

The purpose of improving a method is to devise a tool for resolving contradictions in the practice of conflict events related to increasing the survivability and effectiveness of participation in a conflict event. A method for forecasting the survivability indicators of a special-purpose system based on the method of analytical-stochastic modeling of a conflict event was chosen as the basis for improvement.

The improved method is intended to find a compromise between the need to increase the duration of participation in the conflict and minimize the time of being at risk of loss of ability to function.

The use of the improved method, unlike the existing ones, provides an assessment of the impact of maneuver on the effectiveness of the implementation of tasks and the survivability of SPS. The method implies justifying the techniques for the executive elements to maneuver in order to create favorable conditions and effectively perform tasks in a conflict event.

The method involves the procedure for the formation of initial data; determining the maneuvering intensity of executive elements; comparing the parameters for expedient (rational) and implemented maneuvering techniques; the generalization of the research results.

The accepted indicators of the effectiveness and survivability of a special-purpose system in a conflict event are the mathematical expectations of the number of destructive influences and the number of preserved executive elements as a function of the intensity of maneuvering. The criteria defined for assessing the maneuvering techniques are the greatest values of the increase in efficiency and survivability with the change in the intensity of maneuvering and taking the favorable position by an executive element in a conflict event.

The specified method has helped investigate the peculiarities of changing performance and survivability indicators dependent on the intensity of maneuvering and determine the criteria signs for selecting maneuvering techniques.

Based on the signs of informativeness and the nature of the mutual influence of the relevant indicators, the advantage of the method is 30 % while the objectivity of taking into consideration significant factors increases by 15 %.

Practice needs to predict the consequences of processes of conflict-nature on the grounds of the effectiveness and survivability of its participants

Keywords: forecasting method, maneuvering techniques, evacuation, survivability indicators, conflict event

IMPROVING A METHOD FOR DETERMINING THE MANEUVERING INTENSITY OF THE EXECUTIVE ELEMENT OF A SPECIAL-PURPOSE SYSTEM

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1. Introduction

The peculiarity of any modern conflict events is the dependence of their results on the degree of provision with an appropriate resource, as well as conditions, which provide for a favorable position compared to the enemy [1].

Creating an aggressive environment against the enemy is a prerequisite for the success of the modern conflict, a characteristic feature of which is its transience and high reactivity. A party to the conflict, which is not able to adapt to changes in the situation and create more favorable conditions compared to the enemy, is doomed to defeat [1–4].

One of the signs of adaptability is maneuverability, which is essentially a characteristic of the ability of the elements of the opposing parties to occupy a favorable position in space for destructive influence on the enemy [2].

At the same time, the duration of maneuvering, as part of a conflict event, reduces the time to reproduce the destruc-

tive effect on the enemy, which is risky in terms of the loss of the initiative and, as a result, the failure to perform the tasks of the opposition [1, 2].

However, prolonged stay in position (frontier) increases the risk of loss of ability to fail [2]. Thus, a contradiction arises in the practice of conflict events, resolving which is possible by determining such maneuvering techniques at which the balance of effectiveness and survivability of the executive elements of a special-purpose system in conflict will be preserved.

Examples of such EEs are mobile communication, surface-to-air missile, missile, artillery, radar, radio electronic, radio engineering evacuation (transport) and other systems and complexes. The specified systems and complexes can be elements of the higher control system of air, ground, space, underwater, information spaces, life safety systems, etc.

This fact is evidence of the relevance of this issue and the need for a scientific approach to studying it.

2. Literature review and problem statement

Work [1] describes a methodical approach to determining the rational version of the maneuvering activities of the executive elements (EEs) in a special-purpose system (SPS) at the stages of preparation and participation in the conflict. The general provisions of the approach to the forecast of the consequences of maneuvering activities based on deterministic models of conflict events are set out. The proposed approach in [1] does not describe the functional relationship between the maneuver and the consequences of a conflict event. The criterion for selecting the maneuvering technique is not sensitive to determining the increase in the values of the corresponding indicators.

Paper [2] describes a scientific approach to predicting the survivability of executive elements in conflict events. Their consequences are assessed on the basis of the description of the dynamics of changes in the performance indicators of the implementation of EE tasks during the fight, taking into consideration the stochastic characteristics of the success of the maneuver. And the maneuver is assessed on the basis of the ratio of the available and the required time to move EEs within the conflict zone. However, in [2], the selection criterion for the maneuvering technique is not described, and changes in the corresponding indicators, depending on the maneuver technique, are not determined.

In [3–6], attention is paid to the search for rational solutions to the tasks of covering objects from the destructive influence of the enemy and forcing it to lose the initiative.

In [3], the approach to assessing the loss of EE types in a conflict is not sensitive enough to the specificity of deploying the SPS to participate in the conflict. Study [4], similarly to [3], does not form the rules for the selection of EEs for maneuver. In [5], the rule for assessing the maneuvering capabilities of conflict participants has not been formed. In [6], the system is considered as a set of elements deployed in space to perform conflict tasks, without taking into consideration the dynamics of changing the system structure and the corresponding consequences.

Works [7, 8] describe methods and models to study the destructive effects on objects in the EE area of interest. The search for values of indicators of the consequences of a conflict event in the area of interests of SPS is carried out on the basis of models of spatial conflicts. At the same time, the toolset for determining the corresponding performance indicators in [7] does not provide a search for critical values for their change. In addition, the nature of the change in the ability of EE to perform tasks is not described by appropriate dependences, which, in turn, does not make it possible to study ways to create favorable conditions for participation in the conflict. In [8], the redistribution (change) in EE performance is not reflected in the efficiency and survivability indicators of SPS. The conflict event forecasting procedure [7, 8] requires additional restrictions to eliminate the uncertainty of the forecast and devise appropriate recommendations for creating appropriate conditions for winning the conflict.

