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Comprehensive methodology for the rational distribution of air defence assets to protect troops and objects from various types of air attack assets (general provisions)

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Abstract. This article presents the main provisions of a comprehensive methodology for the air defence assets' allocation to cover troops and objects from various types of air attack assets, which is based on two main methods: predicting the anticipated actions of air attack assets in a strike, the essence of which is the sequential distribution of specific air attack assets to the attack objects considering their importance and the advantage degree of the air attack assets' action on them, which allows to estimate predicted losses of troops and objects for the purpose to employ them further during the assessment of anti-aircraft missile systems capabilities to destroy certain types of air attack assets and the air defence assets' distribution to cover troops and objects, the essence of which is the anti-aircraft missile systems' sequential distribution (anti-aircraft missile systems composition options) to cover the most important objects considering expected actions of air attack assets and the advantage degree of certain types of anti-aircraft missile systems employment to destroy air attack assets of certain classes and types. The methodology's comprehensiveness essence lies in the following: determining the possible enemy's first missile and air strike objects' list, taking into account their importance; predicting the expected actions of air attack assets in the strike, taking into account the advantage of their use against cover objects (based on the eponymous method); assessing the anti-aircraft missile systems' capabilities to defeat certain types (classes) of air attack assets, taking into account the advantage of using these systems against these air attack assets' types; allocation of anti-

aircraft missile systems (based on the eponymous method), taking into account the specifics of their employment by individual types (classes) of air attack weapons to cover objects from air strikes.

Keywords: air attack assets, anti-aircraft missile cover, effectiveness assessment, enemy's actions prediction, air defence, assets allocation.

Introduction

From the experience of repulsing russian aggression, it follows that various types of air attack assets (AAA) can be used against troops and objects, namely: land-based non-strategic ballistic missile (NSBM); air-based, sea-based, land-based cruise missiles (CM); unmanned combat aerial vehicles (UCAV); manned aviation (MA). At the same time, it should be emphasized that the russian aerospace forces` aviation, missile forces and artillery of the land forces, as well as surface ships, submarines and coastal mobile missile systems of the Navy, launched combined strikes with ballistic, aeroballistic and cruise missiles. The following missile carriers were used to launch combined missile strikes:

– air-based cruise missile: X-101, X-55 (training missiles with nuclear warhead imitators), X-555 and X-22 – strategic bombers TU-160, TU-95 and TU-22M3; X-31, X-59 – fighter aircrafts and bombers SU-24, -30, -34, -35);

– sea-based cruise missile “Kalibr” – surface ships and submarines of the Black Sea Fleet and surface ships of the Caspian flotilla;

– land-based cruise missiles – “Iskander-K” tactical missile system;

– anti-ship missiles 3M-55 (P-800) “Onyx” – “Bastion-P” mobile coastal missile system;

– anti-ship missiles X-35 – “Bal” coastal missile system;

– non-strategic ballistic missile – Iskander-M” tactical missile system and “Tochka-U” tactical missile system;

– air-based aeroballistic missile X-47 – MIG-31K aircraft of “Kinzhal” aviation missile system;

– anti-aircraft guided missiles (whose flight, when firing at ground targets, is carried out practically along ballistic trajectories) – anti-aircraft systems launchers (AS) S-300P and S-400.

Table 1 shows some characteristics of the air attack assets used in the Russian-Ukrainian war since the beginning of full-scale aggression (Zhyvotovskyi, 2022), (Nor, 2022), (Katsan, 2022), (Kolesnyk, 2022), (Shkurat, 2023).

Employment of any type of air attack assets against specific targets is primarily determined by their availability, range, importance of the target, capabilities to destroy the target, economic and other considerations.

In meanwhile, air defence assets (ADA) that can be used to protect objects from air strikes are characterized by different capabilities to destroy different types of air attack assets and differ in their firing zones. Some anti-aircraft missile systems cannot be used at all to destroy certain types of air attack asssets (e.g., ballistic and aeroballistic missiles). In addition, covering objects from strikes by certain types of air attack assets (especially ballistic and cruise missiles) requires taking into account some peculiarities of the combat formation build-up of units armed with anti-aircraft systems. Table 2 shows the main characteristics of anti-aircraft systems in service with the Armed Forces of Ukraine at the beginning of the armed aggression of the russian federation, as well as some foreign systems provided by partner countries.

Thus, when organizing the protection of troops and objects from strikes by various types of air attack assets, it is necessary: first, to predict the actions of certain types of air attack assets on troops and objects; second, to ensure the rational distribution of air defence assets to protect troops and objects considering the peculiarities of their employment against certain types of air attack assets.

Materials and Methods

Many works have been devoted to predicting the actions of manned aviation and cruise missiles against troops and objects during air strike (Horodnov, 1999), (Onyshchenko, 2011), (Romanchenko, 2011). However, they do not consider the effects of non-strategic ballistic missiles (NSBMs) and UCAVs against troops and objects, especially when they are used together. In addition, these works do not fully take into account the characteristics of targets when predicting strikes by air attack assets.

Some peculiarities of building the objects' defence from CM and NSBM strikes were analyzed earlier (Romanchenko, 2011), (Toropchyn, 2003), (Zahorka, 1998). However, the objects' defence from these types of air attack assets strikes is considered separately, and the general capabilities of air defence assets to protect troops and objects from rocket and avitaion strikes (RAS) in an operation (during combat operations) are not taken into account.

