ASSESSMENT OF UNMANNED AERIAL VEHICLES' RECONNAISSANCE EFFECTIVENESS WHEN USED BY ARTILLERY RECONNAISSANCE FORMATIONS

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***ABSTRACT**: The information revolution in military affairs (IRMA) has changed the way that wars are fought and won. Exploiting the revolution's core principles enables network-centric warfare, informationalized force to outmaneuver and defeat its adversaries. Unmanned aerial vehicles (UAV) represent a critical advancement in intelligence collection capability, long-range strikes and hybrid warfighting.*

***KEY WORDS:** Fire support, Artillery, Unmanned Aerial Vehicle (UAV), Efficiency.*

***ACRONYMS:** SP – self-propelled; TW – towed; B – batteries (artillery companies); FO – Forward observer; TOC – tactical operation center;*

Introduction

In the modern world, the process of globalization is accelerating and intensifying its direct and ambiguous impact on the security environment. The dynamics of existing and emerging new threats, expressed in the simultaneous processes of improving the international political and military security environment and reducing the likelihood of classic military aggression simultaneously with the emergence of new risks and threats to citizens and society from criminal and transnational nature, requires a new approach in the development of the security strategy with the corresponding change of its parameters.

It has been unequivocally proven that in cases of a sudden crisis or escalation of tensions in interstate relations, the main emphasis is placed on national means of defense not on collective ones. It is necessary to take urgent measures for legislative changes, assessment of the defense capabilities under the new conditions and determination of measures to reduce the existing deficit. There is a serious need of rethinking the current concepts for preparation and conduct of combat operations.

The success in contemporary military conflicts is greatly dependent on efficiency of fire support. The application of effective fire support requires ability for effective combat impact (directly or indirectly) upon the enemy by applying physical or cognitive effects through a combination of maneuver and fire, and where appropriate by other operational means, measures and mechanisms for diminishing enemy's will to conduct combat.

Fire support is a coordinated complex delivery of fire upon the opposing enemy in order to inflict maximum losses on its troops and weapons to generate favorable conditions for achieving the desired end result of the operation. Fire support is one of the main combat functions of artillery, which combines and coordinates the strikes and fire of weapons and their effects. It involves the application of firepower from open and closed firing positions, electronic warfare means, aircraft, and helicopters, coordinated with the ground component to influence upon opposing group by deliberately detaining, obstructing,

disorganizing, or disrupting the enemy's actions during tasks' execution and achieving the desired effects.

Field artillery is the fundamental fire mean of the ground component to destroy various enemy targets located in the main battle area. The main content of the combat use of artillery formations is fire support. Artillery fire support is one of the key combat functions of field artillery units and it can be characterize as application of firepower through the fire of artillery systems. The purpose of weapon delivery from artillery of the allied forces during combat operations is to inflict pre-emptive fire (fire strikes) on the most important objects (targets) of the enemy's battle order, to inflict losses that reduce the combat potential of the opposing group, to change the ratio of forces and means in favor of own forces and to provide conditions for the transition from defensive to offensive actions in certain areas.

1. Factors and criteria for fire support efficiency in contemporary conflicts.

To achieve success in the contemporary operation, it is possible to conduct consecutive defensive or offensive battles in prepared areas in the depths of the defense, combined with sudden counterattacks and extensive use of various engineering fortifications, including remote minefields, forcing the enemy to deploy and fight for any defensive line, to disrupt his original operation plan and slow down the pace of the advance, through skillful maneuvering and active actions of the mechanized formations to force the enemy to retreat in advance prepared areas, where its main battle force will be surrounded and destroyed with planned fire and decisive counterattacks.

In order to meet the contemporary requirements for conducting fire support, artillery fire must be timed, effective, accurate and sudden.

The timeliness of the fire is achieved by performing the following activities:

- Constant and high combat readiness of the artillery formations;
- Maintaining continuous interaction with the maneuverable formations;
- Continuous reconnaissance of the enemy, combat area and surveillance of own troops;
- Timely planning of the fire and maneuver of the artillery formations and setting (specifying) their tasks;
- Operational, sustainable and hidden fire control.

The effectiveness of the fire is achieved by performing the following activities:

- Obtaining reliable and accurate data on the location, size and characteristics of the objects (targets);
- Correct choice of means to damage the target;
- High accuracy and suddenness of fire;
- Use of ammunition with high damage;
- Use of appropriate order for fire mission execution and methods for weapon delivery.

