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Factors Determining Process and Conditions of Warfare at Sea*

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Abstract. The aim to build a concept of warfare is to design an array of actions on the space-time continuum of a battlefield (x, y, z, t) that can use a larger amount of data, transfer it into knowledge and as a result, achieve increase in capability to carry out combat actions in the area of reconnaissance, fire conduct, and maneuvers. The paper presents some data related to the main factors which determine a process and conditions of a combat. An armed conflict is a sequence of tasks and interaction between two opposing fighting systems. To describe the basic types of interaction the following notions can be used: time, space, time-space, logical, functional, superiority, subordination etc.
Key words: warfare at sea, reconnaissance, combat systems

1. FACTORS CHARACTERIZING PROCESS AND CONDITIONS OF WARFARE AT SEA AGAINST AIR, MARITIME AND ON-SHORE THREATS

Warfare is a set of actions (type, number, order) and relations between them, taken by two opposite systems ($A \cap B$). Relations are of time, space, time-space, logical and functional etc. nature [4].

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The aim to build a concept of warfare is to design an array of actions on the space-time continuum of a battlefield (x, y, z, t) that can use a larger amount of data, transfer it into knowledge and as a result, achieve increase in capability to carry out combat actions in the area of reconnaissance, fire conduct, and maneuvers.

Warfare, actions undertaken by systems A ∩ B do not appear in vacuum. They are executed in a reality sector (Fig. 1), in specific conditions. Reality is referred to as anything that possesses time-space properties, lasts in time and what is ascribed an existence independent of us. In other words, anything that can be an object of judgment, i.e. something that can be perceived only by human mind. A reality sector associated with the process and conditions of performance of ZU-23-2MR is an object of our cognizance.

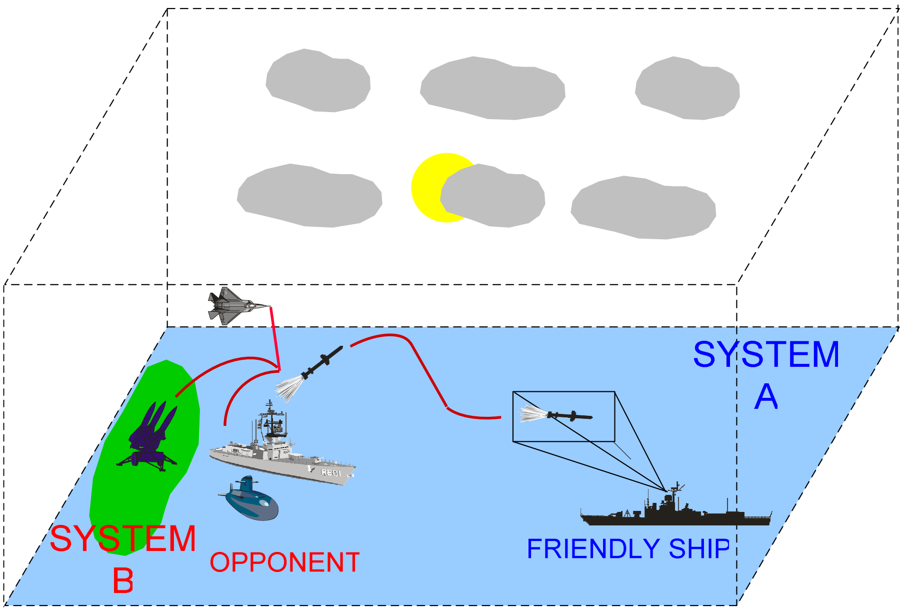


Fig. 1. A reality sector of battlefield

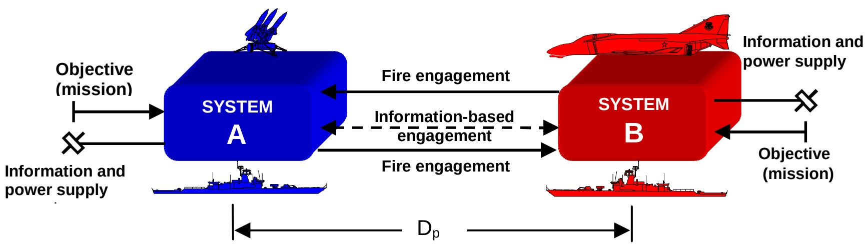


Fig. 2. Opposing systems

Each of the systems (A ∩ B) in combat (Fig. 2 – where: D_p – horizontal distance between the systems) makes efforts to reach their objectives through engagement (with use of fire, data, chemical agents, force etc.) and denying the opponent reaching their objectives.

