-in control systems of products ground automated means of operational control of the following types are applied:

- automated ground means of operational control of the first level, which allow to determine with a high degree of reliability the technical condition of the product and to search for defects with a depth of the light-earth block;
- automated ground means of operational control of the second level, which allow to determine with a high degree of reliability the technical condition of the unit and to determine the search for defects with a depth of up to structural unit;
- utomated ground means of operational control of the third level, which allow to implement in the structural-zomic unit optimal algorithms for finding defects with depth to the non-renewable element.

We will consider in detail the main elements of optimization indicators of efficiency of operation and updating of electronic systems of aircraft in line with the strategy of repair of electronic systems of aircraft. Thus, the main disadvantage of the current repair strategy is to determine the scope of repair work, regardless of the individual operating time of the product and its technical condition. As a result, the cost of repair does not depend on the operating time and technical condition of the product.

In practice, usually, aircraft repair plants receive products with different operating times and in different technical condition and, of course, require different amounts of work to restore quality. The main purpose of the study is to develop recommendations for improving the strategy of electronic systems is to develop recommendations for improving strategies for repairing products, which would determine the scope of work depending on the processing of the resource product and its technical condition.

The main conditions for the implementation of such a strategy are the use of input control using automated ground-based operational control of the first level in determining the depth of disassembly and analysis of failure statistics in order to identify additional resource elements in the product.

Improving the quality and reducing repair costs can be achieved through the introduction of flexible repair technologies, taking into account the operating time, technical condition and improvements of products on the bulletin.

Progressive repair strategy provides a set of rules for assigning a list and scope of repair and restoration work (repair technology), taking into account the impact of products being repaired on the level of safety and regularity of aircraft, repair and control suitability, the nature of changes in reliability during operation, the cost of performing repair and restoration operations or replacement of the unit in the first category.

One of the main conditions for the implementation of a progressive repair strategy is the creation of information support at aircraft repair plants. Depending on the level of controllability of the product, two types of progressive repair strategy can be implemented. The first type of progressive repair strategy is applicable to products with a high level of controllability. A distinctive feature of this type of strategy is the preliminary defecting and determining the option of repair technology based on the results of input control without disassembly. The second type of progressive strategy is used for products with a low level of controllability.

Here, the preliminary defect and the choice of technology is introduced after complete or partial disassembly of the unit by internal control. Depending on the availability of information reliability service at aircraft repair plants, several technology options can be implemented within the selected type of progressive strategy.

Thus, in the presence of an information service of reliability at aircraft repair plants, three variants of technology can be implemented $T_1$ on the first type of progressive strategy and three technology options $T_2$ on the second type of progressive strategy. In the absence of an information service of reliability at aircraft repair plants, respectively, two variants of technology are used $T_1$ and two technology options $T_1$.

Let's define the basic ways and necessary conditions for improvement of strategy of repair of products of radio electronic elements of aircraft. The first condition for the transition to a progressive repair strategy is the creation of an information service of reliability at aircraft repair plants and their interaction with the information service of the aviation technical base. The second condition is the input control of products coming into repair.

In the first stage of improving strategies for control and diagnostic operations, existing ground-based means of operational control can be used. The next step in improving the repair strategy is the introduction of flexible automated ground-based operational control for the control and diagnosis of products. The final stage of improving repair strategies is the creation of local information networks based on flexible automated means of operational control to collect and process the information needed to identify additional resource elements and the formation of optimal repair kits.

Progressive repair strategies can significantly reduce the costs of the aviation company that uses the strategy for the organization of technical operation.

## II. CONCLUSION

In this paper, the mathematical solutions have been proposed to describe various variants of strategies for technical maintenance of modern avionics. The author has optimized operation and retrofitting indicators, which include both technical and economic indicators containing the optimal amount, of spare blocks that are easily replaced, having ensured that the scheduled flight frequency is maintained.

The analysis has been carried out pertaining to the possible variants to construct the system of technical operation and retrofitting of the radio-electronic system of aircraft. The author has justified the generalized indicator to estimate the efficiency of the system of technical operation of the radio-electronic systems and the main directions to increase their efficiency have been determined.

The selection of efficiency indicators of basic variants to construct the system of technical operation and retrofitting in radio electronic systems has been carried out. Mathematical expressions have been obtained, which, in turn, allows one to determine the specific costs in the system of technical operation and retrofitting in radio electronic systems, constructed in accordance with the basic variants.

The research results make it possible to practically calculate the optimal reserves for the aircraft fleet being operated, as well as to take into account the planned deliveries of aircraft for airlines. This fact leads us to conclude that the most optimal strategy has been obtained for technical operation and retrofitting.

## REFERENCES

[1]. Gertsbakh, I. Reliability theory with applications to preventive maintenance, N.Y.: Springer Verlag, 2000, 219 p.

[2]. Nakagawa, T. Two-unit redundant models / T. Nakagawa // Stochastic Models in Reliability and Maintenance. – N.Y.: Springer, 2002. – Issue 1 –165–185 p.

[3]. Konakhovych, G. Research of variants of construction of a system of technical maintenance and repair in aircraft engineering / Bulletin of the Engineering Academy of Ukraine. – 2012. – Issue 1, 52 – 56 p.

[4]. Konakhovych, G., Kozlyuk, I. Optimization of Operation of Advanced Aircraft by Technical and Economic Criteria // Problems of Informatization and Control. – Kyiv: Press of the NAU, 2005. – 79-85 p.

[5]. Kovalenko, Yu., Rybalka, L., Burlaka, M. "Analysis of the efficient functioning of the software in information control systems". Measuring and Computing Engineering in Technical Processes, Issue 1, pp. 95-100, 2016.
[6]. Kucher, O., Vlasenko, P., "Comparative Analysis of Reliability and Efficiency Indicators in Foreign and National Aviation". Knowledge-based Technology, Issue 2, pp. 11-19, 2009.
[7]. Kucher, O., Vlasenko, P., "Management of reliability of airline aircraft fleet ". Aerospace Technology and Technology, Issue 4, pp. 88-94, 2009.

Y. Kovalenko, et. al. "Specificity of optimization of performance indicators of technical operation and updating of radio electronic systems of aircraft." *International Journal of Engineering Research and Applications (IJERA)*, vol.10 (09), 2020, pp 48-58.