DOI: https://doi.org/10.15276/aait.07.2024.14
UDC 004.7:004.942

Combat operations model of a single self-propelled artillery system for the computer game ARMA 3

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ABSTRACT

Military computer games are an important segment of the world media culture and media business. In addition to the entertainment aspect, military simulators play an important role in the training of future military specialists. However, quite often the scenario component of military gaming lags behind the rapid development of real military equipment. World experience of military conflicts of the 21st century shows that the most intensively developing segment of ground forces weapons is its artillery component. In this paper, a model of combat use of a new generation artillery system is developed. The model is intended for modification of the military game ARMA 3. The new generation artillery system is a large-caliber gun with a high level of automation. It has a high rate of fire, maneuverability, and shooting accuracy. Due to these qualities, the new generation artillery system is comparable in combat power to a unit of traditional guns and can carry out combat operations in single mode. A technique has been developed for dynamically assessing the current combat capability of an artillery system, taking into account the resource costs during fire activity, including indirect hits by the enemy. It is shown that in addition to traditional tactical counter-battery tasks, an artillery system can be used to destroy a suddenly emerging high-risk target. A high-risk target is a non-artillery system capable of causing very large damage in a short period of time. Based on the method of dynamically assessing the current combat capability, a tree of artillery system states is constructed. It includes the most probable states of the artillery system and the corresponding design parameters. A ratio is obtained that allows, for a known state of the artillery system, to estimate the number of shots needed to hit the target with the required guaranteed probability. Calculated examples show that a new-generation artillery system is capable of destroying a high-risk target, sometimes even at the cost of its own loss. The developed model is implemented and is being tested as a mod for the war game ARMA 3.

Keywords: ARMA game; next generation artillery system; dynamic combat capability assessment; special threat target

For citation**: Demydenko V. E., Maksymov M. V, Boltenkov V. O. "Combat operations model of a single self-propelled artillery system for the computer game ARMA 3".** ***Applied Aspects of Information Technology*****. 2024; Vol.7 No.3: 207–218. DOI: https://doi.org/10.15276/aait.07.2024.14**

INTRODUCTION

Computer gaming is rapidly developing as a segment of global media culture and media business. [1, 2]. A special place in computer gaming is occupied by military simulation games. The importance of military games is considered today in two aspects. On the one hand, it is a means of entertainment; on the other hand, military games are successfully used as a tool for training future military specialists. They help develop decision-making skills and strategic thinking [3, 4]. The success of the educational and training purpose of military simulation games is largely determined by how quickly the latest achievements of real military equipment and its tactical use in modern combat are introduced into the scenario component of the game [5, 6] . This is especially true for advanced equipment of ground military operations. Here, artillery systems are developing most intensively as the main striking force of ground forces. Combat experience of local conflicts of the twentieth century and the liberation war in Ukraine showed the successful use of a new generation of large-caliber self-propelled artillery systems. However, the scenario side of war games today does not take into account the intensive real modification of the artillery component of gaming [7] . In this aspect, the modification of the scenario side of the artillery component of the war game for using real combat tactics of the new generation of self-propelled artillery in the simulation modeling is an urgent scientific and practical task.

ARMA 3 was chosen as the basic simulator for solving this problem. Certain modifications of it are discussed in [8]. The next modification of this game may be the use of new generation artillery systems capable of hitting not only enemy artillery targets, but also more dangerous objects that can cause huge damage and losses. New generation artillery systems can act as a single combat unit and at the same time solve combat tasks at the level of an artillery battery. This article is dedicated to the development of this modification.

LITERATURE REVIEW

The tactics of combat use of large-caliber artillery today are based on the concept of “shoot and scoot” [9]. The literature has examined in sufficient detail various aspects of the tactics of using artillery systems based on this concept for traditional counter-battery missions [10, 11].

Much less attention is paid to the consideration of another important aspect of the modernization of the artillery component of modern combat. Over the past decade, the world's leading manufacturers of artillery weapons have created new-generation self-propelled artillery systems, hereinafter self-propelled artillery systems (SAS) [12]. One of the features of SAS is the transition to a wheeled self-propelled chassis. Self-propelled artillery systems on a wheeled chassis have several key features.

– Mobility: The wheeled chassis provides high speed on roads and good maneuverability on terrain, allowing for quick changes of position and avoidance of detection.

– Cross-country ability: Although wheeled self-propelled guns are less cross-country than tracked ones, modern models often have improved cross-country ability.

– Ease of operation: Wheeled chassis typically require less maintenance and are easier to operate, which reduces ownership costs.

– Weight and dimensions: As a rule, self-propelled guns on a wheeled chassis are lighter and more compact, which allows them to be used in urban conditions and in confined spaces.

– Speed of deployment: Rapid setup and readiness for firing allows for effective response to changes in combat situations.

These features make self-propelled artillery systems on wheeled chassis attractive for modern armed forces, especially in highly mobile operations.

Another feature of the SAS is the loading system with a fully automatic magazine and a modular charge system that allows for automatic charge build-up. The SAS is equipped with a computer fire control system. All this data is loaded into the onboard computer automatic fire control system.

Another feature of the SAS is the ability to fire in the mode MRSI (multiple rounds simultaneous impact) or “pseudosalpa” (or stonk). In this mode, the SAS fires a series of successive shots at one target with different barrel elevation angles. The shells fly to the target along both flat and high trajectories with almost simultaneous arrival at the target location. It can be considered that firing by the SAS in MRSI mode is equivalent in firepower to firing at a target with a battery of guns with successive shots.

The listed features of SAS make them the most effective artillery weapon of today's battle. This is confirmed by combat experience of their use in the liberation war in Ukraine [12, 13], [14, 15], [16, 17]. However, there is no data in the literature on tactical models of SAS use and their effectiveness.

The methods for assessing the effectiveness of combat use of artillery available in the literature are based on theoretical prediction of the characteristics of target destruction [18, 19], [20]. At the same time, the dynamic assessment of the effectiveness of the combat use of artillery systems, taking into account the consumption of resources during fire operations, is of interest.

GOAL AND OBJECTIVES OF THE RESEARCH

The goal of the study is to develop a combat model of a single self-propelled artillery system of the new generation using the ARMA 3 game as an example.