In the reality sector (Fig. 1), for the purpose of this paper, three objects and coordinate systems associated with them are distinguished (Fig. 3). Of the objects singled out are:

– Earth (x_z, y_z, z_z – including water, land and air);

– ship carrying ZU-23-2MR (x_M, y_M, z_M), referred to as SYSTEM A;

– shell (rocket, tube - x_p, y_p, z_p) fired from ZU-23-2MR;

– target (x_k, y_k, z_k), referred to as SYSTEM B (object affected by energy of shells fired with ZU-23-2MR).

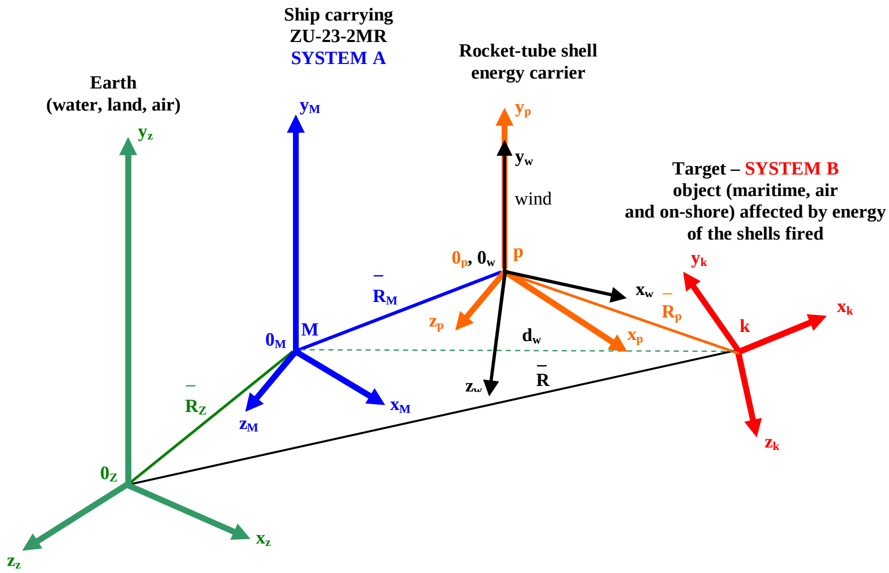


Fig. 3. Objects and coordinate systems related to them considered in this paper [6]; where: 0_z, x_z, y_z, z_z – reference system related to the Earth; 0_M, x_M, y_M, z_M – reference system related to the ship carrying; 0_p, x_p, y_p, z_p – reference system related to the shell; 0_w, x_w, y_w, z_w – reference system related to the wind; 0_k, x_k, y_k, z_k – reference system related to the target; R_z – distance between the center of the reference system in the ship carrying and the center of the reference system in the Earth; R_M – the distance between the center of the reference system in the shell and the center of the reference system in the ship carrying; R_p – the distance between the center of the reference system in the target and the center of the reference system in the wind; R – the summary distance of the center of reference system in the target and the center of the reference system in the earth; M – ship carrying ZU-23-2MR; p – shell; k – object of maneuver – target; d_w – the lead distance from the ship carrying ZU-23-2MR