Paper [9] describes conflict events in the information space. In particular, the architecture of stable systems is considered under the conditions of the danger of destructive influence on the object and ways to counteract them. The state of SPS protection is diagnosed on the basis of the study of the state of the EE information system. However, the procedures for determining the consequences of destructive influence and

the need to create favorable conditions for the functioning of SPS do not provide for the search for an appropriate resource of activity. And this, in turn, cannot fully satisfy the need for recommendations on how to protect the system.

The review of works [1–9] suggests that existing scientific achievements are effective tools to study the effectiveness and survivability of SPS EEs in conflicts. However, investigating the peculiarities of the impact of maneuvering techniques in the interests of creating favorable conditions for participation in a conflict event requires deeper consideration.

Evidence of this is the lack of sensitivity of existing scientific developments to describe the impact of maneuvering techniques on the results of solving typical EE tasks in the conflict.

The above research methods only partially describe the impact on the survivability and effectiveness of the intensity of position change and the creation of a favorable position for participation in a conflict event. And this does not provide an assessment of the relevant indicators and does not make it possible to substantiate the appropriate maneuvering techniques and justify the relevant recommendations to the management bodies.

Thus, there is an unresolved issue in the theory of conflict studies related to the imperfection of existing methods for determining the maneuvering intensity of the executive element of a special-purpose system.

3. The aim and objectives of the study

The purpose of this study is to improve the method for determining the maneuvering intensity of the executive element of a special-purpose system. This will make it possible to describe the pattern of influence exerted on the effectiveness and survivability of SPS by the maneuvering techniques when performing EE tasks and justify a rational method in order to create favorable conditions for participation in a conflict event.

To accomplish the aim, the following tasks have been set:

- to determine the main stages in the method for determining the maneuvering intensity of the executive element of a special-purpose system;
- to describe the procedure for investigating the effectiveness and survivability of SPS in a conflict event;
- to examine the peculiarities of using the method in the interests of justifying the maneuvering intensity of the executive element of a special-purpose system in a conflict event.

4. The study materials and methods

An integrated approach forms the basis for the study of maneuvering techniques of the executive element of a special-purpose system [2].

The following methods were used during our study.

In order to study the patterns of change in the effectiveness and survivability indicators of SPS EEs in a conflict event, the methods of analytical-stochastic modeling of influence on the objects of destructive effects (ODE) [2] were used.

The description of conflict events corresponds to the stages of operational activities on the part of opposing systems. Characteristic are the military activities (air, ground, sea, etc.), special, combat, cyber actions, fighting, etc.

A special-purpose system is considered as a set of executive elements covered by the management of the minimum set of special and technical means necessary for performing tasks in a conflict event [2, 10]. Examples of executive elements are radar stations for reconnaissance, fire systems and complexes for defeating enemy means, electronic suppression means, vehicles for transportation and evacuation, etc.

Numerical differentiation methods were used to evaluate and determine rational SPS EE maneuvering techniques.

The hypotheses and assumptions taken for the study are characteristic of the conflict event and are described in detail in [2, 10].

An additional hypothesis of the method is the inability of EE to perform tasks once the measures are not completed to create favorable conditions. The beginning of destructive influence on ODEs is possible only from the moment of reaching the appropriate position (boundary).

The reliability of the study results is confirmed by the use of the verified scientific and methodological approaches and the procedure for proving the adequacy of the analytical-stochastic model given in works [2, 6, 10].

5. Results of the study on improving a method for determining the maneuvering intensity of the executive element of a special-purpose system

5.1. The main stages of the method for determining the maneuvering intensity of the executive element of a special-purpose system

To determine the maneuvering intensity of the executive element of a special-purpose system, a conflict event was considered with the participation of the executive element of a special-purpose system [2, 6, 10].

The executive element performs typical activities in order to destructively influence the objects of the opposing party, which may result in the success of reproducing destructive influence [2, 10]. The specified number of EEs is consolidated into a special-purpose system (SPS). EE's readiness to perform tasks in the conflict is determined by the degree of technical readiness K_{TR} the duration of the march (movement) t_m , the time required to take the position T_{TP} the time of setting the readiness to perform typical tasks t_{red} are determined by TTC.

The objects of the opposing party for SPS are ODEs whose number is N_{ODE} . The probable nature of ODE activities is determined by the conditions for their detection with the intensity of occurrence in the conflict zone (in the area of EE interests) I_{ODE} . Characteristics of the maneuvering techniques in the activities of SPS EEs is the number of spare positions of EEs (N_p), the intervals between them (I_{pos}) and the length of the route to them (S_p), the average speed of maneuver (movement) V_{av} .

The idea for improving the method [2] involves operations to take into consideration the peculiarities of the impact of significant factors on the quality indicators of SPS functioning.

In this case, the decisive ones for the improvement are:

- first, ensuring the assessment of the impact of EE maneuvering capabilities on the effectiveness of tasks and the survivability of SPS. In particular, determining the patterns of influence of the intensity of EE maneuver $I_m = \frac{K_{TR}}{T_{TP}}$, where TTC is the average frequency of change in a position, as well

as occupying a favorable position $I_{OPP} = \frac{K_{TR}}{t_m + t_{TP} + t_{red}}$ on the

mathematical expectations (ME) of the number of destructive influences on ODE MDE(t) and preserved EEs M_{pres} EE(t) in a conflict event;

- second, rendering a recommendation nature to the method, that is, the possibility of determining the rational (best in certain conditions) options for SPS EE maneuvering according to the indications of the mathematical expectation of the number of changes in EE positions $M_{CP}(t)$ and the average intensity of maneuvering over a certain time I_M . This will make it possible to substantiate the appropriate values of the average frequency of change in the position T_{TP} and the duration of the maneuver (movement) t_m for the occupation of the position, which will provide favorable conditions for participation in a conflict event.