Table 1. Some characteristics of main air attack assets used in russian-Ukrainian war.

Class (type) of air attack assets	Firing range (launch), km	Launch weight, kg	Warhead weight, kg	Maximal velocity, m/s	Flight height (max.), km	Accuracy (CEP), m	Maneuver possibility
Non-strategic ballistic missiles							
TMS 9M723 MS "Iskander-M"	500	3800	480	2100	50,0	5-7	+
TMS 9M79-1 MS "Tochka-U"	120	2010	470	800	26,0	100	–
Aeroballistic missiles							
ABM X-47M2 aviation MS "Kinzhal "	2000	3500	500	4080	50,0	3-5	+
ABM X-22 "Burya"	550	5675	900	1550	24,0	300	–
Anti-aircraft guided missiles							
AGM 5B55 S-300P SAM	120	1660	130	2000	27,0	*	–
AGM 48H6 S-400 SAM	259	1830	180	2000	27,0	*	–
Air-based cruise missiles							
CM X-555	3500	1280	410	230	6,0	20	+
CM X-101	5000	2400	430	270	6,0	10	+
CM X-59	290	930	320	290	50,0	5	
CM X-31	250	715	110	1000	16,0	*	
Sea-based cruise missiles							
CM 3M-14 "Kalibr-NK, -PCH"	2500	1450	450	270	6,0	5	+
Land-based cruise missiles							
CM 9M729 MS "Iskander-K"	2500	1770	450	270	6,0	5	+
Anti-ship CM 3M-55 "Onyx" of coastal MS "Bastion-P"	800	3000	300	880	14,0	3	–
Anti-ship CM X-35 of coastal MS "Bal"	130	620	145	290	6,0	10	+

Note* - data is absent.

Thus, the issue of substantiating the procedure and methods that should be used to allocate air defence assets in the organization of covering troops and objects from attacks by various types of air attack assets remains relevant today. The article proposes the general provisions of a comprehensive methodology for the rational allocation of air defence assets to protect troops and objects from attacks by various types of air attack assets, based on two main methods: determining the expected actions of air attack assets during strike and allocating air defence assets to protect troops and objects.

A Method for Predicting the Air Attack Assets' Expected Actions in a Strike.

Assessment of air enemy's possible actions is one of the important elements of air defence organization that ensure the validity of decisions made in the organizing process of the troops and objects from air strikes' protection, improving and developing methods of the air defence assets combat employment.

Table 2. Main characteristics of anti-aircraft assets.

Name of anti-aircraft asset	Main characteristics of the system						Capability to destroy BM and ABM
	Maximal range / target engagement height, km	Target's maximal velocity / AGM, m/s	Channeling on target, km	AGM weight / warhead, kg	Number of missiles (shots) in the SAM/ in the launcher, pcs.	Deployment time min.	
Anti-aircraft assets which were in service with the Armed Forces of Ukraine							
SAM system S-300PT (PS)	75 / 27	1300 / 2000	до 6	1665 / 133	48 / 4	90 (5)	+
SAM system S-300B1	75 / 25	3000 / 1200	до 6	2500 / 150	24 / 4	5	+
SAM system «Buk-M1»	35 / 22	830 / 1100	1	690 /70	4	5	–
CV SAM «Tor-M1»	12 / 6	700 / 850	1	165 / 15	8	5	–
CV SAM «Osa-AKM»	10 / 5	500 / 500	1	126 / 15	6	3	–
CV SAM «Strila-10M»	5 / 3,5	415 / 550	1	40 / 5	8	1	–
SPAAG «Tunguska-M»	8 / 3,5	500 / 900	1	42 / 9	8 (1904)	3	–
SPAAG-23-4 «Shilka»	2,5 / 1,5	450 / -	1	–	(2000)	3	–
ZU-23	2,5 / 1,5	400 / –	1	–		0,5	–
Anti-aircraft assets provided by partners							
«Patriot PAC-2» SAM MIM-104 C/D	90 / 25	2200 / 1750	до 8	906	до 36 / 4	30	+
«Patriot PAC-3» PR ERINT	40 / 20	3000 / 2300	до 8	316 / 24	до 144 / 16	30	+
MIM-104 F »	150 / 25	3000 / 2000	до 8	1500 / 90	до 36 / 4	30	+
SAMP-T	100 / 20	1000 / 3M	16	445 / 15	48 / 8	15	+
IRIS-T	40 / 20	1000 / 3M	24	87 / 11	24 / 8	10	–
Improved Hoc	50 / 18	/ 900	1	590 / 54	18 / 3	45	–
NASAMS	40 / 16	1000 / 1020	3	150 / 22	48 / 6	15	–
Krotal	10 / 6	500 /1250	1	73 / 13	8	3	–
SPAAG «Gepard»	4 / 3	400	1	–	(319)	3	–

The input data for predicting the expected actions of the air attack assets during strike are: the state's facilities and our troops to be covered from air strikes, as well as the composition of the grouping of air defence assets (for all objects that can be targeted by air attack assets, their importance is determined); the possible composition of the enemy's groups.