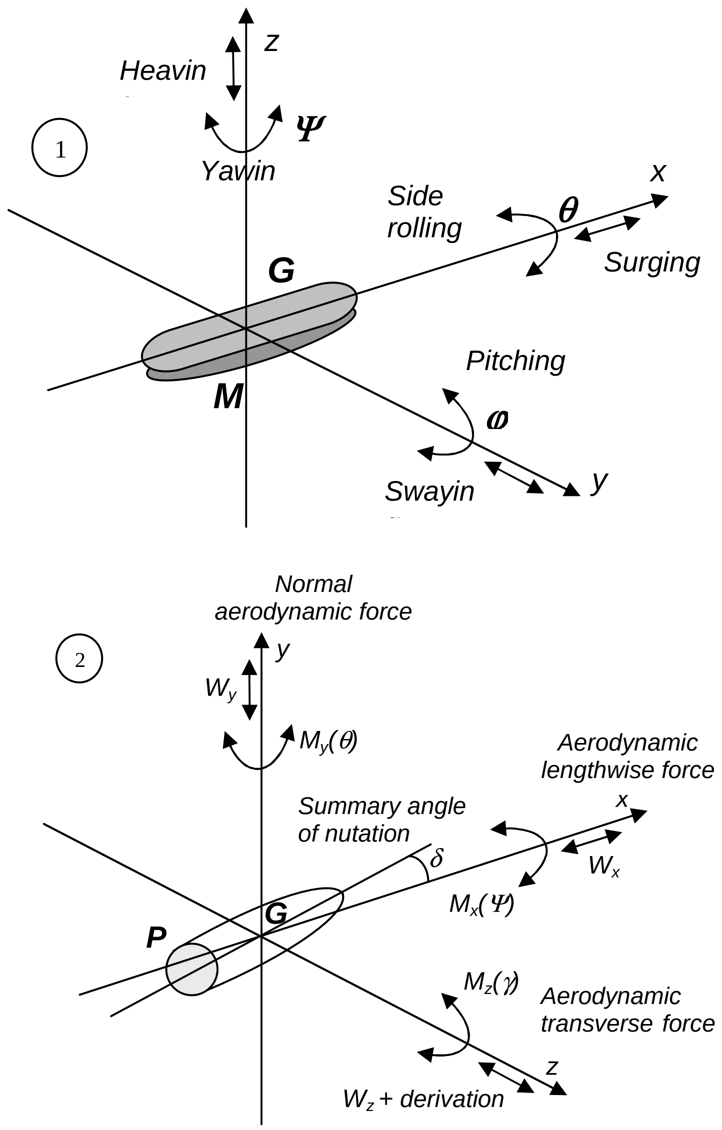


Fig. 4. Movement diagram – in six degrees of freedom – for the ship carrying ZU-23-2MR and the shell carrying energy fired by means of ZU-23-2-MR; where: 1 – system of six degrees of freedom related to the ship; 2 – system of six degrees of freedom related to the shell; G – centre of gravity; P – shell; M – weight

Specific degrees of freedom (Fig. 4) are associated with the ship carrying the ZU-23-2MR and the shell carrying the energy fired by means of the set considered.

Target – dummy target (Fig. 3) is functionally and/or structurally the smallest object whose technical condition is weakened by a collision with a shell. In this sense the target can constitute the whole object, e.g. enemy ship, enemy mine, special ops groups, cruise objects, air objects, a bunker, attacked by a shell-energy carrier fired by means of ZU-23-2-MR, not exclusively a steel plate in which the shell made a flight-trough hole.

Table 1. Sea state scale and Beaufort scale

<table>
<tr><th>Sea state scale</th><th>Mean and maximum (in parenthesis) wave height [m]</th><th>Sea state scale descriptive terms</th><th>Sea surface descriptive terms</th></tr>
<tr><td>0</td><td></td><td>Glassy</td><td>Sea like mirror</td></tr>
<tr><td>1</td><td>0,1(0,1)</td><td>Rippled</td><td>Ripples with the appearance of scales are formed, but without foam crests</td></tr>
<tr><td rowspan="2">2</td><td>0,2(0,3)</td><td rowspan="2">Slight waves</td><td>Small wavelets, still short, but more pronounced. Crests have a glassy appearance and do not break</td></tr>
<tr><td>0,6(1,0)</td><td>Large wavelets. Crests begin to break. Foam of glassy appearance. Perhaps scattered white horses</td></tr>
<tr><td>3</td><td>1(1,5)</td><td>Small waves</td><td>Small waves, becoming larger; fairly frequent white horses</td></tr>
</table>