The basic procedures of the method are the formation of initial data and modeling of the conflict event using the method of analytical-stochastic modeling, as well as the procedure for deciding on the option of building SPS and calculating the intensity of the maneuver.

The new procedures are to determine the intensity of SPS EE maneuver using the numerical differentiation method and to determine the necessary (appropriate) selection criteria in terms of meeting them.

The method consists of four stages (Fig. 1):

1. Stage 1 "Formation of initial data" includes procedures for determining the quantitative and qualitative composition, TTC, and the number of SPS EEs, the degree of EE readiness to maneuver. As for ODE: the characteristics, probable nature of counteraction to the destructive influence on objects by SPS. Also, we determine the number of positions (frontiers), the occupation of which can provide favorable conditions for the implementation of destructive impact on ODE, the intervals between positions (boundaries), the length of the route to them.

Based on the results of the formation of the initial data, a mock-up of the network of routes of SPS EE maneuver is built. With the help of geo, navigation, and other information systems, we determine the peculiarities of the process of modeling maneuvering techniques to perform EE tasks, as well as partial indicators that are the initial data for modeling a conflict event [2]. The patterns of a conflict event can be described on the basis of an analytical-stochastic model that meets the requirements of efficiency and reliability of simulation results [2].

2. Stage 2 "Determining the SPS EE maneuvering intensity" includes procedures from the eponymous subunits of the maneuvering intensity and the occupation of EE favorable position, in particular:

- the subunits "Formation of the scale of changes in the intensity of EE maneuver" and "Formation of the scale of change in the intensity of the occupation of EE favorable position" determine the permissible values for the intensity of the maneuver and the occupation of a favorable position, respectively. In these procedures, we perform the analysis of the nature of changes in the performance indicators to create favorable conditions for implementing SPS tasks. The number of calculation steps for the intensity of EE maneuver is multiple of the ratio of the duration of ODE response to the threat of destructive influence and the average time required by SPS to perform typical tasks. The number of steps to change the calculation of the intensity of occupying EE favorable position is multiple of the ratio of the average path, which can be traveled by EE to the minimum site of the spare position (boundary);

- the subunit “Calculation ME of the number of destroyed number of destructive effects (DE) and preserved EEs on the scale of maneuvering intensity” (Calculation ME of the number of objects of destructive effects and preserved EEs on the scale of the intensity of the maneuver (movement)) determines the nature of changes in the effectiveness of SPS functioning with a change in the intensity of maneuver;
- the subunit “Calculation ME of the number of destroyed number of DE and preserved EEs on the scale of change in the intensity of occupying EE favorable position” “Calculation ME of the number of objects of destructive influence and preserved EEs on the scale of intensity of occupation of a favorable position” determines the nature of changes in the effectiveness of SPS functioning with a change in the intensity of occupying EE favorable position. The basis for deriving appropriate dependences is the method of analytical-stochastic modeling of conflict nature processes [2, 11];
- the subunits “Assessment ME of the increase in the number of destructive influences (DIs) and preserved EEs on the scale of intensity of maneuver” and “Assessment of the ME increase in the number of DIs and preserved EEs on the scale of intensity of occupying EE favorable position” employ the method of numerical differentiation;

- the subunits “Determining the required values of the intensity of the maneuver” and “Determining the required values of the intensity of occupying a favorable position” determine the rational values for the intensity of the maneuver and for occupying a favorable position, respectively.
- The adopted criterion of rationality is: for the intensity of maneuver, the maximum value of the growth rate of the ratio of numerical values of performance and survivability of SPS; for the intensity of occupying a favorable position, the minimum value of the growth rate of the ratio of numerical values of SPS performance and survivability indicators.
3. Stage 3 “Comparison of the required distances and duration of stay in a favorable position and intervals between current (existing) positions according to the existing options for building (deploying) a special-purpose system” is implemented in the unit of the same name.
4. Stage 4 “Generalization of the study results” involves assessing the acceptability of the calculation results and choosing the option of constructing the SPS and EE maneuvering calculation with acceptable intensity. Otherwise, change the quantitative and qualitative composition of SPS and perform the next cycle of research.