It is proposed to predict the expected actions of the enemy during the employment of different types of air attack assets during strike on the basis of the A Method for Predicting the Air Attack Assets' Expected Actions in a Strike, the structural diagram of which is shown in Fig. 1.

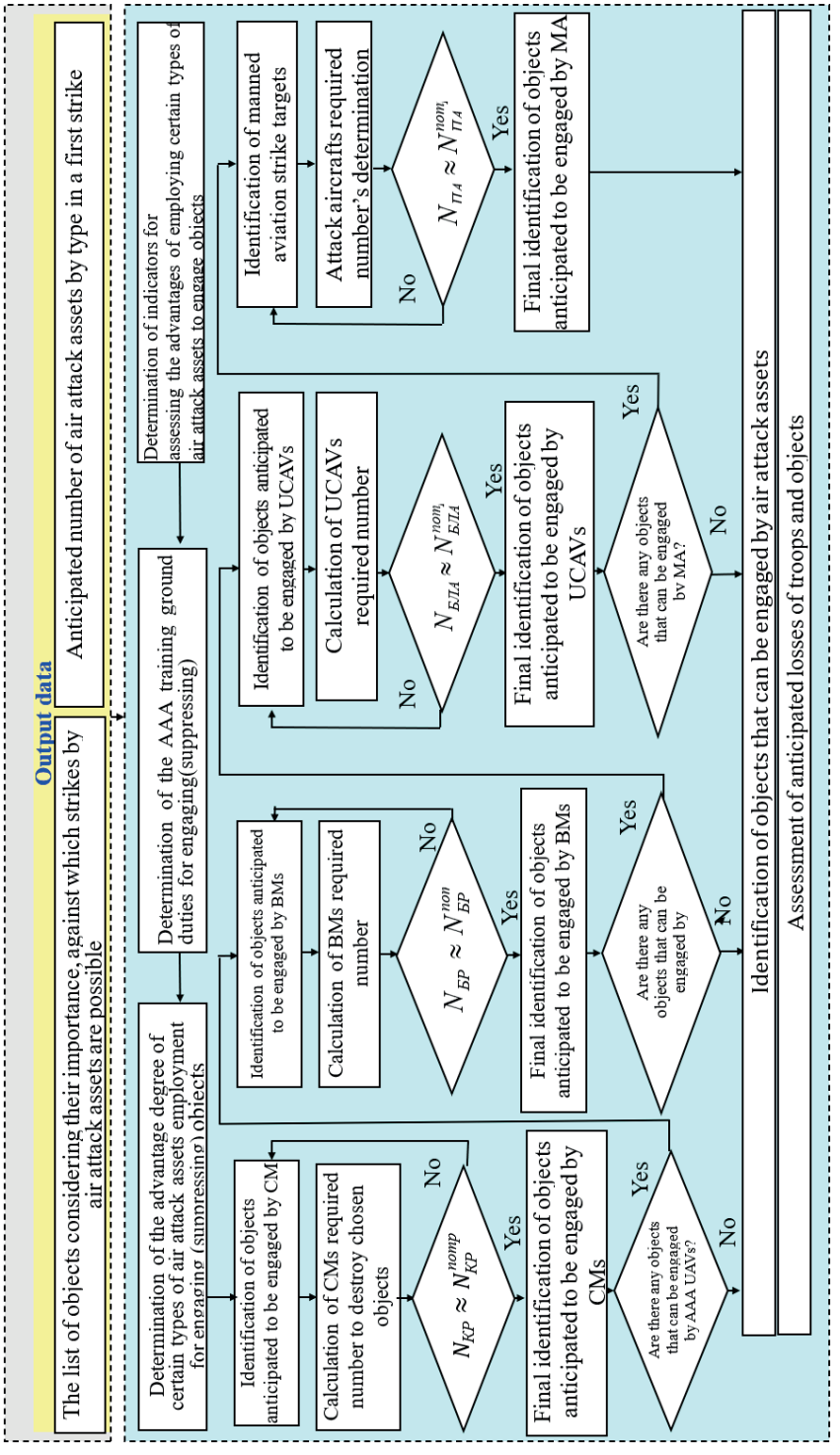


Figure 1. A Method for Predicting the Air Attack Assets' Expected Actions in a Strike block diagram

According to this method, for each target, taking into account its importance, it is planned to determine the degree of advantage of using specific types of air attack assets to defeat (suppress) it.

To determine the superiority degree, indicators can be used that characterise: condition fulfilment for the AAA's required range (determined by a topographic map); object's target destruction (suppression) probability when using one AAA; AAA's missile cost to destroy (suppress) an object; the object's coverage degree by air defence assets; possible personnel losses when using AAA; the necessity to deliver a point attack on an object; limitation on AAA's certain type number, etc.

To determine the advantage degree of AAA (air attack assets) certain types' application for each object, taxonomy methods can be used (Pliuta, 1989), the computational procedures of which have been worked out in detail in solving other problems.

The assessment results of the superiority degree of actions against the objects of AAA's certain types are the basis for forecasting the expected AAA actions against troops and objects.

Initially, considering the experience of military conflicts and the accepted operational formation of the AAA in the RAS (Rocket Aviation Strike), it is envisaged to distribute the strike forces to the CM (cruise missiles). To accomplish this task, as in (Horodnov, 1999), the iteration method is employed.