Table 1a. Sea state scale and Beaufort scale

<table>
<tr><th rowspan="2">Sea state scale</th><th rowspan="2">Beaufort scale</th><th rowspan="2">Beaufort scale descriptive terms</th><th colspan="2">Equivalent for wind speed at altitude of 10 m above sea level</th></tr>
<tr><th>m/s</th><th>knots</th></tr>
<tr><td>0</td><td>0</td><td>Calm</td><td>0-0,2</td><td>1</td></tr>
<tr><td>1</td><td>1</td><td>Light air</td><td>0,3-1,5</td><td>1-3</td></tr>
<tr><td rowspan="2">2</td><td>2</td><td>Light breeze</td><td>1,6-3,3</td><td>4-6</td></tr>
<tr><td>3</td><td>Gentle breeze</td><td>3,4-5,4</td><td>7-10</td></tr>
<tr><td>3</td><td>4</td><td>Moderate breeze</td><td>5,5-7,9</td><td>11-15</td></tr>
</table>

Sea state plays an important role under combat conditions of system “A” against a maritime opponent. Table 1 shows a selected sea state scale and Beaufort scale.

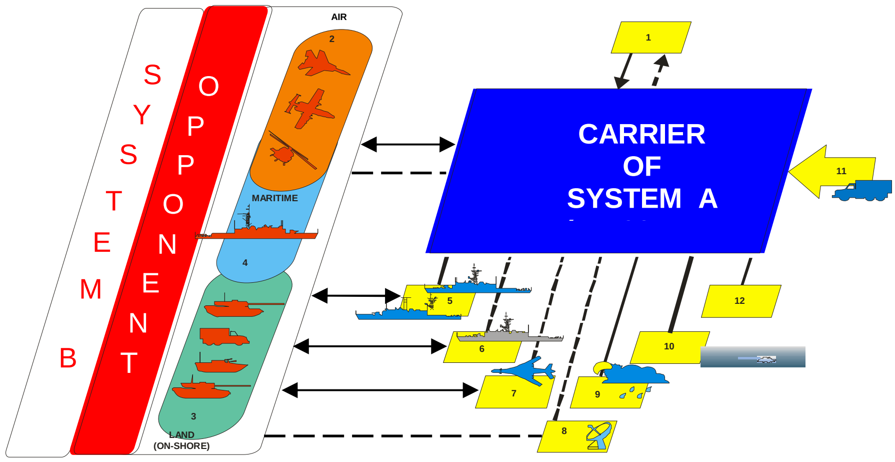


Fig. 5. Factors characterizing surroundings of the carrier of system A (ZU-23-2MR)[1];
where: 1– commander of the system; 2 – air opponent; 3 – land (on-shore) opponent;
4 – maritime opponent; 5 – defended object; 6 – neighboring reconnaissance-fire conduct system; 7 – friendly aircraft; 8 – external sources of information on situation in the area of operation; 9 – weather conditions; 10 – terrain (on-shore) conditions;
11 – external source of supply of ammunition and missiles;
12 – other reconnaissance-fire conduct systems

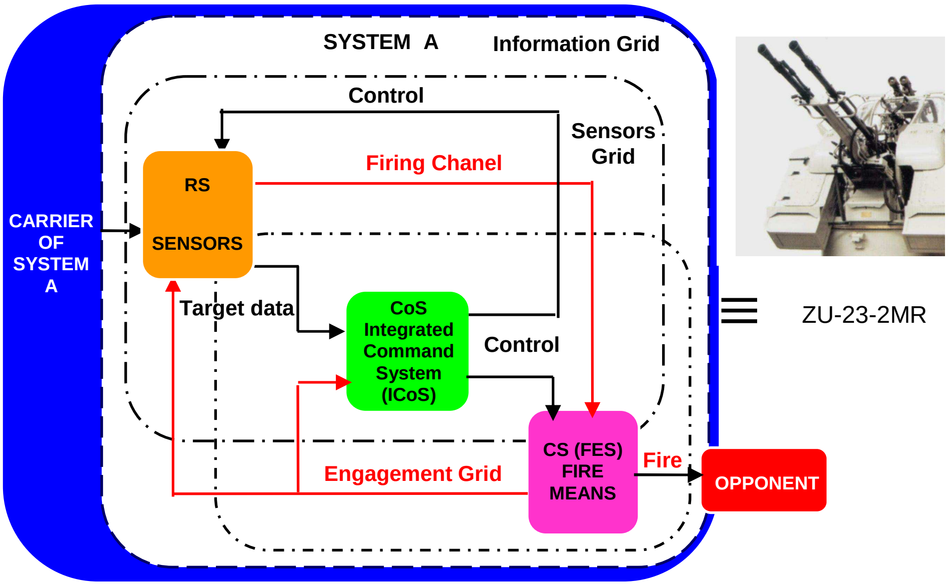
– information-decision engagement;
– information engagement;
– force engagement;
– fire engagement