The accuracy of the fire is achieved by:

- Timely and fully implementation of measures of fire preparation and fire control;
- Using the most accurate methods to determine fire data;
- Adjusting fire in course of the weapon delivery.

The suddenness of the fire is essential for destroying the enemy, especially of highly maneuverable targets and it's achieved by:

- Performing a covert maneuver and deploying artillery formations in battle order;
- Fire data preparation's concealment;
- Choosing the most appropriate time to initiate fire;
- Compliance with the rules for covert command of the troops.

Contemporary requirements become especially important for the artillery formations conducting fire support, this is summarized primarily by the technological leap in the development and implementation of modern reconnaissance and weapons systems, in the increased combat capabilities of reconnais-

sance, firepower, and command and control means. The difficulties in delivering fires at the enemy are due to the great complexity, dynamics, unpredictability, asymmetric, and fast-action of tactical combat actions. They set new requirements for artillery formations concerning increasing the probability of a favorable outcome in a hypothetical conflict in modern armed conflict's conditions. These requirements are primarily related to the improvement of several main components:

- shortening targeting time;
- timely decision-making;
- execution of the call for fire command, by fire support units;

Contemporary requirements for effective fire support are in coherence with the use of unmanned aerial vehicles (UAV) by military formations. The implementation of UAVs can provide huge opportunities to reduce the time for reconnaissance of the enemy and gather intelligence to support the decision-making process; it also can provide new capabilities to the formations involved in the intelligence process. They are related to the technological innovations and technical capabilities of UAVs. In military conflicts, where danger for human lives is more significant, application of drone technology is a big necessity due to the enhancement of military personnel and equipment safeguarding, this enforce UAVs usage for certain missions and tasks.

2. Assessing the probability of damage from artillery formations against maneuverable targets, when using optical means for reconnaissance.

In order to evaluate the efficiency of artillery fire against maneuverable targets, it is necessary to calculate the probability of objects remaining on position for the duration of their reconnaissance and destruction. Also should be determined the efficiency of artillery fire upon that target if it is on position.

To determine the probability of fire position's occupation by objects of enemy forces for the time of its reconnaissance, it is necessary to determine the average time spent by enemy targets (depending on the mobility of the target), time to prepare an observation post, time to recon and processing of the target's data by the reconnaissance group.

$$P_{t_1} = e^{-\frac{t_1}{t_0}}, \quad (1)$$

where:

- t_1 – Complete time for recon the target(preparing an observation post, time to recon and processing of the target's data by the reconnaissance group);
- t_0 – Average time spent by enemy targets on position (depending on the mobility of the target);
- e – Napier's constant (mathematical constant) equal to 2.71828;
- P_{t_1} – Probability objects to be detected if they have occupied fire position.

After detection of enemy targets, fire support units execute fire tasks to destroy them. The objects that are being fired upon will try to flee from the position as fast as possible. That leads to the necessity to determine the probability of the target's presence on the position for the time of fire task (duration of weapon delivery).

$$P_{t_c} = e^{-\frac{t_c}{t_0^l}}, \quad (2)$$

where:

- t_c – duration of the fire task;
- t_0 – time for enemy to flee from position;
- e – Napier's constant (mathematical constant) equal to 2.71828;
- P_{t_c} – Probability objects to remain on position for the duration of fire task.

To determine the complete probability for forward observer (FO) to occupy the observation post, to detect the target, for fire support units to calculate fire data and to execute the fire task, while the target still remains on position, formulas (1) and (2) can be combined as follows:

$$P_{t_s} = e^{-\frac{t_c}{t_0^l}\frac{t_1}{t_0}}, \quad (3)$$

where:

- t_1 – Complete time for recon the target(preparing an observation post, time to recon and processing of the target's data by the reconnaissance group);
- t_0 – Average time spent by enemy targets on position (depending on the mobility of the target);
- t_c – duration of the fire task;
- t_0 – time for enemy to flee from position;
- e – Napier's constant (mathematical constant) equal to 2.71828;
- P_{t_s} – Probability objects to remain on position for the duration of reconnaissance and destruction (time for observation unit to prepare observation post, time to detect the target, time to prepare fire data and time to execute the fire task).

In order to determine the efficiency of artillery fire against target, when take into account how long it will remain on position, there can be used probability of damage, if target remains on position and probability objects to remain on position for the duration of reconnaissance and destruction according to the formula:

$$P\ t\ = P_{t_s} * P(D), \quad (4)$$

It's going to be used standardized coefficients for the degree of damage that needs to be inflicted to achieve target destruction or completing the fire mission. The probability of damage will be reviewed as a key factor in artillery fire effectiveness and in general effectiveness of artillery fire support.