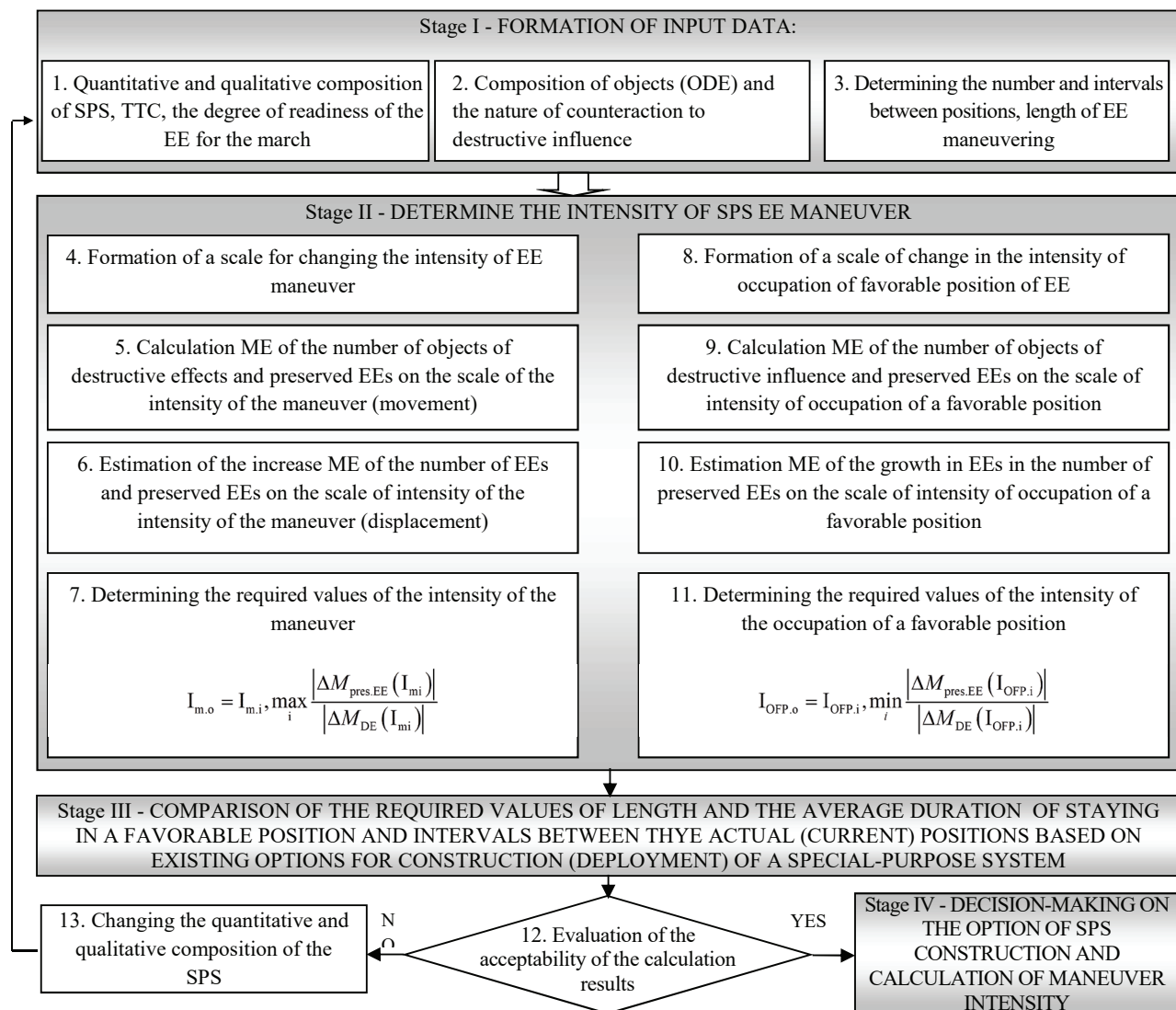


Fig. 1. Structural-logical scheme of the method for determining the maneuvering intensity of the executive element of a special-purpose system

5. 2. The procedure for studying the indicators of effectiveness and survivability of a special-purpose system in a conflict event

The procedure to study the performance and survivability indicators involves calculations in accordance with the stages of the method (Fig. 1).

It is important to note that the average periodicity of position change is essentially the time of performing typical tasks during a conflict event – destructive influence and preparation for maneuver (movement) t_{prep} . Therefore, the T_{TP} values should be within the limits of the average cycle of a destructive effect on ODE, and should not exceed the difference between the average time of effective counteraction by ODE T_{CA} and t_{prep} :

$$T_{DE} \leq T_{TP} \leq T_{CA} - t_{prep}. \quad (1)$$

Considering condition (1), the number of steps to increase T_{TP} within a certain interval should be chosen multiple of T_{DE} , and the number of steps to calculate I is determined from the following formula

$$I = ent \left(\frac{T_{CA} - t_{prep}}{T_{DE}} \right). \quad (2)$$

Considering (2), the calculation of possible values of the frequency of change in the EE position is carried out and a scale for changing the intensity of the EE maneuver with the index $i = \overline{1, I}$ is formed.

The description of the dependence of the SPS EE effectiveness and survivability in a conflict event of a certain duration $t = t_{conf}$ is carried out on the basis of the results of calculations of the corresponding indicators at I steps on the scale of the intensity of the maneuver from $I_{m \min}$ to $I_{m \max}$ at a fixed minimum value $I_{OFF, \min}$. ME of the EE quantity $M_{DE}(I_{mi}/I_{OFF, \min})$ and preserved SPS EEs $M_{presEE}(I_{mi}/I_{OFF, \min})$ are determined from analytical equations (3), (4) described in detail in [2, 11]

$$i = \overline{1, I}; \quad M_{DE}(I_{mi}/I_{OFF, \min}) = n_{EE} \frac{I_{ODE}}{\lambda_i(\lambda_i + a)} (1 - e^{-\lambda_i t}), \quad (3)$$

$$M_{presEE}(I_{mi}/I_{OFF, \min}) = n_{EE} \left[1 + \frac{\lambda_i(I_{ODE} + I_{mi}) + I_{mi}a + I_{ODE}z}{\beta} \right] e^{-\lambda_i t}, \quad (4)$$

where μ is the productivity of SPS EEs.

The values of the intermediate values λ_i , a , β , z are calculated taking into consideration the specified conditions [2].