Conditions in which combat process is carried out are characterized by:

- factors characterizing surroundings of the system under consideration, e.g. „A” (Fig. 5);
- factors characterizing inside of system “A” (Fig. 6);
- time, including among others $T_a \geq T_r$,, where available time (T_a), response time (T_r) and time for which the target (object) remains present in the zone of reconnaissance and fire.

Elements of surroundings are not an integral part of the system „A” but they are connected with it and they condition its performance (Fig. 5).

Performance of system „A” is also dependent on elements of its inside, constituting its functional structure.



Functional structure

Fig. 6. Subsystems of system „A" taking part in execution of the sequence of actions in combat [3], where: RS – reconnaissance subsystem; CoS – command subsystem; CS (FES) combat subsystem (fire engagement subsystem)

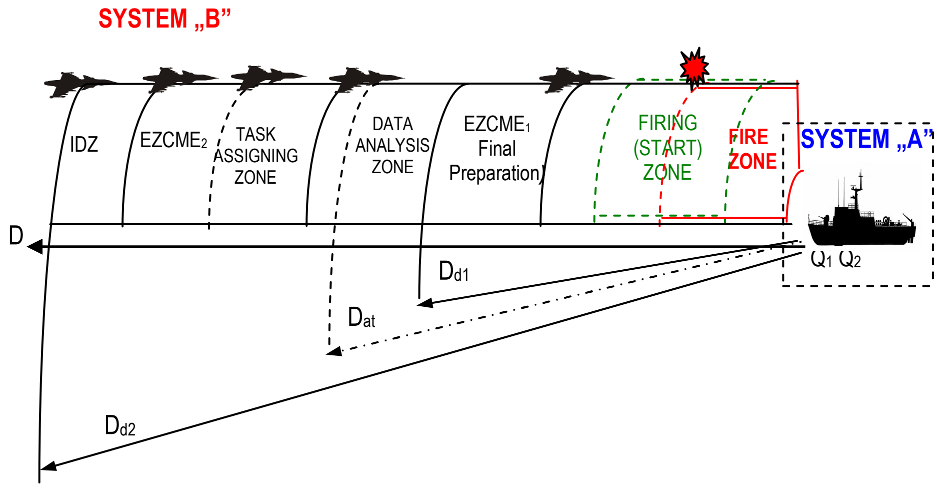


Fig. 7. Example of sequence of actions in combat [4], where: IDZ – Information Delay Zone; EZCME – Estimation Zone of Conditions of Mission Execution; D – range (km); D_{d2} – range of detection by Q_2; D_{at} range of assigning tasks; D_{d1} – range of detection by Q_1; Q_1, Q_2 – decision makers

The inside, among others, of system „A” taking part in combat is composed of subsystems reconnaissance (sensors) command (ICoS) and fire engagement (FES) (Fig.6) in order to achieve high awareness of the array of actions (Fig. 7) their speed, pace, synchronization and enhancement of their effectiveness through selection of the condition and type of armament, are interconnected to form an information grid.

Problems solved by system „A” at points Q_1 and Q_2 (Fig. 7) are shown in table 2.

Table 2. Problems solved by system “A” at points Q_1 and Q_2 (example)

Q_1 (ZU-23-2MR operator)	Q_2 (Ship captain, head of department 2, simulator engineer)
1. Which direction?	1. Which directions?
2. Which target? 3. Which type of weapon to use to engage ?	2. Which targets?
4. How to solve the problem of a hit?	3. In which order?
5. Which mode?	4. Which way? – which reconnaissance-fire conduct systems? – what number of shells?
6. Which way to hit target?	5. To whom, when and how to assign the task?
7. How many shells?	
8. How many fire engagements?	
9. At which moment to begin?	
10. Should one more try be made?	
11. When to finish and move fire on another target?	
12. Is the result as I have predicted?	6. Is the result as I have predicted?