Objects of destruction (suppression) for CM are determined taking into account their importance and the degree of advantage of actions against them of this type of AAA. Iterations are carried out until the required number of CMs for destruction (suppression) of selected objects $\left(N_{KP}^{потр.}\right)$ is equal to the number of CMs that can be used in RAS (N_{KP}). Based on the results of iterations, the number of objects for which the effect of the CM is predicted may either decrease or increase.

Next, the presence of objects for which no CMs have been applied is checked. If there are no such objects, the objects that are expected to be affected by the AAA (in this case, only by the CM) are finally determined. If there are still targets that can be struck by the AAA, they are then distributed for destruction (suppression) by the AAAs next type (in this case, NSBM), also using the iteration method. The procedures used to allocate objects for destruction (suppression) by AAAs different types are similar.

Thus, the expected effects of AAAs different types on troops and objects in the RAS are predicted.

The results of determining the targets on which the effects of the AAAs are expected to be directed allow estimating the projected losses of troops and objects from their strikes.

The mathematical expectation of the value of the predicted losses that can be caused by a CM separately to economic and public administration objects and military objects in conventional units of their importance is determined by the formula:

$$M_{KP} = \sum_{i} B_{зн.i}^{KP} P_{зн.} + \sum_{j} B_{прид.i}^{KP} P_{прид.}, \quad (1)$$

where i, j are, respectively, the numbers of the economic and public administration object or military object to be destroyed or suppressed;

$m_{зн.}^{KP}$, - respectively, the number of objects to be destroyed or suppressed;

$B_{зн.i}^{KP}$ - is the importance coefficient of the i-th object;

$B_{приd.j}^{KP}$ - is the importance coefficient of the j-th object;

$P_{зн.}, P_{приd.}$ - probability of destruction, suppression of the object, respectively.

Similarly, the mathematical expectations of troops losses and objects from strikes by NSBMs (M_{NSBM}), UCAVs (M_{UCAV}), and MAs (M_{MA}) are determined in conventional units of importance.

The mathematical expectations of the total losses of economic and governmental objects and military targets from strikes by air attack assets are as follows:

$$M_{o} = M^{o}_{CM} + M^{o}_{NSBM} + M^{o}_{UCAV} + M^{o}_{MA};\ M_{в} = M^{в}_{CM} + M^{в}_{NSBM} + M^{в}_{UCAV} + M^{в}_{MA}. \quad (2)$$

Accordingly, the mathematical expectations of the projected values of relative losses are determined by the following formulas:

$$R_{o} = \frac{M_{o}}{\sum_{v=1}^{L} B_{v}};\ R_{в} = \frac{M_{в}}{\sum_{\xi=1}^{S} B_{\xi}}, \quad (3)$$

where B_v, B_ξ *are* the importance *coefficients* of the *v-th* economic and public administration object and the *-th* military object, respectively;

L, S - the number of economic and public administration objects and military objects, respectively, which may be targeted by the AAA for the purpose of striking (determined at the first stage of the methodology).

Thus, the proposed Method for predicting the expected actions of the AAA in a strike allows us to estimate the possible losses of troops and objects from air strikes in order to use the results of such prediction in the future when allocating air defence assets to protect the most important objects and troops.

Allocating air defence assets to protect troops and objects' method

The allocation of air defence forces and assets to protect troops and objects from attacks by various types of air attack assets is one of the important tasks in the organization of air defence.

To ensure such distribution, taking into account the peculiarities of the employment of air defence assets for certain types of air attack assets, we propose the of Allocation of Air Defence assets to Protect Troops and Objects' Method, the structural diagram of which is shown in Fig. 2.

When allocating air defence assets, the main attention should be paid to ensuring reliable anti-missile defence of the most important objects against NSBM strikes. This is primarily due to the advantage and suddenness of their employment in the first strikes of an enemy air offensive. The employment of cruise missiles in massive strikes has become an essential component of all operations conducted by the United States and its allies. It should be noted that the massive employment of expensive CRs in military operations (over 1 million US dollars per unit) is justified only at the first stage of hostilities. In the future, the main burden in fulfilling the tasks of destroying the enemy should be borne by aviation, which employs precision weapons.

For example, modern guided aviation bombs provide a relatively impressive effect at a lower cost, 60 times lower. Therefore, when allocating air defence assets to protect objects from unmanned aerial vehicles, it is necessary to take into account the possibility of using them even at the first stage of military operations of the MA (Manned Aviation).

The allocation of air defence assets depends on many factors that must be taken into account when organizing the protection of troops and objects from air strikes. The need to take into account the peculiarities of covering objects from strikes by such AAA as NSBM and CR requires a more thorough approach to the construction of combat formations of air defence units, i.e., the ways of employment air defence assets.

Obviously, when organizing air defence for each facility, it is necessary to assess the effectiveness of its coverage. For such an assessment, it is impossible to employ models for assessing the effectiveness of the air defence system as a whole, because they do not fully take into account the changes in the ways of covering individual objects from attacks by different types of air attack assets. In this case, it is preferable to employ partial models and methods (Romanchenko, 2011), (Chuev,

1965), which will optimize the composition and methods of employing air defence assets to protect individual objects.