The task of assessing the increase ME in the number of EEs $MDE(I_{mi}/I_{OFF, \min})$ and preserved SPS EEs $M_{presEE}(I_{mi}/I_{OFF, \min})$ is based on the procedure for finding a partial derivative from ∂I_m at constant values of other variables. Taking into consideration the fact that the law of distribution of performance and survivability indicators is known [2], the search for a partial derivative $\frac{\partial M_{DE}(I_m/I_{OFF, \min})}{\partial I_m}$ and $\frac{\partial M_{presEE}(I_m/I_{OFF, \min})}{\partial I_m}$ can be replaced by a numerical differentiation procedure for the corresponding number of calculation steps (2):

$$\begin{aligned} \frac{\partial M_{DE}(I_m/I_{OFF, \min})}{\partial I_m} &\approx \frac{\Delta M_{DE}(I_{mi})}{\Delta I_m} = \\ &= \frac{M_{DE}(I_{m(i+1)} + \Delta I_m) - M_{DE}(I_m)}{\Delta I_m}, \end{aligned} \quad (5)$$

$$\begin{aligned} \frac{\partial M_{presEE}(I_m/I_{OFF, \min})}{\partial I_m} &\approx \frac{\Delta M_{presEE}(I_{mi})}{\Delta I_m} = \\ &= \frac{M_{presEE}(I_{m(i+1)} + \Delta I_m) - M_{presEE}(I_m)}{\Delta I_m}. \end{aligned} \quad (6)$$

It is known [2, 11] that the maneuver leads to a potential decrease in efficiency and EE increased survivability. The reason for this is the decrease in the time of its stay in the state T_{TP} and the growth in I_m , which, in turn, is characterized by a decrease in $M_{DE}(t)$ and the growth in $M_{presEE}(t)$.

Therefore, it is logical to find a rational (the best under these conditions) value $I_{m,0} = I_{m,0}$ at which the growth of the indicator $M_{presEE}(I_{mi})$ in relation to the reduction in is the largest. Thus, the modulo ratio $|\Delta M_{presEE}(I_{mi}/I_{OFF, \min})|$ to $|\Delta M_{DE}(I_{mi}/I_{OFF, \min})|$ should acquire the maximum value.

Based on the above, the next step is to calculate the ratio of derivative modules (the rate of change in the numerical values of indicators) $|\Delta M_{presEE}(I_{mi})|$ to $|\Delta M_{DE}(I_{mi})|$, and, according to the criterion of its maximum, to determine the rational value $I_{m,0}$

$$I_{m,0} = I_{m,i}, \max_i \left| \frac{\Delta M_{presEE}(I_{mi})}{\Delta M_{DE}(I_{mi})} \right|, \quad i = \overline{1, I}. \quad (7)$$

The approach to the formation of the scale of changes in the intensity of occupying a favorable position by EE is similar.

To this end, the limits of the permissible values for the intensity of occupying EE favorable position I_{OFF} are calculated, defining for which is the duration of the EE maneuver (movement) t_m to the spare position (milestone) [2, 11].

It is reasonable that the following condition should be a restriction for t_m

$$\frac{S_{\min}}{V_{av}} \leq t_m \leq t_{conf} - t_{TP} - t_{red}, \quad (8)$$

where S_{\min} is the minimum allowable value of the reserve position distance (boundary) (as a rule, the value of at least the separate range of counter-party reconnaissance means is selected);

V_{av} – the average speed of maneuver (movement) of EE;

t_{conf} – the duration of a conflict event;

t_{TP} – the time required for EE to take the position (boundary);

t_{red} – the time it takes to bring EE to readiness to perform typical tasks in a conflict event.

The number of calculation steps, J is determined from the following formula (9)

$$\frac{S_{\min}}{V_{av}} \leq t_m \leq t_{conf} - t_{TP} - t_{red}, \quad (9)$$

Based on the calculation results (9), we calculate ME of the number of DIs and preserved EEs on the scale of the intensity of occupying a favorable position. Based on the value $I_{m,0}$, the indicators $M_{presEE}(t)$ and $M_{DE}(t)$

are determined, by changing the intensity of occupying a starting position in the range from $I_{TP.min}$ to $I_{TP.max}$ [11]

$$M_{DE}(I_{OFPj} / I_{m.o}) = n_{EE} \frac{I_{ODE}}{\lambda_{oj}(\lambda_{oj} + a)} (1 - e^{-\lambda_{oj}t}), \quad (10)$$

$$M_{pres.EE}(I_{OFPj} / I_{m.o}) = n_{EE} \left[1 + \frac{\lambda_{oj}(I_{ODE} + I_{m.o}) + aI_{m.o} + zI_{ODE}}{\beta} \right] e^{-\lambda_{oj}t}. \quad (11)$$

In the interest of assessing the increase ME in the number of DIs and preserved EEs with an increase in the intensity of occupying a starting position, numerical differentiation is carried out according to formulas (12), (13):

$$\frac{\partial M_{DE}(I_{OFP} / I_{m.o})}{\partial I_{OFP}} \approx \frac{\Delta M_{DE}(I_{OFPj})}{\Delta I_{OFP}} = \frac{M_{DE}(I_{OFP(j+1)} + \Delta I_{OFP}) - M_{DE}(I_{OFPj})}{\Delta I_{OFP}}, \quad (12)$$

$$\frac{\partial M_{pres.EE}(I_{OFP} / I_{m.o})}{\partial I_{OFP}} \approx \frac{\Delta M_{pres.EE}(I_{OFPj})}{\Delta I_{OFP}} = \frac{M_{pres.EE}(I_{OFP(j+1)} + \Delta I_{OFP}) - M_{pres.EE}(I_{OFPj})}{\Delta I_{OFP}}. \quad (13)$$

The intensity of occupying a favorable position is inversely proportional to the duration of the EE maneuver, with a decrease in which the first increases. In this case, the value of the mathematical expectation of the time of EE stay in a state of destructive influence for ODE, and, as a result, $M_{DE}(t)$ increases. At the same time, $M_{pres.EE}(t)$ tends to increase as, during the EE maneuver, the capabilities of the enemy to detect it and, accordingly, the counteraction decrease.

Consequently, there is a need to find such a value $I_{OFP.o} = I_{OFP.o}$ at which the growth in the indicator $M_{pres.EE}(I_{OFPj})$ in relation to a decrease in $M_{DE}(I_{OFPj})$ is minimal, that is, the ratio of modulo $|\Delta M_{pres.EE}(I_{OFPj})|$ to $|\Delta M_{DE}(I_{OFPj})|$ should be at a minimum.