A list of factors characterizing surroundings and inside of system „A” is shown in table 3.

Table 3. Factors characterizing the surroundings and the inside of system „A" (Fig. 5 and 6)

Factors characterizing the surroundings of system "A"	**Factors characterizing the inside of system "A"**
1. Air situation: – weather conditions; – form of friendly aircraft activity; – form of opponent aircraft activity. **2. Maritime situation:** – sea state (0, 1, 2, 3); – form of activity by Polish Navy; – form of activity by opposing Navy. **3. Land situation:** – terrain conditions; – form of friendly forces activity; – form of opponent forces activity. **1.** Invariables. **2.** Variables: a) independent; b) dependent.	**1.** Mission (tasks) **2.** Structural organization of the system: functional, regular post-based; spatial (group); linear-functional; technical; hierarchical; decision-based. **3.** Place, role and capabilities of commanders (function personnel) in the structure when using means of execution, including: a) information (ordering, somebody to do/not to do something); b) rules of performance; c) ways of performance; d) criteria for inspection and assessment.
– situation of the background; – situation of the clutter.	

Factors characterizing external and internal factors of the process can be, within a specific time interval, variable or invariable. If variable, then independent of or dependent on fire-opening decision makers.

2. PROCESS AND CONDITIONS OF SEARCHING FOR AND TRACKING OBJECTS IN COMBAT

To obtain information on the opponent, in performing a reconnaissance mission, the actions must occur as follows: searching and tracking.

Searching should lead to detecting an object (detection is defined as an occurrence that consists in isolating an object from the background).

The aim of searching (in sector $\Delta\beta$ of boundaries β_1 β_2, Fig. 8) is to detect an object in the preset space (reconnaissance zone) and time, i.e. determining its original position.

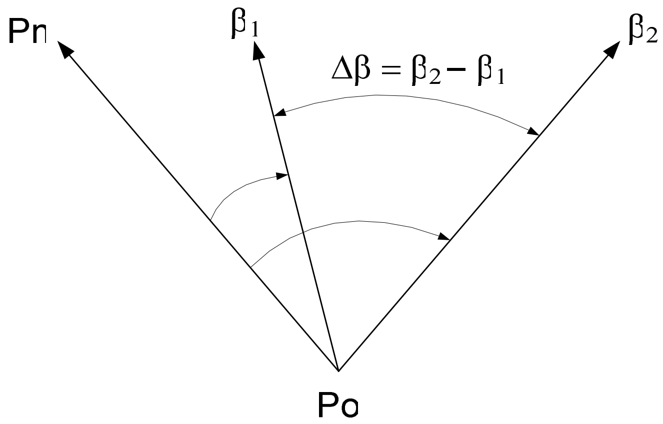


Fig. 8. Sector $\Delta\beta$, where: P_O – fire position; β_1 – left boundary of the search sector [in degrees]; β_2 – right boundary of search [in degrees]

Isolating an object from the background – detection (discovering existence) should, in turn, make it possible to track it, that is to create conditions to provide further information on the object for fire decision makers.

Tracking the object detected is a process of determining its identity. The search process ended with detection can, therefore, be regarded as prior to the process of tracking, which makes it possible to:

- identify status of "friend – foe" (in connection with implementation of the anti-aircraft missile system „GROM" aboard Polish Navy ships there is a necessity to define requirements concerned with use of IFF);
- identify properties of the object, informing about the form of activity and ending with a decision related to further steps.

The character of the search process depends on the type and properties of the search space as well as the ways and means of action. Thus, they can be regarded as types of criteria used to classify models of ways of search.