To achieve the set goal, the following tasks were solved:

– a methodology for dynamically assessing of the combat capability current state of a single SAS has been developed;

– a state tree of a single SAS has been developed;

– the dependence of the number of SAS shots required to hit a particularly high-danger target within a given time interval was obtained,

– demonstration calculations were carried out, confirming the adequacy of the model.

MAIN PART

New game unit

It is proposed to introduce a new game unit into the ARMA 3 game – a new generation self-propelled artillery system (NGAS). The NGAS characteristics are given in Table 1. The Archer NGAS, manufactured by BAE Systems (Sweden), was chosen as the NGAS prototype [21, 22].

Table 1. **Tactical and technical indicators of the game units of the NGAS**

Characteristic	Significance
Chassis	Wheeled
Wheel arrangement	6 x 6
Caliber	155 mm
Firing range	30 km
Rate of fire	8 rounds per minute
Maximum speed on the highway	80 km/h
Maximum speed cross-country	60 km/h

Source: **compiled by the authors**

Methodology for dynamic assessment of the combat capability current state of a single SAS

Let the general scheme of combat use of a single SAS look as follows. In the process of SAS targeting, N targets are designated from the upper control level and their coordinates are communicated for sequential destruction. According to the intensively implemented NATO standard STANAG 2934, targeting is understood as a reasoned determination of the priority of enemy targets, the sequence of their destruction and the issuance of commands to destroy [23]. In the context of this article, we will consider the terms "targeting" and "target designation" to be synonyms. Fire destruction of targets is carried out from prepared firing positions $FP_i, i=\overline{1,N}$, each of which is within the firing range of the corresponding target. After firing at the target T_i at *the i*-th position of the SAS, in accordance with the "shoot and scoot" concept, the SAS moves to position number i + 1 to fire at the target T_{i+1} (Fig. 1).

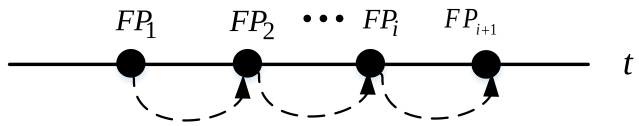

Fig. 1. **Scheme of movement of the SAS according to the "shoot and scoot" concept**
Source: **compiled by the authors**

After completing a combat mission at the *i*-th position, a dynamic assessment of the current combat capability of the SAS can be carried out. Since combat capability can be assessed by various indicators, the following practical criteria were selected for its assessment.

1. Current shot efficiency

According to the definition [24], a shot is effective if the wear of the SAS barrel does not exceed the permissible value. This in turn means that the initial velocity of the projectile v_0^t due to barrel wear $(v_0^{table} - \Delta v_0^t)/v_0^{table}$ at the time of evaluation t is not less than 0.95 of the table value v_0^{table} In the proposed methodology, the level of correct assessment of the current effectiveness of a shot is assessed according to the criterion of the following rank assessment.

$$Crit_1 = Lv_0^t = (v_0^{table} - \Delta v_0^t)/v_0^{table}. \qquad (1)$$

$$Crit_1 = L\Delta v_0^t = \begin{cases} 1, if\ n_{shots}^t < 25, \\ 1/2, if\ 26 < n_{shots}^t < 40, \\ 1/3 else \end{cases} \qquad (2)$$

where Δv_0^t is the deviation of the initial velocity of the projectile from the tabular one, n_{shots}^t is the number of shots fired from the barrel from the time of the last instrumental assessment of the initial velocity v_0 until the moment of firing t.

2. Shooting accuracy reduction factor

This criterion takes into account fire damage (indirect hits) of the SAS by the enemy n_{attacs}. These damages reduce the probability of a shot hitting the target p_{fact} compared to the probability of a SAS hitting without damage p.

$$Crit_2 = SARF = p_{fact}/p, \qquad (3)$$

$$Crit_2 = SARF = \begin{cases} 1, if\ n_{attacs} = 0, \\ 1/2, if\ n_{attacs} = 1, \\ 1/3, if\ n_{attacs} = 2 \end{cases} \qquad (4)$$

3. Residual ammunition stock

The assessment of the remaining ammunition at time t AS_t is carried out according to the criterion

$$Crit_3 = AS_t = (AS_{full} - n_{shots}^t)/AS_{full}, \qquad (5)$$

where AS_{full} is the full ammunition load of the SAS.

We consider $AS_t^* = 3$ the criterion value to be critically low $Crit_3$ (at $AS_{full} = 21$).

4. Possibility of shooting in MRSI mode

The ability to fire in MRSI mode as a result of an indirect hit by an enemy projectile may become impossible due to the failure of the vertical barrel movement mechanism or the control system for this mechanism.

Accordingly, the ability to fire in MRSI mode is assessed by the criterion

$$Crit_5 = MRSI = \\ = \begin{cases} 1, \; if \; n_{attac} < 2, MRSI \; is \;\; possible \\ 0, if \; n_{attac} \geq 2, MRSI \; is \;\; impossible \end{cases}. \qquad (6)$$

5. Rate of fire

The rate of fire of the SPG may decrease due to indirect hits from enemy shells. The current rate of fire RF_t It is proposed to evaluate by the following criterion

$$Crit_4 = RF_t = \begin{cases} 1 \; (1 \; level), \\ 1/2 \; (2 \; level), \\ 1/3 \; (3 \; level) \end{cases} \qquad (7)$$

The 1st level of rate of fire corresponds to the situation $RF_t = RF_{\max} = 8$ of shots per minute, where $RF_{\max}$ is the maximum rate of fire, the 2nd level of rate of fire corresponds to the situation $RF_t = RF_{\max} - 2,$, the 3rd level of rate of fire corresponds to the situation $RF_t = RF_{\max} - 3$.

6. Residual mobility

The movement of the SAS from each firing position to the next can be carried out both by road and over rough terrain. Despite the adaptability of the new generation SAS to movement over rough terrain, during such movement the tires of the wheel chassis can be damaged, which reduces the speed of movement at time *t* and maneuverability of the SAS.