Therefore, during the assessment, the ratio of modulo $|\Delta M_{pres.EE}(I_{OFPj}/I_{m.o})|$ to $|\Delta M_{DE}(I_{OFPj}/I_{m.o})|$ is compared and determined, and, according to the criterion of its minimum, the rational value $I_{OFP.o}$ is determined.

$$I_{OFP.o} = I_{OFPj}, \min_j \frac{|\Delta M_{pres.EE}(I_{OFPj} / I_{m.o})|}{|\Delta M_{DE}(I_{OFPj} / I_{m.o})|}, \quad j = \overline{1, J}. \quad (14)$$

According to criteria (7), (14), we choose the EE maneuvering techniques based on the existing SPS deployment options and determine the best one. During such selection, the number of positions (frontiers) is determined, the distance to which corresponds to the calculated values [11].

Once the calculation results are acceptable, we determine ME of the number of changes in positions (boundaries) for intensities $I_{m.o}$, $I_{OFP.o}$ and determine the average intensity of EE maneuvering to spare positions (frontiers) in accordance with the concept of the conflict event [11]

$$M_{CP}(t) = \frac{I_{m.o} I_{OFP.o} (N_P - 1)}{\lambda_{oo}(\lambda_{oo} + z)} (1 - e^{-\lambda_{oo}t}), \quad (15)$$

$$I_M = \frac{M_{CP}(t)}{t}. \quad (16)$$

In the case of inconsistencies, the quantitative composition of SPS is altered, and the calculation cycle is repeated.

5.3. Investigating the peculiarities in substantiating the maneuvering intensity of the executive element of a special-purpose system

Conditions characteristic of an air operation [6] were accepted for the study. During a conflict event, the process of performing the task of reconnaissance of airspace in the interests of radar provision of consumers [4] is considered.

It is believed that the success of sending information on the air situation is equivalent to the success of destructive influence.

The capabilities of radar support include a group of mobile radar stations with automated means of data transmission to destructive means. The destructive impact task is similar to the presence of information about air objects.

The limitations of this study are:

- a full-capacity airspace reconnaissance system consisting of 12 radar stations;
- the ordinality of the incoming flow of air objects as objects of destructive influence;
- the effectiveness of mutual destructive influence is taken equal to 1.

Calculations for the dependences of performance indicators were carried out in Microsoft Excel 2016.

The scenario of the conflict event, according to which SPS includes $n_{EE}=12$ EEs has been adopted. DI is carried out consistently with the performance of tasks $\mu = 1 \frac{DE}{min}$,

the conflict zone (in the SPS interests – air reconnaissance systems), there are operate 25 ODEs (air objects), 25 % of which are intended for direct counteraction to SSE EEs. The accepted intensity of entering the zone of SPS EE activities is $I_{OFP} = 1 \frac{DE}{min}$. The duration of the conflict event is

$t_{conf}=200$ min. [11].

EEs acquire the ability to perform destructive effects on ODEs after the completion of measures to create favorable conditions – maneuvering.

Based on the fully accessible analytical-stochastic model of a conflict event [2, 10], we derived the dependences $M_{DE}(I_{mi}/I_{OFP.min})$ (3), (4), (10), (11), preserved SPS EEs $M_{pres.EE}(I_{mi}/I_{OFP.min})$ (Fig. 2), and the ratio of growth modules of these indicators obtained on the basis of numerical differentiation (5), (6), (12), (13) (Fig. 3).

The analysis of dependences (Fig. 2) shows that as the value of the intensity of the EE maneuver I_m increases, $M_{pres.EE}(I_m)$ increases. At the same time, this leads to a decrease in the time of its stay in the state of DI, which leads to a decrease in $M_{DE}(t_{conf})$. The equality of $M_{DE}(I_m)$ and $M_{pres.EE}(I_m)$ is visible in the I_m value in the range from 0.11 to 0.12 (pos/min).

It is also characteristic that the long-term presence of EE in the position leads to an increase in M_{DE} only to values $I_m=0.017$ (pos/min), and, with a further decrease in intensity, the change of positions does not occur. This is explained by the fact that with prolonged stay in the position ODEs counteract SPS EEs, which leads to the loss of its ability to perform tasks in a conflict event. The increase in the intensity of changes in EE positions leads to the growth of $M_{pres.EE}$ and the simultaneous decrease in M_{DE} . Thus, the largest increase

in the survivability rate $M_{pres.EE}$ with the values of the performance indicator M_{DE} occurs within the I_m values from 0.044 to 0.09 and is 6.8% with a relative decrease in M_{DE} to the maximum permissible by 6.9%.

With significant distances of spare positions from the real (main) one, the values of SPS EE performance indicators almost do not change (Fig. 4, 5).

A significant impact on their change occurs within the I_{OFP} values from 0.045 to 0.09 (pos./min.). In this interval,

$M_{pres.EE}$ increases by 3.7%, M_{CP} – by 3.8%, and M_{DE} – by 1.8%. This is due to the fact that the intensity of the change in the position I_{OFP} is inversely proportional to the time required to take the position t_{TP} , the readiness t_{red} , and EE maneuver t_m , and is the quantity by which the time of the active phase of the conflict event decreases, that is, the time of being in the state of implementation of typical tasks. Under such conditions, an increase in the effectiveness of SPS in a conflict event is achieved, by an average of 19%.