The distribution of air defence assets launches with the protection organization for the most important objects, taking into account the results of predicting the expected actions of the AAA and the degree of advantage of employing certain types of SAM's to defeat certain types (classes) of AAA.

To protect the object, several or many variants of the SAM composition are formed. Employing the topographic map, the possibility of leveraging SAMs that were previously intended for covering other objects is taken into account.

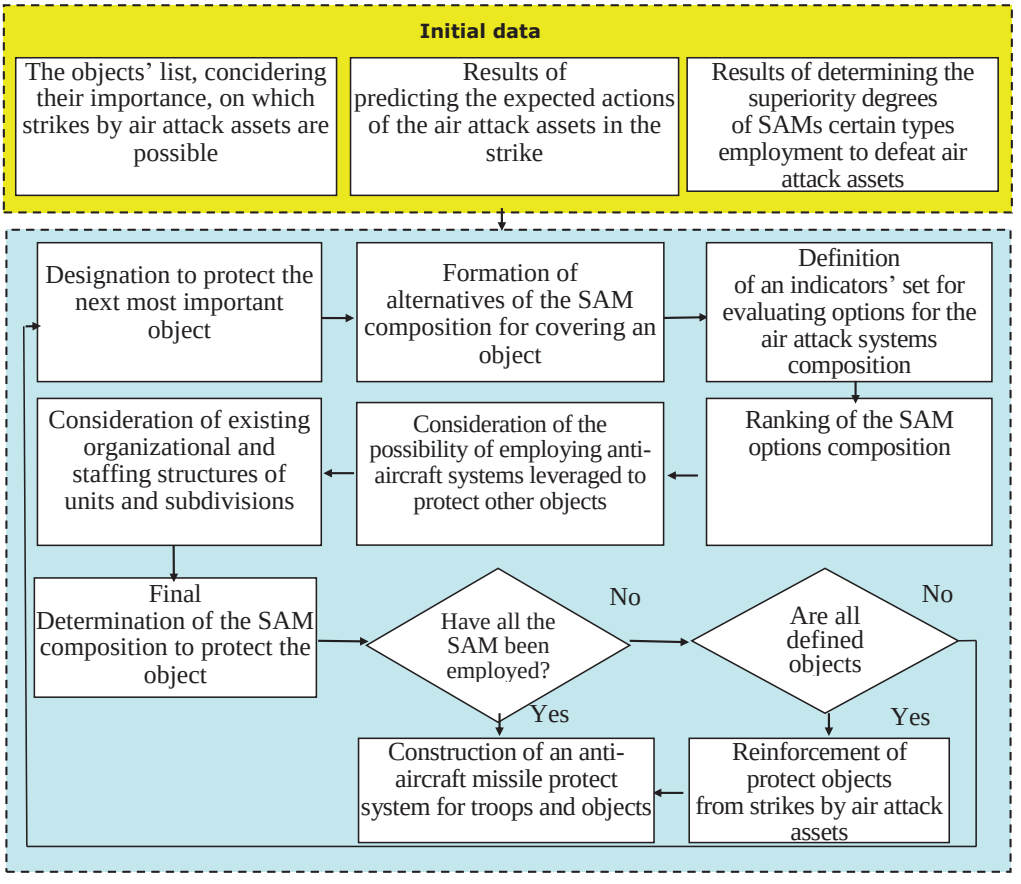


Figure 2. Flowchart of the Air Defence Forces and Assets Allocation for Troop and objects' cover Method

The selection of a rational variant of the SAM composition is carried out employing a set of indicators that characterize: the fire capabilities of the SAM composition that can be realized during the repulsion of an air defence strike on the object; the effectiveness of covering the object; losses of SAMs during an air attack assets strike repulsion; the SAM composition's cost; missile costs, etc.

Taxonomy methods can be employed to determine the rational composition of air attack assets for covering an object based on a set of the listed indicators (ranking of anti-aircraft missile system composition options) (Pliuta, 1989).

The process of allocating air defence assets to protect targets continues until all SAMs that can participate in the air operation are used or until all targets are protected.

If there are any SAMs left that are not employed, the coverage of individual targets is reinforced. This is how the system of air defence missile coverage of troops and objects is practically justified.

A comprehensive methodology for the air defence assets' rational allocation to protect troops and objects from attacks of air attack assets various types.

The structural diagram of the comprehensive methodology for the air defence assets' rational distribution to protect troops and objects from attacks by air attack assets various types is shown in Fig. 3.

At the methodology's ***first stage***, all targets that may be struck by AAA in the first rocket aviation strike of an air offensive operation are identified and their importance is assessed.

If we draw on the experience of recent military conflicts, it turns out that they usually began with an air offensive by the party that started them.

The first strikes were carried out against air defence objects, airfields, missile systems, troop control centers, energy objects, communication hubs, and other important targets employing unmanned air attack assets. At the same time, the employment of unmanned air attack assets in the first strikes to fulfill the tasks of an air offensive were not ruled out. This is due to the limited number of unmanned air attack assets and the need to perform special tasks.

The defending party may conduct an air operation, one of the main tasks of which is troops and objects' air defence. To organize this task, it is necessary, first of all, to determine the list of objects that can be targeted by AAAs to fulfill the tasks of the first rocket aviation strike.