The residual maneuverability RM at time t is proposed to be assessed by the criterion

$$Crit_6 = RM = \begin{cases} 1 \; (1 \; level), \\ 1/2 \; (2 \; level), \\ 1/3 \; (3 \; level) \end{cases} \qquad (8)$$

here maneuverability corresponds to the 1st level, if $v_t = v_{\max}$, where $v_{\max}$ is the maximum speed of movement, to the 2nd level, if $v_t = v_{\max}/2$, to the 3rd level, if $v_t = v_{\max}/3$.

The six proposed criteria can be integrated into the overall assessment of current combat capability by convolution using the ideal point method according to the norm L_2:

$$Crit_t^{ideal\_point} = \sqrt{\sum_{k=1}^{6} w_k \left(Crit_k - Crit_k^{ideal\_point} \right)^2},$$
$$\sum_{k=1}^{6} w_k = 1, \qquad (9)$$

where $Crit_k^{ideal\_point}$ is the maximum possible value of the corresponding criterion; w_k are weights of the relevant criteria corresponding to the combat situation.

Thus, the proposed methodology consists of assessing the specified criteria of current combat capability according to the ratios (1-8) and, if necessary, calculating the integrated assessment (9).

It is important to note that the movement of the self-propelled gun between firing positions can occur both on roads and over rough terrain (Fig. 2).

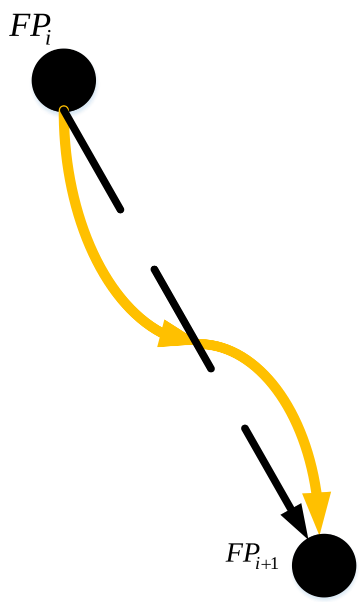

Fig. 2. **Movement of the SAS from one position FP_i to the next FP_{i+1} (yellow – road; black – rough terrain)**
Source: **compiled by the authors**

When the SAS moves along a road, the high speed significantly saves travel time. However, as a rule, roads are intensively shelled by the enemy. In this regard, the probability of the SAS being hit while moving is high. When moving over rough terrain, the SAS speed is lower, the wear of the chassis is higher, but the probability of shelling is significantly lower. In addition, when moving over rough terrain, the trajectory of movement is a vector connecting the points of the initial and final position of the SAS. Therefore, the length of the trajectory in this case is minimal.

If there are several possible routes of movement from position FP_i to position FP_{i+1}, the optimal one can be selected as a result of solving a two-criteria transport problem with minimization of the objective functions – travel time t and losses Q [25]:

$$\begin{aligned} F_{tr}^1 &= \min t(FP_i \Rightarrow FP_{i+1}), i = \overline{1,n} \\ F_{tr}^2 &= \min Q(FP_i \Rightarrow FP_{i+1}) \end{aligned} . \quad (10)$$

In this case, losses are estimated as the product of the probability of hitting and the cost of the SAS. It is proposed to consider the probability of hitting as proportional to the time of movement along a road under enemy fire. The two-criterion transport problem is easily reduced to a linear programming problem. The time to solve it on a computer of average performance does not exceed 5 s [26].

Model of combat use of SAS in a special tactical situation

The methodology presented above makes it possible to construct a model of combat use of SAS in a special tactical situation.

The main combat mission of the SAS is counter-battery warfare. The SAS, using the “shoot and scoot” tactic, sequentially fires at N targets T_i, moving to the appropriate firing positions $FP_i, i = \overline{1,N}$.

A more complex tactical situation is simulated below. Let us assume that suddenly after the target has been fired upon T_i from the firing position, FP_i the SAS receives information from the upper targeting level about the appearance of an high-danger target (HDT) and the need to destroy it with fire.

The especial danger target is not an artillery battery. This target can cause serious damage and therefore its game value is tens of times greater than any of the targets T_i. The peculiarity of this target is that it represents an especial danger and must be destroyed during a short period of time – the “window of high danger” (WHD) Δt_{WHD}. The HDT coordinates are transmitted to the SAS. The HDT is considered destroyed if at least two SAS shells hit it with a probability of p^*. The HDT is covered by artillery assets with an unlimited fire resource. Targeting for the HDT is received at the moment the SAS moves from the firing position FP_i to the position FP_{i+1}. After receiving the HDT targeting, the SAS stops moving and fires from a short stop from the temporary firing position TFP. The spatial and temporal pictures of the described tactical situation are presented in Fig. 3 and Fig.4, respectively.