The input data for the calculation of artillery fire efficiency are shown in table 1, due to the non-classification character of the report, the data for objects will be approximate to fulfill the purposes of the report.

Table 1. Approximate duration of position occupation, fire preparation and execution, and leaving the position by ground fire support objects in opposing force.

	Objects	Time, min			
		Occupying fire position and preparation for fire, min	Executing fire tasks, min	Leaving fire po-sition, min	Summarized time, min
1.	Tactical rockets battery	20-25	5-10	5-8	30-43
2.	MLRS battery	4-5	2	1-2	7 - 9
3.	203,2 mm SP battery	7-9	5-8	3-5	15-22
4.	203,2 mm TW battery	18 - 24	6-7	12 - 13	36 - 44
5.	155mm (152mm) SP B	5 – 8	4 – 8	3 – 4	12 – 20
6.	155mm (152mm) TW B	16 – 22	6 – 7	8 – 11	32 – 40
7.	120mm SP mortar	4 – 6	4 – 5	3 -4	11 – 15
8.	AT battery	1 – 3	1 – 2	1	3 – 6
9.	AA battery	15	2 – 3	10	27 – 28

There also will be made assumption that targets will be only detected by optical means of reconnaissance and only they will be reviewed. Technical means for reconnaissance will not be reviewed in the report.

The duration of following processes will be set to approximate amount to fulfill the purposes of the report as follows:

- Occupying observation post by FO – 10 minutes;
- Detecting and transfer information by FO to TOC for one target – 1 minute;
- Execution of fire mission – 5 minutes;
- Probability of damage for all targets will – 30% damage (Destruction).

Table 2 Probability of damage.

№	Objects	Probability			
		P_{t_1}	P_{t_c}	P_{t_s}	$P(t)$
1.	Tactical rockets battery	0,81	0,15	0,68	0,26
2.	MLRS battery	0,37	0,00	0,00	0,10
3.	203,2 mm SP battery	0,69	0,05	0,33	0,21
4.	203,2 mm TW battery	0,81	0,32	0,78	0,28
5.	155mm (152mm) SP B.	0,68	0,02	0,23	0,18
6.	155mm (152mm) TW B	0,79	0,26	0,73	0,27
7.	120mm SP mortar	0,58	0,02	0,13	0,15
8.	AT battery	0,00	0,00	0,00	0,09
9.	AA battery	0,70	0,22	0,59	0,25

Comment:

- P_{t_1}, P_{t_c} and P_{t_s} – calculated using formulas (1), (2) and (3);
- $P(t)$ – probability of damage, when considering how long target will be on a position, calculated using formula (4).

Conclusions from table 1 and 2:

- Due to the mobility of most objects in opposing force and timed occupation of position, calculation of probability that objects will remain on position for the duration of reconnaissance and destruction is mandatory for contemporary military engagements;
- Probability of damage, when considering how long target will be on a position $P(t)$ shown in table 2 reveals the probability of damage that is most likely will be inflicted on that target;
- Probability of damage (efficiency of artillery fire and fire support in general) mainly depends on timed and sudden strikes, and efficient projectile usage, but if the factor time is not take into consideration and other factors are accounted for, the efficiency of artillery fire will be zero or it will not be determined correctly;
- Time as a factor depends both on characteristics of enemy targets and the haste of target acquisition process;
- The data from table 1 and 2 shows that the mobility characteristic of targets leads to the need of acceleration in target acquisition process, especially for high maneuverable targets.

3. Assessing the probability of damage from artillery formations against maneuverable targets, when using UAVs for reconnaissance.

For the purposes of the report there are reviewed of two UAVs class "mini", that are used in military formation in foreign countries.

First one is quadrocopter type – "ANAFI USA", military grade UAV class "mini" produces by "Parrot" company primary for US Armed forces, its primary characteristics are:

- Flight-ready – 55 sec;
- Flight time – 32 min;
- Maximum transmission range – 4km;
- Service ceiling – 6km;
- Maximum horizontal speed – 14.7 m/s (52.9 km/h);
- FLIR BOSON infrared image sensor.

Second one that will be reviewed is Skylark I-Lex – high performance man-portable UAV military grade, class "mini", fixed-wing type, produced by "Elbit systems" for Israeli armed forces, its primary characteristics are:

- Flight range – 40km;
- Service ceiling – 18km;
- Endurance – 3 hours;
- Highly autonomous and advanced image processing capabilities.