It is believed that at the time of a military conflict, the number of AAAs by type is known. Predicting the expected number of AAAs in the first strike is based on their combat readiness and reserve coefficients. The operational formation of the first RAS, taking into account the employment of AAA in recent military conflicts, may include: a CR echelon; an NSBM echelon; groups or single UCAVs; a echelon or groups of MAs for various purposes.

At the first stage of the methodology, all targets that can be struck by AAAs in the first rocket aviation strike of an air offensive operation are identified. For this purpose, a topographic map is used, which shows economic and governmental facilities that may be located in the war zone, as well as the structure of the grouping of our troops.

To determine the coefficients of importance of economic and public administration objects and the coefficients of operational and tactical importance of military objects, it is advisable to use

the Method of Hierarchy Analysis (MAI) (Saaty, 1985), (Samokhvalov, 2007). Hierarchical representations of the tasks of determining the coefficients of importance of economic and public administration objects, as well as the coefficients of operational and tactical importance of military objects are shown in Fig. 4 (Onishchenko, 2011), (Tarasov, 2015).

The methodology's ***third stage*** is preparatory for the air defence assets' allocation with the aim to cover troops and objects from AAA strikes.

The effectiveness of defeating specific types of AAAs by anti-aircraft systems is determined by the results of shooting range tests or employing known models of their operation and analytical methods (Romanchenko,2011).

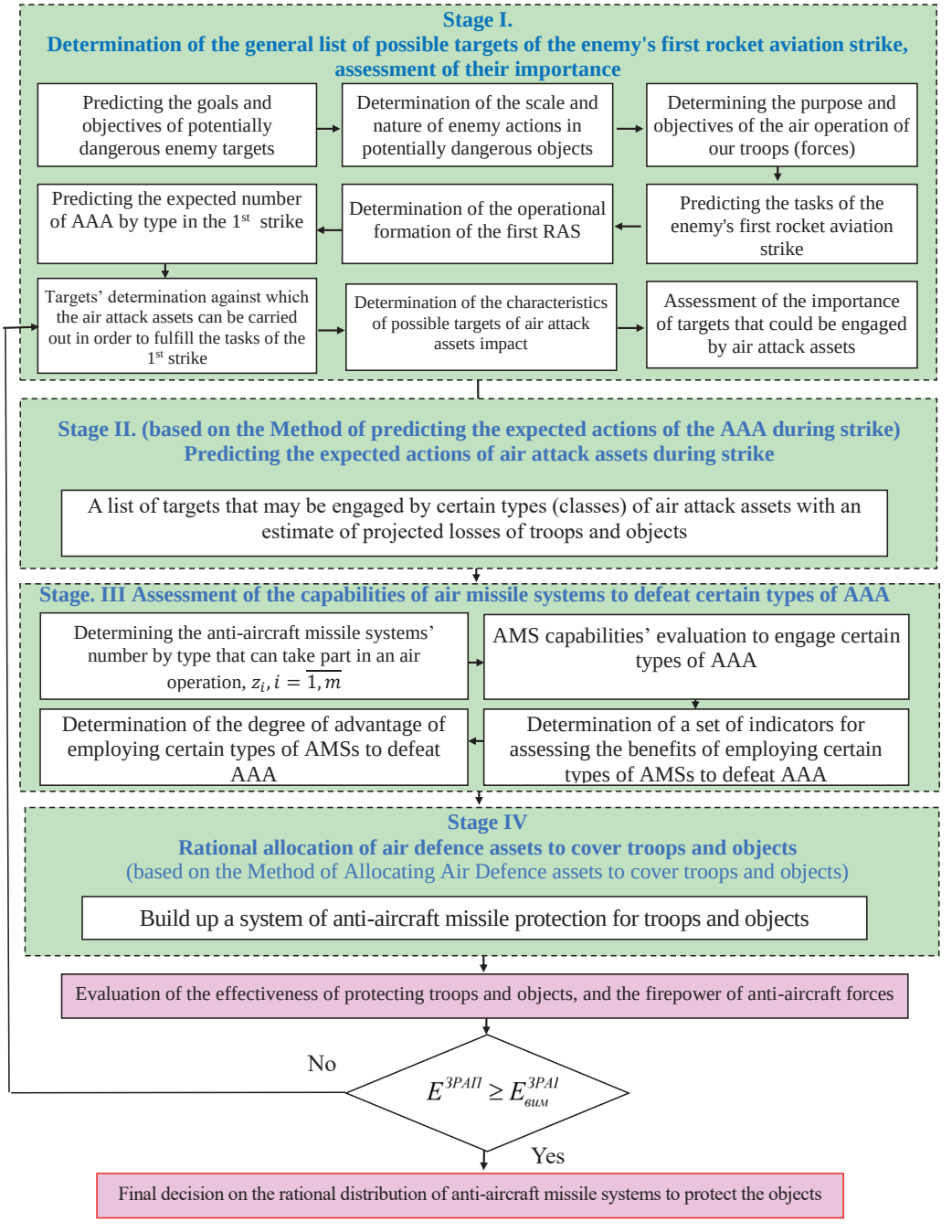


Figure 3. Block diagram of a comprehensive methodology for the allocation of air defence assets to cover troops and objects from strikes by various types of AAAs