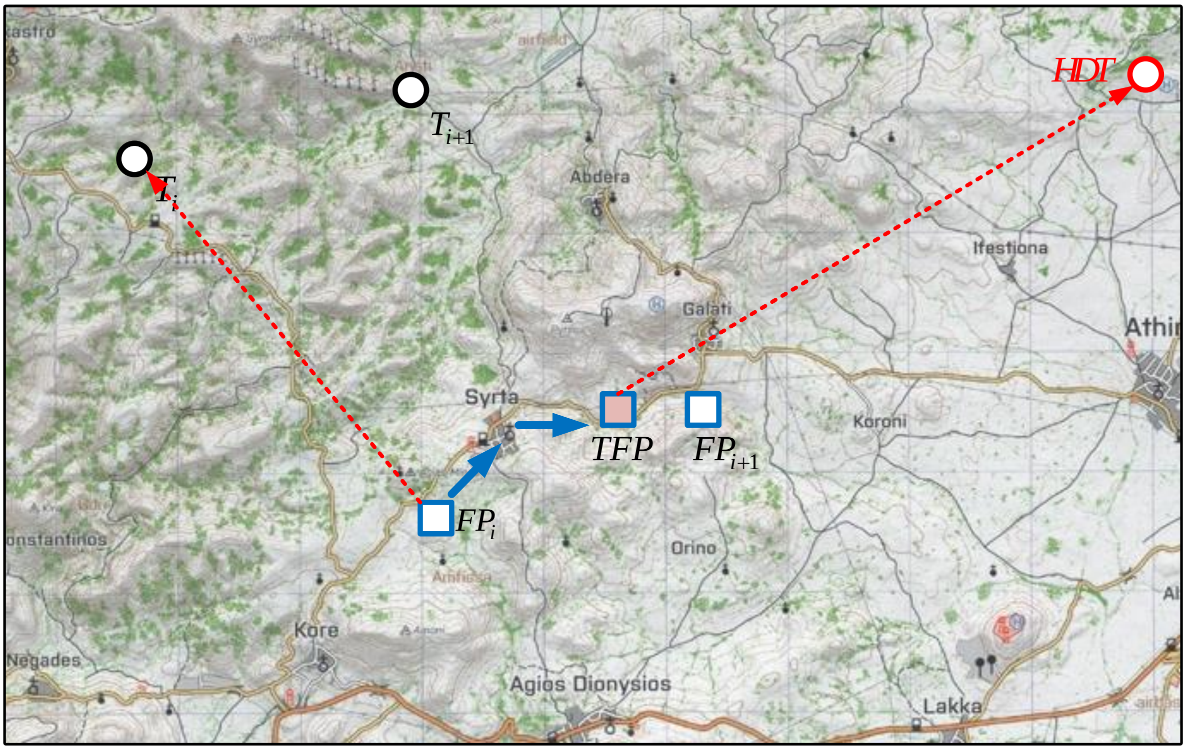

Fig. 3. **Spatial picture of shooting at high-danger target**
Source: **compiled by the authors**

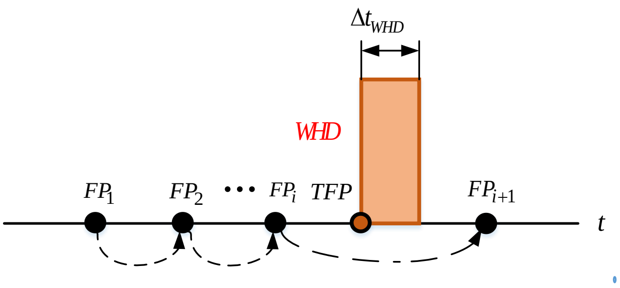

Fig. 4. **Time picture of shooting at high-danger target**

Source: **compiled by the authors**

Let's assume that after the shooting ended, a raid FP_i was carried out at the position adynamic assessment of the current state of combat readiness of the SAS in accordance with the above-formulated methodology. This makes it possible to construct a tree of states of the SAS (Fig. 5) [27]. The tree of states differs from a more typical decision tree in that it considers not the complete system of events, but the most probable events. The tree of states of the SAS is constructed on the basis of the above-formulated methodology of dynamic assessment of the current state of combat readiness of the SAS. The first level of branching 1, …, 5 corresponds to the criteria $Crit_1,...,Crit_5$. The next level of branching determines the possibility of performing combat operations or the values of numerical parameters corresponding to the rank assessments used further in the calculations.

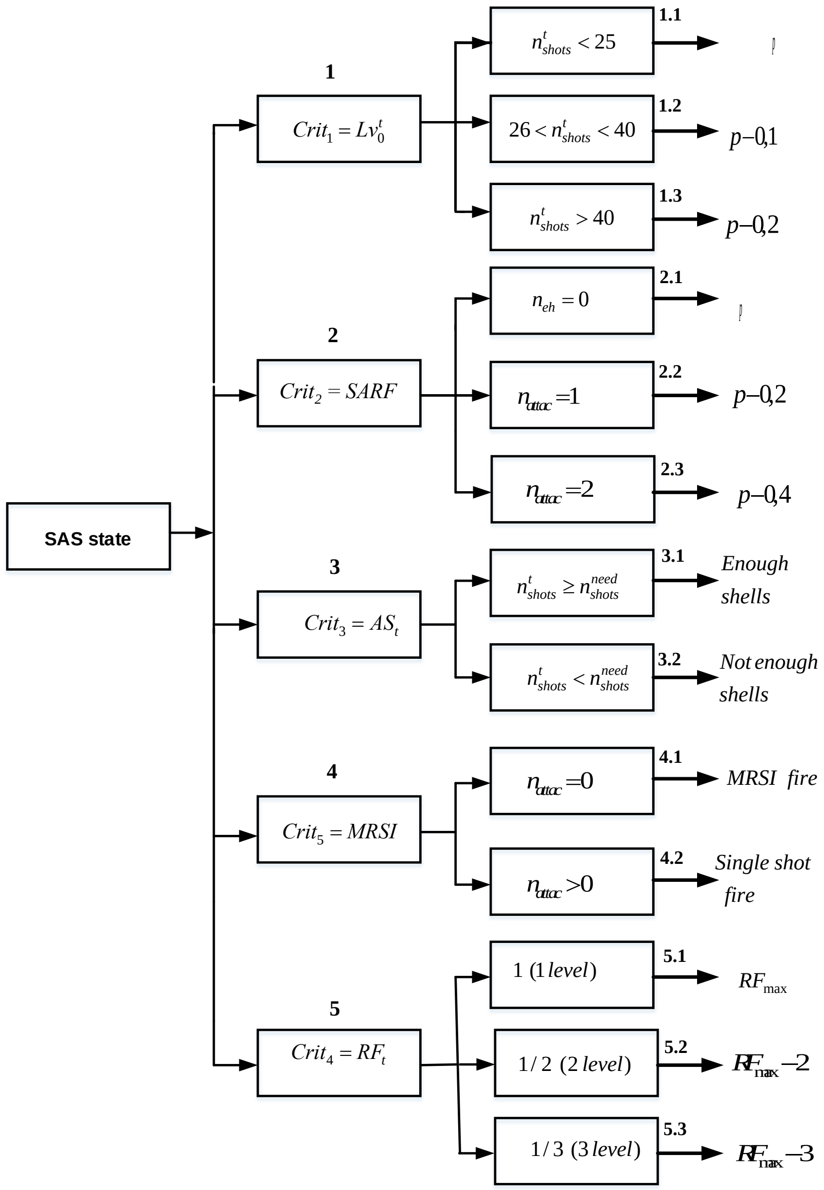

Fig. 5. **The tree of combat readiness states of the SAS at the time of the start of the high-danger target shelling**

Source: **compiled by the authors**

The current state of combat readiness of the SAS can be clearly represented by a yuple

$$State^t < 1, n1; 2, n2; 3, n3; 4, n4; 5, n5 >,$$

where
$n1 \in \{1.1, 1.2, 1.3\}, n2 \in \{2.1, 2.2, 2.3\}, n3 \in \{3.1, 3.2\},$
$n4 \in \{4.1, 4.2\}, n5 \in \{1, 5.5.2, 5.3\}$
are the numbers of the terminal branches of the state tree.