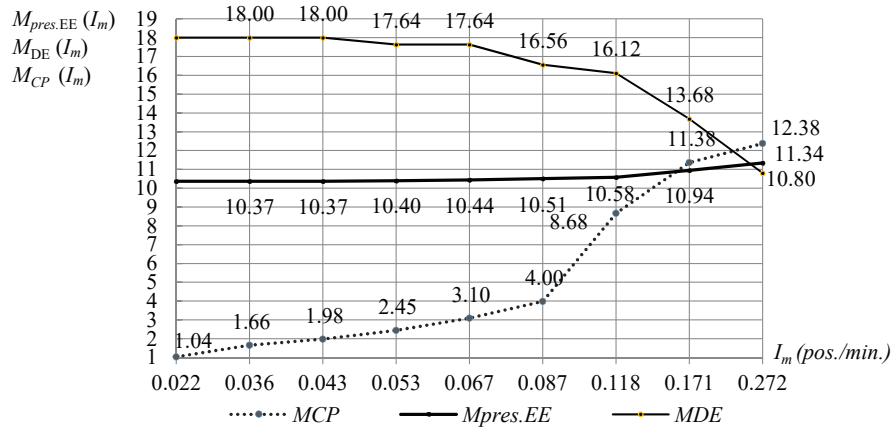


Fig. 2. Dependences of M_{DE} and $M_{pres.EE}$ on the intensity of maneuver

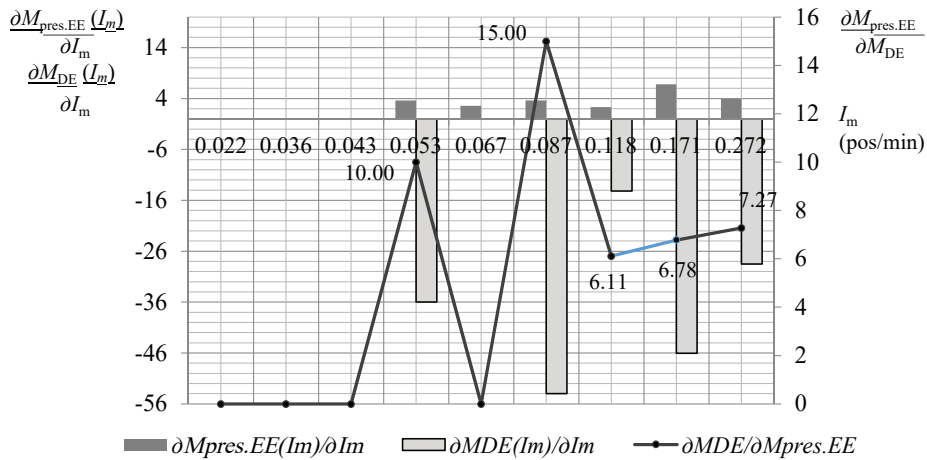


Fig. 3. The ratio of M_{DE} and $M_{pres.EE}$ growth modules depending on the intensity of the maneuver

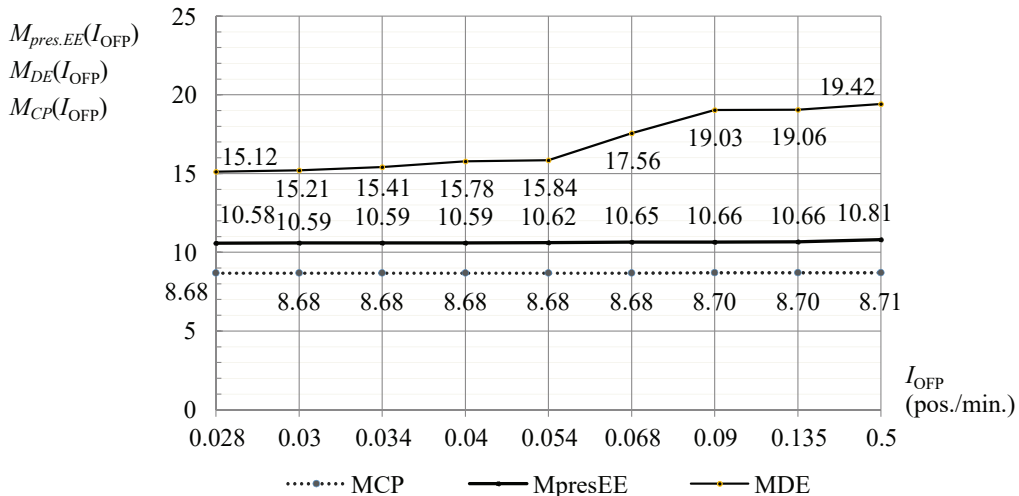


Fig. 4. Dependences of M_{DE} and $M_{pres.EE}$ on the intensity of taking a favorable position

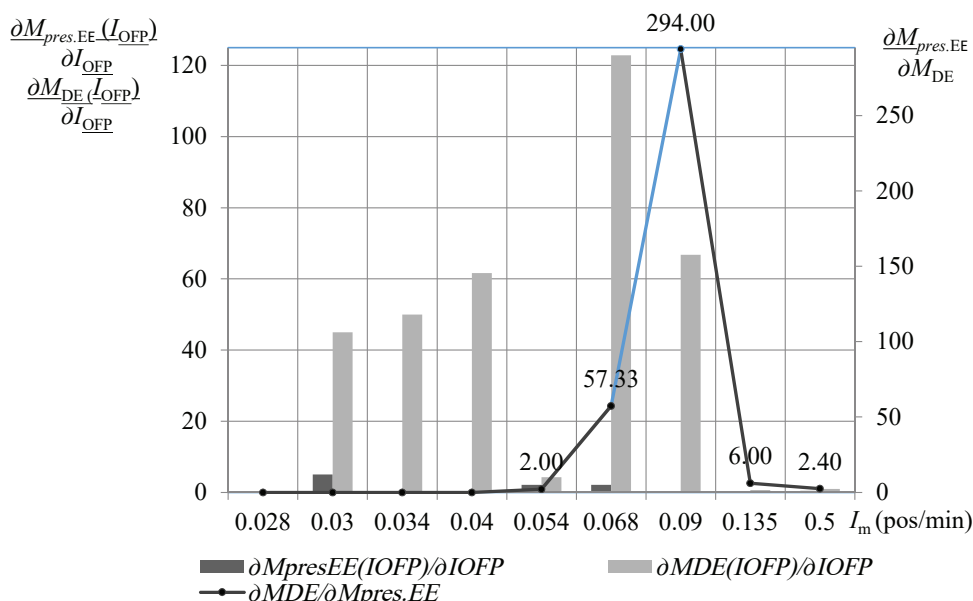


Fig. 5. The ratio of M_{DE} and $M_{pres.EE}$ growth modules depending on the intensity of occupying a favorable position