Based on the information obtained from reconnaissance of air and land objects, it can be concluded that in training essential are:

a) in the case of a single object: size, shape, area, color, (for optical surveillance), effective return surface (signal form entering a radar), value and fluctuation of infrared (thermal) radiation;
b) in the case of a group object: number of single objects, position (distance) and significance in the group and the reconnaissance zone within the type of object (name and type of object are not significant for modeling);
c) coordinates of the object and factors of object's movement (are significant elements at all the stages of determining and using the information related to its properties);

d) countermeasures used by the airborne opponent against air defense systems (employing interference, carrying out missions under the cover of interference, anti-shell and anti-missile maneuvers and not entering the fire zone have an important effect on modeling the conduct of the airborne opponent, among others in the conditions of the Central Exercise Field of the Air Force in Ustka.

With regard to functioning of the air-defense systems and their use in training, the properties listed in table 4 gain in special importance.

With regard to automation of the process of training on a target and projection of properties, three ways of object tracking are distinguished: manual, semiautomatic and automatic.

Factors characterizing the objects reflect the properties which are used to infer about their importance and to make a choice for destruction. It must be added that:

- actions by objects can be observed within the limits of detection capabilities of friendly forces equipped with own or superior's assets;
- analysis of opponent's conduct can be done with use of data received from the superior (from radar factors, air situation plotting board – early search radar), in the project using information received from the superior and visual observation by an operator etc.;
- appearance of the opponent in the reconnaissance and fire zones is of probabilistic nature.

Note. Taking into consideration, among others, coordinates and enemy object movement factors their importance is determined and the target to be destroyed is selected.

Table 4. Possibilities of determining properties of object in the course of tracking it

General properties of object	**Specific properties of object**	**Means of surveillance**	
		Operator of ZU-23-2MR	
		Eyesight	**Eyesight, Binoculars**
Composition	1. Properties of one object		
	– shape	x	x
	– size	x	x
	– area	x	x
	– effective return surface	-	-
	– phenomenon of thermal energy radiation	-	-
	2. Properties of a group object		
	– number of individual objects in group	x	x
	– array with regard to height;	x	x
	– array with regard to range	x	x
Type	Ballistic missile	x	x
	Jet plane	x	x
	Propeller driven plane	x	x
	Motor glider	x	x
	Cruise missile	x	-
	Helicopter	x	x
	Glider	x	x
	Parachute dropping	x	x
Coordinates for air object	Angular and linear quantities which can be used to determine position of one point (C) with reference to the other (PO) assumed as original	-	-
Air object movement factors	Angular or linear quantities, which apart from coordinates, determine the position of velocity vector ($\vec{V}$) in space	-	-

Table 4a. Possibilities of determining properties of object in the course of tracking it

General properties of object	Specific properties of object	Means of surveillance Operator of ZU-23-2MR Eyesight, optical and thermal cameras	 Eyesight, radars
Composition	1. Properties of one object		
	– shape	x	-
	– size	x	x
	– area	x	x
	– effective return surface	-	x
	– phenomenon of thermal energy radiation	x	x
	2. Properties of a group object		
	– number of individual objects in group	x	x
	– array with regard to height;	x	x
	– array with regard to range	x	x
Type	Ballistic missile	x	-
	Jet plane	x	-
	Propeller driven plane	x	-
	Motor glider	x	-
	Cruise missile	x	x
	Helicopter	x	x
	Glider	x	-
	Parachute dropping	x	-
Coordinates for air object	Angular and linear quantities which can be used to determine position of one point (C) with reference to the other (PO) assumed as original	x	x
Air object movement factors	Angular or linear quantities, which apart from coordinates, determine the position of velocity vector ($\vec{V}$) in space	x	x

3. CONCLUDING REMARKS

The paper presents some data related to the main factors which determine a process and conditions of a combat. An armed conflict is a sequence of tasks and interaction between two opposing fighting systems. To describe the basic types of interaction the following notions can be used: time, space, time-space, logical, functional, superiority, subordination etc.

In combat, each of the systems attempts to reach its objectives through engagement of military nature (the interaction can be in terms of power, barrage, information gathering, etc.) and to deny the opposing system reaching its objectives at the same time. The purpose of developing a concept of warfare is to work out a sequence of actions that can make it possible to use larger amounts of information to reach higher combat effectiveness and maneuverability.

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