The next sequence of evaluation of the possibility of defeating the HDT is as follows. Let the probability of hitting the target with one SAS shot in an ideal state be equal to p.

Taking into account the current state of the SAS, the values of the probability of hitting the target with one SAS shot are determined in accordance with the state tree. The number of shots n^* required by the SAS in the current state to hit a high-dangerous target with K hits with probability is estimated p^*. The probability $(n^* - K)$ of misses is equal to $(1-p)^{n^*-K}$, and the probability *of K* hits is equal to $1-(1-p)^{n^*-K}$. According to the conditions formulated above, the inequality must be satisfied

$$\begin{aligned} &1-(1-p)^{n^*-K} \geq p^*, \\ &1-p^* \geq (1-p)^{n^*-K} \end{aligned}. \quad (11)$$

Assuming $p \neq 1, p^* \neq 1$ and moving to strict equality, we obtain the dependence:

$$n^* = \log(1-p^*) / \log(1-p) + K. \quad (12)$$

Rounding the value obtained from the expression (12) n^* up to the nearest integer

$$n^{**} = \lceil n^* \rceil, \quad (13)$$

it is possible to obtain the number of shots required to hit the target with probability p^*. Visualization of dependence (12) is presented in Fig. 6.

It should be noted that due to the discrete integer nature of the variable, n^{**} when using Fig. 12 it is necessary to use only the nodal values of the grid applied to the surface.

The obtained value n^{**} is compared with the available ammunition according to criterion 3. If $n^{**} > n^t_{shots}$, the task is impossible. If there is sufficient ammunition, the condition of criterion 4 is checked. If firing in MRSI mode is impossible , firing can only be done with single shots at a rate of fire determined by criterion 5.

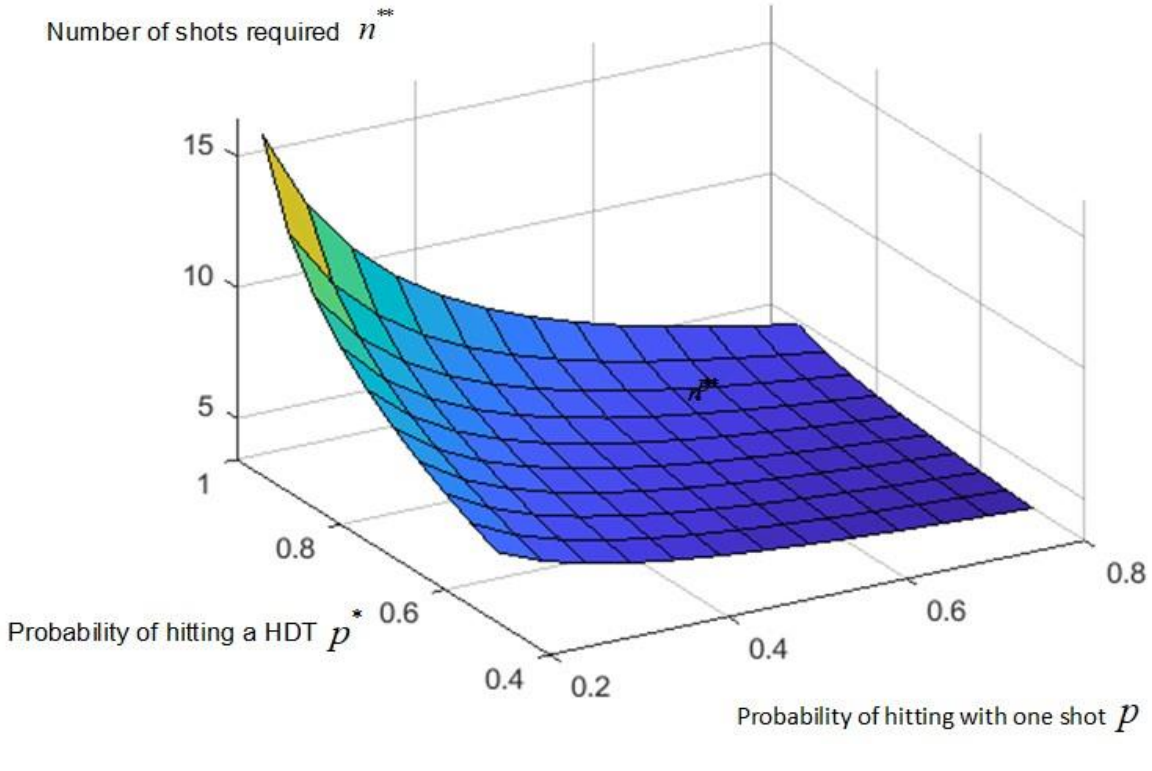

Fig. 6. **Graphical representation of the dependence (12)**
Source: **compiled by the authors**

Next, the time budget for hitting a particularly dangerous target is estimated.

Time to complete combat mission to defeat HDT t^* includes the time of preparation of the SAS for firing from a short stop t_{prep_fire}, the time of fire activity $t_{fire} = n^* / RF_t$ and the flight time of the projectiles up to EDT t_{flight}:

$$t^* = t_{prep\_fire} + t_{fire} + t_{flight}. \quad (14)$$

This time should not exceed the duration of the window of particular danger Δt_{WHD}:

$$t^* < \Delta t_{WHD}. \quad (15)$$

If condition (15) is not met, it is not practical to perform the task.