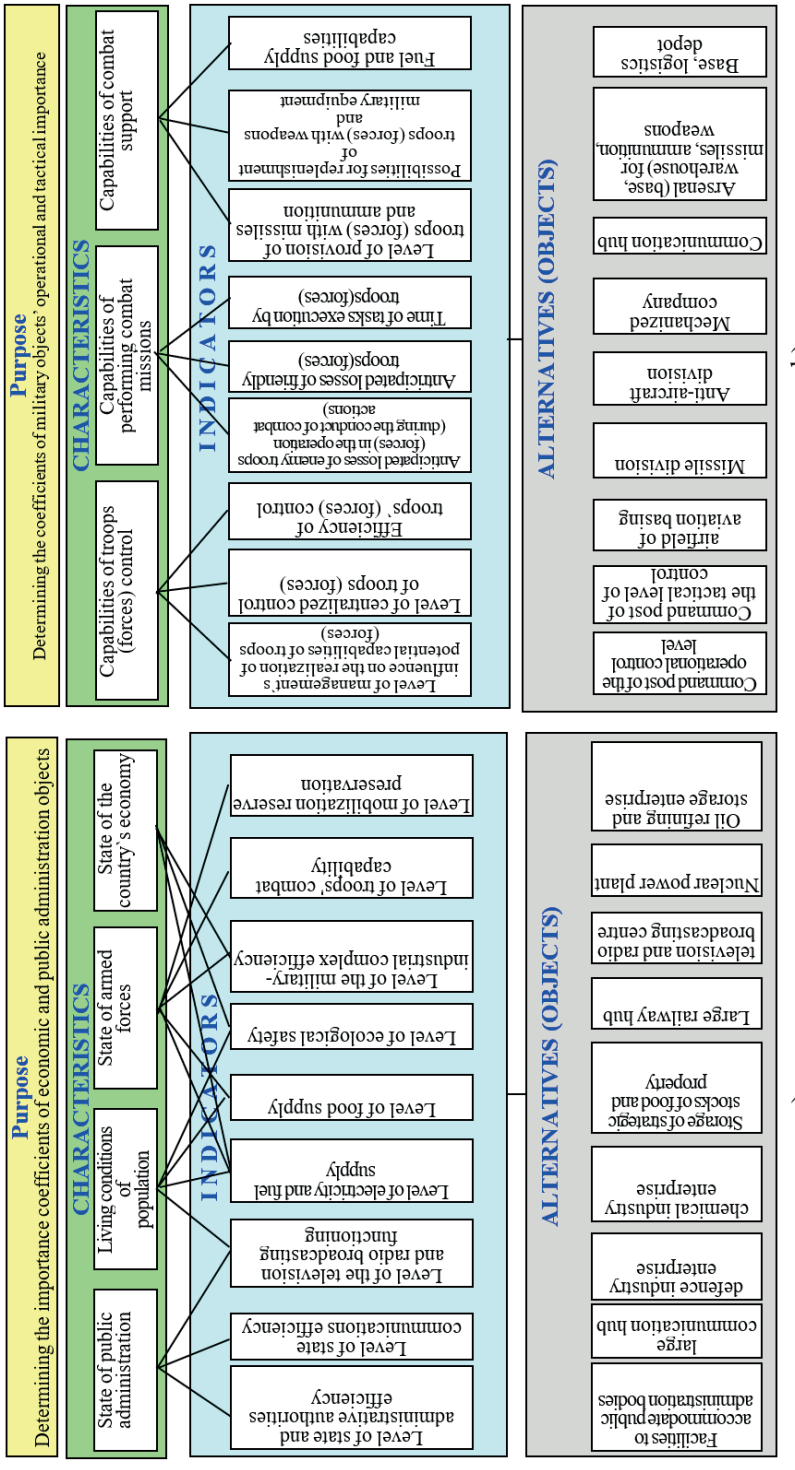


Figure 4. Hierarchical depiction of determining coefficients task: a)importance of economic and public administration objects (option); b) military objects' (option) operational and tactical importance

To determine the degree of advantage of using a SAM particular type to defeat a certain type of AAA, it is advisable to empoy indicators that characterize: the ability to operate on a certain type of AAA; probability, range and height of AAA defeat; protection against interference; limitations on the number of SAMs of a certain type, etc.

As in determining the degree of superiority of AAA actions against an object, the taxonomy method can be employed to assess the degree of superiority of SAMs actions against AAA.

To perform the methodology's ***fourth stage***, it is proposed to employ the previously mentioned aspects of *Allocating Air Defence Forces and Assets to Cover Troops and Objects Method*, as a result of which an air defence cover system for troops and objects is practically created.

The predicted effectiveness of the anti-aircraft cover system for troops and objects can be determined by mathematical models or analytical methods (Horodnov, 1999), (Romanchenko, 2011), (Tarasov, 2015), (Drobakha, 2004).

If the effectiveness of the anti-aircraft missile protection system for troops and objects does not meet the established requirements, it is necessary to specify the objects and re-distribute air defence assets to protect them.

Results and Discussions

Employing partial models and methods, it is possible to determine the mathematical expectations of the number of AAAs that can be destroyed by air defence assets from the composition of the details intended to destroy (suppress) each f-*st* object of the economy and public administration.