6. Discussion of results of studying the survivability of the executive element of a special-purpose system

The improved method for determining the maneuvering intensity of the executive element of a special-purpose system differs from [1–10]. The difference of the method is the ability to ensure the assessment of the impact of EE maneuvering capabilities on the effectiveness of the implementation of tasks and the survivability of SPS, as well as the determining the expedient (in certain conditions) EE maneuvering techniques.

The stages of the method (Fig. 1) are the formation of the initial data; determining the maneuvering intensity of SPS EEs; the comparison (evaluation) of maneuvering techniques; the generalization of the study results.

The study of performance and survivability indicators of a special-purpose system in a conflict event involves compliance with two conditions (1), (8).

The procedure of the study is based on the use of dependences to determine the SPS effectiveness and survivability indicators derived from the analytical-stochastic modeling of a conflict event (3), (4), (10), (11). Changing the values of the corresponding indicators of effectiveness and survivability is described by dependences (5), (6), (12), (13), based on the method of numerical differentiation.

The accepted criteria for choosing a maneuvering technique are (7), (14).

Under the conditions of acceptability of the calculation results, the indicator of maneuvering capabilities (15) is determined, and the average intensity of EE maneuvering to the spare positions (frontiers) (16) is determined in accordance with the concept of a conflict event.

Indicators (15) and (16) have practical value and provide a prognostic basis for calculating the needs of SPS EEs in logistical tools for participation in a conflict. In addition, (15), in its physical content, is a requirement for the number of spare positions (frontiers) that must be prepared (provided) to participate in the conflict.

The main peculiarity of substantiation of the intensity of maneuvering of the executive element is the study of the ratio of modules of increase in the performance and sur-

vivability indicators of a special-purpose system (Fig. 3, 5) according to the method of numerical differentiation.

The nature of their change with the change in relevant intensities describes the patterns of influence of the ways of deploying SPS and EE maneuvering on the corresponding consequences (Fig. 2, 4).

The main limitation of this method is the complexity of the formation of initial data for research and the impossibility of one-time conduct and preparation and destructive influence. Note that obtaining the recommended values for indicators (15), (16) is possible under conditions (1), (8).

Unlike [1, 3–7], this method additionally provides for investigating the impact on maneuver performance indicators. And, compared to [8, 9], it makes it possible to taking into consideration the impact of productivity on the performance and survivability indicators and determining the appropriate resource (technique) of activity.

Unlike [2], it reflects the speed of change in the effectiveness of SPS depending on the maneuvering technique in order to create favorable conditions in a conflict.

The informativeness of the method, according to the set of indicators and the nature of their mutual influence (3), (4), (10), (11), (15), compared to those indicated in [1–10], increases by 30 %, and ensures an increase in the objectivity of taking into consideration significant factors at the level of 15 %.

The method can be further advanced by adapting it to study the patterns of change in the performance indicators described by other methods of modeling the conflict event, provided that additional hypotheses and assumptions are substantiated.

The method was validated at scientific and practical conferences and seminars; it was implemented during military-strategic games in the form of simulated conflict events at the Ivan Chernyakhovskiy National Defense University of Ukraine.

7. Conclusions

1. The improved method for determining the maneuvering intensity of the executive element of a special-purpose

system involves four main stages. The initial stage is the formation of the source data. Next, the SPS EE maneuvering intensity is determined, the required distance and duration of being in a favorable position at intervals between actual (existing) positions (frontiers) according to the existing options for building (deploying) the system are compared. At the final stage, the results of the study are summarized. The basic basis for the application of the method is the results of modeling the pattern of change in the values of performance and survivability indicators for SPS EEs, depending on the EE maneuvering techniques. The main difference of the method is the ability to determine the rational (expedient) SPS EE maneuvering techniques in the interests of creating favorable conditions for participation in a conflict event. Practice needs to predict the required number of spare positions and boundaries, the early arrangement of which could ensure success in a conflict event.

According to the signs of informativeness and the nature of the mutual influence of the relevant indicators, the advantage of the method is 30 %; the objectivity of taking into consideration significant factors increases by 15 %.

2. The procedure for investigating the SPS effectiveness and survivability indicators in a conflict event involves the construction of the distribution of values of the corresponding indicators (mathematical expectations of the number of

destructive influences and the number of preserved EEs) on the relevant scales.

Expedient maneuvering techniques are determined by compliance with the criteria for changing the values of the effectiveness and survivability of SPS EEs on the scales of the intensity of maneuvering and taking a favorable position by means of numerical differentiation.

3. Our study of the peculiarities of the method has shown that in practical activities the procedure for justifying the intensity of maneuvering of the executive element of a special-purpose system in a conflict event is quite simple. The given example demonstrated the ease of using graphical models of changing the values of indicators based on the results of calculations. And the possibility of finding simple solutions based on analytical approaches emphasizes the improved method's clear recommendation nature that achieves the goal of the study.

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