A special issue is the safety of the SAS when it is detected by enemy artillery covering the HDT . Let us assume that the SAS is detected by enemy artillery after four shots [11]. Then, after a while, t_{fire}^{enemy} an enemy salvo can hit the SAS with a high probability.

$$t_{fire}^{enemy} = 4 / RF_t + t_{prep}^{enemy} + t_{flight}, \quad (16)$$

where t_{fire}^{enemy} is the time for the enemy to evaluate the TFP coordinates and prepare for firing. Here it is assumed that the enemy's covering artillery is located close to HDT, so the flight time of the shells is approximately the same as from TFP to HDT.

If $t^{**} = t_{fire} + t_{flight} < t_{fire}^{enemy}$, then the combat mission of destroying a particularly dangerous target can be accomplished at the cost of losing the SAS. However, given the many times higher cost of the HDT, in this case the player gains a large gain. If, $t^{**} > t_{fire}^{enemy}$ the residual maneuverability $Crit_6$ criterion comes into force, and the SAS must leave the temporary firing position at maximum speed.

Examples of calculations of the effectiveness of SAS for hitting a particularly dangerous target

Below are some examples of the SAS effectiveness evaluation for EDT defeat for different SAS states at the time of targeting. The target is considered to be destroyed if it is defeated by K =3 s probability p^* = 0.95. In this case, p = 0.9. Duration of the window of particular danger Δt_{WED} = 300 s. We assume that the distance TFP–HDT is such that the flight time of the projectile t_{flight} = 60 s. We also assume the flight time of the projectiles fired by the enemy's covering artillery to be the same.

Example 1. The SAS is in the state $State^t < 1,1.1; 2,2.1; 3,3.1; 4,4.1; 5,5.1 >$ according to the results of the dynamic assessment . The current state of the system corresponds to the cortege: the initial velocity of the projectile is tabular; the SAS has not been damaged by enemy fire; the ammunition is sufficient; the MRSI firing mode is available; the rate of fire is maximum (the state corresponding to the "ideal point"). To hit the target with a probability of p^*=0.95 according to (12-13), n^{**} =4 shots are required. These 4 shots are fired in the MRSI mode. in t_{fire}=30 s. After this, the SAS can leave the TFP after a time $t_{prep\_fire} + t_{fire}$ of =50 s. If the SAS is detected by the enemy after the 4th shot, then during the flight time of the enemy shells t_{flight}=60 s, it will move at a speed of 60 km/h to a distance of 1 km from the TFP. The total time to complete the combat mission $t^* = t_{prep\_fire} + t_{fire} + t_{flight}$ =20 s +30 s + 60 s = 110 s does not exceed the duration of the special danger window Δt_{WED} =300 s.

Example 2. According to the results of the dynamic assessment, the SAS is in the state $State^t < 1,1.1; 2,2.2; 3,3.1; 4,4.2; 5,5.2 >$. The current state of the system corresponds to the cortege: initial projectile velocity – tabular; fire damage to the SAS by the enemy – one fire impact has been made; ammunition – sufficient; MRSI firing mode – unavailable; rate of fire – 6 rounds per minute. Then p = 0.7. To hit the target with a probability p^* of = 0.95 according to (12-13), n^{**} = 7 shots are required. Shooting is carried out in the normal mode with a rate of fire of 6 rounds per minute. Then t_{fire} = 70 s. The SAS can leave the TFP after a time $t_{prep\_fire} + t_{fire}$ of = 90 s. If the SAS is detected by the enemy after the 4th shot (after 40 s), then during the $t_{prep}^{enemy} + t_{flight}$ arrival time of the enemy shells 20 s + 60 s = 80 s it will move at a speed of 40 km/h to a distance of approximately 0.8 km from the TFP and will avoid direct fire damage. The total time to complete a combat mission $t^* = t_{prep\_fire} + t_{fire} + t_{flight}$ = 20 sec + 70 sec + 60 sec = 150 sec does not exceed the duration of the high-danger window Δt_{WED} = 300 sec.

Example 3. According to the results of the dynamic assessment, the SAS is in the state

$State^t < 1,1.1; 2,2.2; 3,3.1; 4,4.2; 5,5.3 >$ The current state of the system corresponds to the cortege: initial projectile velocity is tabular; enemy fire damage to the SAS – two fire impacts were made; ammunition is sufficient; MRSI firing mode is unavailable; rate of fire is 5 rounds per minute. p = 0.5. To hit the target with a probability p^* of = 0.95 according to (12-13), n^{**} = 10 shots are required. Shooting is carried out in the normal mode with a rate of fire of 5 rounds per minute. Then t_{fire} = 120 s. After the 4th shot, the SAS will be detected by the enemy, the enemy's projectiles will reach TFP in a time of 20 s + 60 s = 80 s from the moment of the 4th shot, i.e. at 138 seconds from the beginning of the fire activity . The time reserve for moving the SAS is 18 seconds. This is not enough for movement, and the SAS will be hit. However, by this time it will have fired 10 shells, which guarantees the destruction of the high-danger target with a probability of 0.95. The total time to complete the combat mission $t^* = t_{prep\_fire} + t_{fire} + t_{flight}$ = 20 s + 120 s+60 s=200 s does not exceed the duration of the high-danger window Δt_{WED} =300 s. This example demonstrates that at the cost of losing the SAS, the high-danger target can be guaranteed to be destroyed.

The examples provided demonstrate that the developed four-component model of combat operations of a single self-propelled artillery system in a complex tactical situation (Fig. 7) allows us to evaluate the combat capability of the SAS when performing the task of destroying a suddenly discovered target of particular danger.

The proposed model can also be used in a different formulation of the problem. The application of the model allows one to estimate the probability of hitting a high-danger target for a known ammunition supply and the state of the SAS. If this probability is not high, then performing the combat targeting task is inappropriate and is fraught with the loss of the SAS. The input data for the proposed model is the current state of the SAS at the time of the appearance of a high-risk target, estimated according to the criteria system described above.