Due to the technical characteristics of the UAV, the time for recon a target at any range will be approximately 7 min (1 minute for flight preparation and 6 minutes for the flight to the enemy forces area). Also time for execution of fire mission will be accepted for 5 minutes and Probability of damage for all targets will – 30% damage (Destruction). Calculations are presented in table 3

Table 3 Efficiency of fire support while using UAVs for recon

№	Objects	Probability			
		P_{t_1}	P_{t_c}	P_{t_s}	$P(t)$
1.	Tactical rockets battery	0,88	0,15	0,78	0,28
2.	MLRS battery	0,58	0,02	0,13	0,15
3.	203,2 mm SP battery	0,79	0,05	0,50	0,24
4.	203,2 mm TW battery	0,87	0,32	0,85	0,28
5.	155mm (152mm) SP B	0,78	0,02	0,39	0,22
6.	155mm (152mm) TW B	0,86	0,26	0,82	0,28
7.	120mm SP mortar	0,70	0,02	0,27	0,19
8.	AT battery	0,53	0,02	0,09	0,14
9.	AA battery	0,80	0,22	0,71	0,27

Table 4 Comparison of probabilities of damage from table 2 and table 3.

№	Objects	Probability							
		$P_{t_1}{}^1$	$P_{t_1}{}^2$	$P_{t_c}{}^1$	$P_{t_c}{}^2$	$P_{t_s}{}^1$	$P_{t_s}{}^2$	$P(t)^1$	$P(t)^2$
1.	Tactical rockets battery	0,81	0,88	0,15	0,15	0,68	0,78	0,26	0,28
2.	MLRS battery	0,37	0,58	0,00	0,02	0,00	0,13	0,10	0,15
3.	203,2 mm SP battery	0,69	0,79	0,05	0,05	0,33	0,50	0,21	0,24
4.	203,2 mm TW battery	0,81	0,87	0,32	0,32	0,78	0,85	0,28	0,28
5.	155mm (152mm) SP B	0,68	0,78	0,02	0,02	0,23	0,39	0,18	0,22
6.	155mm (152mm) TW B	0,79	0,86	0,26	0,26	0,73	0,82	0,27	0,28
7.	120mm SP mortar	0,58	0,70	0,02	0,02	0,13	0,27	0,15	0,19
8.	AT battery	0,00	0,53	0,00	0,02	0,00	0,09	0,09	0,14
9.	AA battery	0,70	0,80	0,22	0,22	0,59	0,71	0,25	0,27

Comment:

- $P_{t_1}{}^1$, $P_{t_c}{}^1$, $P_{t_s}{}^1$ and $P(t)^1$ – are probabilities calculated in table 2;
- $P_{t_1}{}^2$, $P_{t_c}{}^2$, $P_{t_s}{}^2$ and $P(t)^2$ – are probabilities calculated in table 3;

Conclusions:

- The probability of detecting a target P_{t_1} in optical reconnaissance is lower than in UAV reconnaissance and depends mainly on the time required for the target to occupy the firing position and

prepare for fire. The comparison in Table 4 show that the probability of detection, especially for maneuverable targets, increases significantly in UAV reconnaissance (bolted borders and yellow background);

- The probability of destroying the targets with lower maneuverability, included in the study is slightly higher when using UAVs in the target acquisition process, due to the lower value of the time factor;

Conclusion

Due to the wide range of tasks that UAVs can perform, they prove to be one of the most important technical improvements that need to be adopted in the military environment. Artillery formations, in turn, are in dire need of such technology, as it will lead to the increment of capabilities. In the report we only compare the probabilities of detecting and probability of damage, but there is a lot more that UAVs can be used for starting from lower tactical level up to strategic level of contemporary military conflicts.

Artillery batteries can use UAVs for reconnaissance of roads and deployment areas, reconnaissance of routes and areas for firing positions and also for protection and surveillance of fire position borders (area) for enemy attacks.

Artillery reconnaissance formations can use UAVs not only for target reconnaissance but also for reconnaissance of roads and deployment areas for observation posts, surveillance of battle area and creation of a digital map in the depth of the enemy zone.

Overall, UAVs prove advantageous when deployed in military environment, since they reduce the risk of endangering human lives; involve fewer costs and several vehicles can be deployed at the same time. All of the above certificates that UAVs will have vital role in any future military conflict and they will be a valuable extension to a unit's operational capability.

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