Then the probability of preserving the f-*st* object is determined by the formula (Romanchenko, 2011):

$$P_{зб.i} = \left(1 - P_{li}\right)^{r_i - \Delta r_i}, \tag{4}$$

P_{li} where is the destruction's probability of the f-*st* object when employing one AAA (determined at the second stage of the methodology).

The mathematical expectation of the value of relative losses of economic and public administration objects is determined by the formula:

$$R_{\partial} = \frac{\sum_{i=1}^{m^{\partial}_{зн.}} \left(1 - P_{зб.i}\right) B_i}{\sum_{l=1}^{L^{\partial}} B_l}, \tag{5}$$

where B_i is the importance coefficient of the *1st* object of economy and public administration; L^{∂} - the number of economic and public administration objects that may be affected by an AAA (determined at the first stage of the methodology);

$m^{\partial}_{зн.}$ - the *number of* economic and public administration objects to be destroyed in the first RAS (determined at the methodology's second stage).

The probability of survival of military objectives and the mathematical expectation of the military objectives' relative loss are determined by similar formulas.

When determining the mathematical expectations, it is necessary to take into account the destruction of AAAs not only by air defence assets covering the object, but also by other air defence systems, *i* .e., "in flight".

For the targets against which the employment of CMs, UCAVs, and MAs is expected, the values can be roughly determined using a mathematical model or analytical methodology for assessing the

effectiveness of the anti-aircraft system for troops and objects (Horodnov, 1999). Similarly, the value can be determined for the objects against which the employment of ballistic missiles is expected. Methods are employed to determine the mathematical expectations of the number of destroyed AAAs by type when repelling an *СМ, ВМ, UCAVs, or МА* air strike. The probability of destruction of any AAA by type from the strike force and means is determined by the following formulas:

$$P_{зн.КР} = \frac{M_{КР}}{N_{КР}}; \quad P_{зн.БР} = \frac{M_{БР}}{N_{БР}}; \quad P_{зн.БЛА} = \frac{M_{БЛА}}{N_{БЛА}}; \quad P_{зн.ПА} = \frac{M_{ПА}}{N_{ПА}}, \tag{6}$$

where $N_{КР}$ $N_{БР}$ $N_{БЛА}$ $N_{ПА}$ are the number of CMs, BMs, UCAVs, and aircraft participating in the AO.

Then the mathematical expectation Δr_i of the number of destroyed CMs from the CM squadron assigned to destroy the f-*st* object can be determined by the formula:

$$\Delta r_i = r_i P_{зн.СМ}. \tag{7}$$

Similarly, mathematical expectations are determined for the targets where UCAVs and MAs are expected to be emloyed.

Taking into account (7), formula (4) has the form:

$$P_{зб.i} = (1 - P_{li})^{r_i(1-P_{зн.СМ})}. \tag{8}$$

The definition of the mathematical expectation of the relative losses' value differs from its definition by formula (3), because the mathematical expectation takes into account the functioning of anti-aircraft protection system of troops and objects from air defence strikes, which is designed on the results of the air defence forces assets distribution employing the proposed methodology.

Conclusion

The methodology described above is as close as possible to the practical activities of command and control bodies involved in organizing the protection of troops and objects from air strikes. The process of allocating air defence assets to protect objects from air strikes is based mainly on the employment of practical experience of specialists. At the same time, the developed methodology allows to take into account the peculiarities of using certain types of anti-aircraft missile systems to protect objects from strikes of various types of air attack assets, as well as to substantiate recommendations for its improvement, and thereby increase the efficiency of the anti-aircraft missile system for covering troops and objects.

Thus, in order to develop recommendations for improving the effectiveness of combating unmanned air attack assets in the context of their integrated employment, an improved methodological apparatus is proposed to substantiate the allocation of air defence assets to protect troops and objects from attacks by different types of air attack assets, which includes:

- method for predicting the expected SAMs actions in a strike, the essence of which is the specific SAMs sequential distribution to the objects of attack, taking into account their importance and the degree of advantage of this SAM action on them, which allows to estimate the projected losses of troops and objects in order to use them in the future when assessing the capabilities of SAMs to defeat SAMs certain types (classes);

- method of allocating air defence assets to protect troops and objects, the essence of which is the SAMs (SAM composition options) sequential allocation to protect the most important objects, taking into account the expected actions of the AAA and the degree of advantage of using SAMs certain types to destroy AAAs certain classes and types;

- comprehensive methodology for the rational allocation of air defence assets to protect troops and objects from strikes by various types (classes) of air attack assets. The essence of the methodology is the following: determination of the list of possible targets of the enemy's first rocket aviation strike, taking into account their importance; predicting the AAAs expected actions in a strike, taking into account the advantages of their employment against protect objects (based on the method of the same name) assessing the SAMs capabilities to defeat AAAs certain types (classes), taking into account the advantages of employing these systems on these types of AAAs; SAMs distribution (based on the method of the same name), taking into account the peculiarities of their use on AAAs certain types (classes) to protect objects from air strikes.

Recommendations

The proposed comprehensive methodology makes it possible to solve a multi-criteria problem when build up an anti-aircraft missile protection system for a certain number of objects and troops, as well as when substantiating recommendations for organizing the protect of troops and objects from attacks by both AAAs certain types (primarily, BMs, CMs, UCAVs) and in the conditions of their integrated use.

In general, the methodology can be employed both in research and in planning an air operation.

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