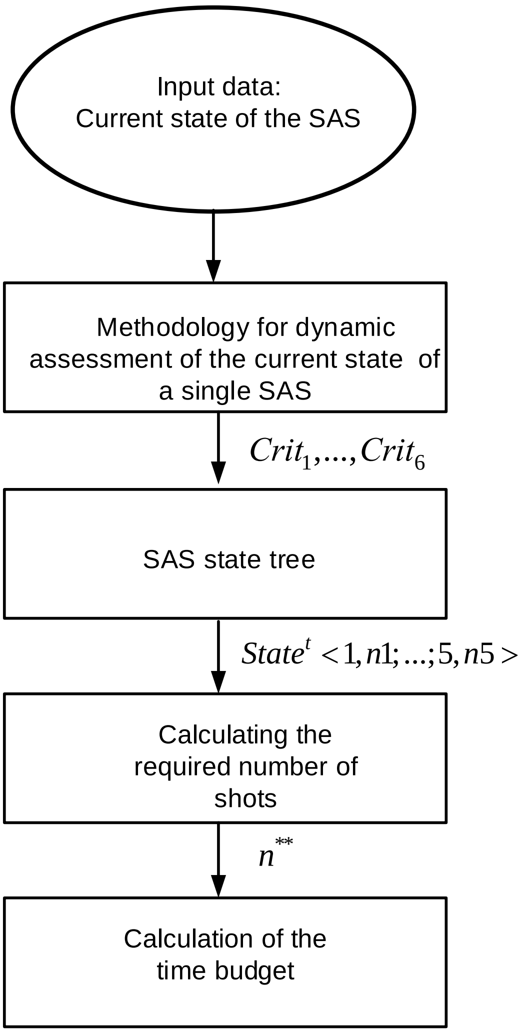

Fig. 7. **Four-component model of combat operations of a single self-propelled artillery system**
Source: **compiled by the authors**

Results and conclusions

A combat model for a new generation single self-propelled artillery system has been developed.

During the research the following tasks were solved:

– a methodology for dynamically assessing the combat capability current state of a single SAS has been developed;

– a state tree of a single SAS has been developed;

– the dependence of the number of SAS shots required to hit a particularly dangerous target within a given time interval was obtained,

– demonstration calculations were carried out, confirming the adequacy of the model.

The possibility of using a new generation self-propelled artillery system to hit a suddenly appearing target of particular danger is shown. The developed model is intended for modification of the military computer game ARMA 3. Currently, a mod implementing the developed model is being tested. The mod will be presented in the ARMA 3 community.

Thus, the goal of the study has been achieved, all set tasks have been completed.

REFERENCES

1. Cazenave, T., Saffidine, A., Sturtevant, N. (Eds.). “Computer games. Communications in computer and information science”. *27th International Conference on Artificial Intelligence*. Stockholm, Sweden. 2018. DOI: https://doi.org/10.1007/978-3-030-24337-1.

2. Ulbricht, S. “Ethics of computer gaming: A groundwork. Palgrave macmillan”. 2022. DOI: https://doi.org/10.1007/978-3-662-64397-6.

3. Riocampo, S. L. “Virtual interactive system based on gamification for basic military training in the area of management of weapons”. *International Conference on Virtual Reality and Visualization (ICVRV*). Hong Kong, China. 2019. p. 167–171. DOI: https://doi.org/10.1109/ICVRV47840.2019.00039.

4. Mouat, T. “The use and misuse of wargames”. *Scandinavian Journal of Military Stu*dies. 2022; 5 (1): 209–220. DOI: https://doi.org/10.31374/sjms.121.

5. Samčović, A. “Serious games in military applications”. *Vojnotehnički Glasnik / Military Technical Courier*. 2018; 66 (3): 597–613. DOI: https://doi.org/10.5937/vojtehg66-16367.

6. Rhee, H. K., Song, D. H. & Kim, J. H. “Comparative analysis of first person shooter games on game modes and weapons-military-themed, overwatch, and player unknowns’ battleground”. *Indonesian Journal of Electrical Engineering and Computer Science*. 2019; 13 (1): 116–122. DOI: https://doi.org/10.11591/ijeecs.v13.i1.pp116-122.

7. Mantello, P. “Military shooter video games and the ontopolitics of derivative wars and arms culture”. *American Journal of Economics and Sociology*. 2017; 76 (2): 483–521. DOI: https://doi.org/10.1111/ajes.121848.

8. Maksymov, M. V., Boltenkov, V. O., Gultsov, P. S. & Maksymov, O. M. “Verification of artillery fire under the influence of random disturbances for the computer game ARMA 3”. *Applied Aspects of Information Technology*. 2023; 6 (4): 362–375. DOI: https://doi.org/10.15276/aait.06.2023.24.

9. Shim, Y. & Atkinson, M. P. “Analysis of artillery shoot-and-scoot tactics”. *Naval Research Logistics (NRL)*. 2018; 65 (3): 242–274. DOI: https://doi.org/10.1002/nav.21803.

10. Oprean, L.-G. “Artillery from the perspective of firing effects and ensured Capabilities”. *Scientific Bulletin*. 2020; 25: 107–113. DOI: https://doi.org/10.2478/bsaft-2020-0015.

11. Maksymova, O. B., Boltenkov, V. O., Maksymov, M. V., Gultsov, P. S. & Maksymov, O. M. “Development and optimization of simulation models and methods for controlling virtual artillery units in game scenarios”. *Herald of Advanced Information Technology*. 2023; 6 (4): 320–337. DOI: https://doi.org/10.15276/hait.06.2023.21.

12. Kislitsyn, A. & Dorofeev, N. “Directions for the development of domestic self-propelled artillery systems based on the analysis of samples of artillery weapons from the leading countries of the world”. *Social Development and Security*. 2021; 11 (6): 98–107. DOI: https://doi.org/10.33445/sds.2021.11.6.7.

13. Świętochowski, N. “Field artillery in the defensive war of Ukraine 2022-2023. Part I. Combat potential, tasks and tactics”. *Scientific Journal of the Military University of Land Forces*. 2023; 210 (4): 341–358. DOI: https://doi.org/10.5604/01.3001.0054.1631.

14. Świętochowski, N. “Field artillery in the defensive war of Ukraine 2022-2023. Part II. Methods of task implementation”. *Scientific Journal of the Military University of Land Forces*. 2024; 211 (1): 57–76. DOI: https://doi.org/10.5604/01.3001.0054.4136.

15. Markov, D. “Use of artillery fire support assets in the attrition approach in the Russia-Ukraine conflict”. *Environment. Technology. Resources. Proceedings of the 15th International Scientific and Practical Conference*. 2024; 4: 178–182. DOI: https://doi.org/10.17770/etr2024vol4.8208.

16. Ganjiyev, S. J., Usmonov, S. R. & Karimov, A. X. “Use of artillery in modern war (A brief analysis of the Ukrainian conflict)”. *Galaxy International Interdisciplinary Research Journal*. 2023; 11 (3): 118–121. – Available from: https://www.giirj.com/index.php/giirj/article/view/4825.

17. “Shoot-and-Scoot: The archer artillery system in Ukraine”. – Available from: https://gunpowdermagazine.com/shoot-and-scoot-the-archer-artillery-system-in-ukraine/ January 25, 2023.

18. Aliev, A. A., Bayramov, A. A. & Sabziev, E. N. “Effectiveness ofartillery systems”. *Advanced Information Systems*. 2018; 2 (3): 115–122. DOI: https://doi.org/10.20998/2522-9052.2018.3.20.

19. Katsev, I. “Evaluation method of the artillery’s effectiveness against unitary target”. *Security & Future*. 2018; 2 (4): 196–198. – Available from: https://stumejournals.com/journals/confsec/2018/4/196.full.pdf.

20. Moon, S.-H. “Weapon effectiveness and the shapes of damage functions”. *Defence Technology.* 2021; 17 (2): 617–632. DOI: https://doi.org/10.1016/j.dt.2020.04.009.

21. “ARCHER Mobile Howitzer 8x8”. – Available from: https://www.baesystems.com/en/product/archer#/April 20, 2024.

22. “ARCHER Mobile Howitzer 6x6”. – Available from: https://www.baesystems.com/en/product/archer# / April 20, 2024.

23. Horbenko, V., Kuchynska, A. & Gudym, V. Features of targeting in modern joint and future multi-domain operations.. *Air Power of Ukraine*. 2023; 2(5): 10–16. DOI: https://doi.org/10.33099/2786-7714-2023-2-5-10-16.

24. Boltenkov, V., Brunetkin, O., Dobrynin, Y., Maksymova, O., Kuzmenko, V., Gultsov, P., Demydenko, V. & Soloviova, O. “Devising a method for improving the efficiency of artillery shooting based on the Markov model”. *Eastern-European Journal of Enterprise Technologies.* 2021; 6 (3 (114)): 6–17. https://www.scopus.com/record/display.uri?eid=2-s2.0-85123511164&origin=resultslist&sort=plf-f&src=s&sid=0d1a843d2a9f783a0cb05d4bd5a6f328&sot=b&sdt=b&s=TITLE-ABS-KEY%28Devising+a+method+for+improving+the+efficiency+of+artillery+shooting+based+on+the+Markov+model%29&sl=109&sessionSearchId=0d1a843d2a9f783a0cb05d4bd5a6f328#metrics.
DOI: https://doi.org/10.15587/1729-4061.2021.245854.

25. Antai, I., Hellberg, R. & Skoglund, P. “Logistics growth in the armed forces: development of a theoretical framework and research propositions”. *Defence Studies.* 2023; 24 (1): 84–106. DOI: https://doi.org/10.1080/14702436.2023.2249441.

26. Phyo, S. M., Hlaing, S. Z. & Lwin, M. M. “Multi-criteria decision analysis in urban transport system by applying function resonance analysis method”. *International Conference on Advanced Information Technologies (ICAIT).* Yangon, Myanmar. 2020. p. 230–235. DOI: https://doi.org/10.1109/ICAIT51105.2020.9261795.27.

27. Oran, R. Y. “Constructing diagnostic trees: A stepwise approach to institutional design, Earth System Governance”. 2019; 1: 100002. DOI: https://doi.org/10.1016/j.esg.2019.02.001.

Conflicts of Interest: the authors declare no conflict of interest

Received 12.08.2024
Received after revision 16.09.2024
Accepted 20.09.2024

DOI: https://doi.org/10.15276/aait.07.2024.14
УДК 004.7:004.942

Модель бойових дій одиночної самохідної артилерійської системи для комп'ютерної гри ARMA 3

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АНОТАЦІЯ

Військові комп'ютерні ігри є важливим сегментом світової медіа культури та медіа бізнесу. Окрім розважального аспекту, військові імітатори відіграють важливу роль у підготовці майбутніх військових фахівців. Проте досить часто сценарний компонент військового геймінгу відстає від стрімкого розвитку реальної військової техніки. Світовий досвід військових конфліктів XXI століття показує, що сегментом озброєння сухопутних військ, що найбільш інтенсивно розвивається, є його артилерійська компонента. У цій роботі розроблено модель бойового застосування артилерійської системи нового покоління. Модель призначена для модифікації військової гри ARMA 3. Артилерійська система нового покоління є знаряддям великого калібру з високим рівнем автоматизації. Вона має високу скорострільність, маневреність, точність стрілянини. Завдяки цим якостям артилерійська система нового покоління з бойової могутності підрозділу традиційних знарядь і може здійснювати бойові дії в одиночному режимі. Розроблено методику динамічної оцінки поточної боєздатності артилерійської системи з урахуванням витрат ресурсів у процесі вогневої діяльності, включаючи непрямі влучення супротивника. Показано, що крім традиційних тактичних завдань контрбатарейної боротьби артилерійська система може застосовуватися для знищення мети, що раптово проявилася, особливої небезпеки. Під метою особливої небезпеки розуміється неартилерійська система, здатна протягом короткого проміжку часу завдати дуже великої шкоди. На підставі методики динамічної оцінки поточної боєздатності збудовано дерево станів артилерійської системи. До нього включені найбільш ймовірні стани артилерійської системи та відповідні цим станам розрахункові параметри. Отримано співвідношення, що дозволяє відомого стану артилерійської системи оцінити кількість пострілів, необхідні поразки мети з необхідної гарантованою ймовірністю. На розрахункових прикладах показано, що артилерійська система нового покоління здатна знищити мету особливої небезпеки, іноді навіть власної втрати. Розроблена модель реалізована та тестується у вигляді моди для військової гри ARMA 3.

Ключові слова : гра ARMA; артилерійська система нового покоління; динамічна оцінка боєздатності; мета особливої небезпеки

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