Problems of effectıve applıcatıons of aır defense means agaınst aır target actıvatıng at low altıtudes

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Abstract-This paper examines the defeat of various types of air attack weapons, such as fighters, helicopters, cruise missiles, reconnaissance unmanned aerial vehicles, armed unmanned aerial vehicles, drones and kamikazes by air defense systems, taking into account their low-altitude operation. For this purpose, efficiency coefficients are determined that characterize the defeat of low-altitude air attack weapons by anti-aircraft missile systems, taking into account their tactical and technical characteristics. To solve the problem, the first party was considered to be air attack weapons, such as fighters, helicopters, cruise missiles, reconnaissance unmanned aerial vehicles, armed unmanned aerial vehicles, drones and kamikazes, and the second party was considered to be the S-125 2TM, BUK-MB, Barak-8, S-300 PMU2, TOR-M2KM, Patriot MIM-104, Panisir S-1, Nasams-III, Igla-S, Strela-10, OSA-AK(M) anti-aircraft missile systems. Therefore, a mathematical model of the problem was developed using game theory. The obtained problem was solved using the simplex method. It was determined that the TOR-M2KM anti-aircraft missile system, which is an air defense system for engaging low-altitude air attack weapons, can be used primarily against fighters, helicopters, unmanned aerial vehicles, armed unmanned aerial vehicles and unmanned aerial targets during combat operations. Of the air attack weapons, it is proposed to use cruise missiles first of all during combat operations, and kamikazes at the next stage. It is advisable to use the Barak-8 air defense system against cruise missiles. The obtained results can be used in planning the effective implementation of an air defense system against low-altitude air attack weapons.

Keywords-unmanned aerial vehicle, armed unmanned aerial vehicle, air attack weapons, air defense system, radar station, anti-aircraft missile system, mathematical modeling, game theory.

I. INTRODUCTİON

Research into the field of low-flying target engagement is of great importance for the development of modern air defense systems. Such targets are often challenging targets for radar and defense systems. Since, flying at low altitudes, these targets can hide from ground radars and shorten their trajectories with the help of geographical obstacles. Development of high-precision radar systems is of great importance for tracking these targets. Among these technologies are more sensitive radars and AI-based tracking systems to prevent objects flying close to the ground from hiding from radars. Using powerful electronic warfare technologies to prevent such targets. Works to confuse radars, disrupt drone control, and neutralize the target in cooperation with other defense systems. Electro-optical and infrared sensors are widely used to detect visual and thermal signatures of targets. These sensors are especially effective at night and in difficult weather conditions. Using highly maneuverable, fast-moving, and suitable missiles designed to engage targets.

Targets can exploit terrain features such as mountains, buildings, and other natural obstacles. Therefore, effective target detection requires the integration of topographic information and target tracking technologies.

Electronic warfare techniques are used to disrupt or remove radio frequencies of targets. This is especially important to prevent unmanned aerial vehicles from evading defense systems. The use of unmanned aerial vehicles against unmanned aerial vehicles has also become relevant in recent times. The enemy uses both physical destruction methods and signal jamming or deception technologies to neutralize unmanned aerial vehicles.

Air defense systems detect and destroy airborne targets, providing highly sensitive and accurate attacks on low-flying targets, working in conjunction with radar and anti-aircraft missiles. Research into the destruction of these targets, along with the development of new technologies and the modernization of existing defense systems, also has a major impact on the tactics and strategy of future warfare. This area of research is very broad and important from both a technological and tactical point of view. One of the main aspects of destroying low-flying supersonic targets is the selection of effective missile systems. Modern anti-aircraft missile systems are equipped with high-precision missiles with integrated guidance and control systems capable of effectively destroying low-flying targets in conditions of active maneuvering.

Combining anti-aircraft missile systems into a single air defense system and coordinating the actions of various types of weapons and reconnaissance assets allows creating a powerful air defense system and effectively combating low-flying supersonic targets in various combat scenarios.

Thus, detection and destruction of low-flying supersonic targets by anti-aircraft missile systems is a complex but solvable task due to the integration of advanced technologies, sensor systems and weapons. Modern anti-aircraft missile systems are highly effective and provide reliable protection against low-flying supersonic targets. Currently, planning the effective implementation of detection and destruction of low-flying air attack assets by air defense assets is a pressing issue.

II. LOW ALTİTUDE AİR ATTACK WEAPONS

Low altitude air attack weapons are a technology that provides a significant tactical advantage in military conflicts. They are used to confuse enemy air defense systems through their radar evasion capabilities and low altitude flight. The most common low altitude air attack weapons include:

Fighter, Helicopter, Cruise missile, Unmanned aerial vehicle, Armed unmanned aerial vehicle, Drone and Kamikaze.

Low-altitude air attack vehicles play an important role in the Russian-Ukrainian war, in particular, drones and helicopters are one of the main means of gaining a tactical advantage for both sides. Russia, in particular, widely uses Iranian-made Shahid-136 kamikaze drones. These drones fly at low altitudes, and due to their small size and high speed, they are difficult to detect by radar. They are programmed to accurately hit targets and are used against Ukrainian infrastructure, energy facilities and military bases. Ukraine widely uses the Bayraktar TB2 unmanned aerial vehicle. This unmanned aerial vehicle operates at low and medium altitudes, destroying ground targets such as tanks and air defense systems. Low-altitude combat helicopters are the primary firepower for both sides. For example, Russian Ka-52 and Mi-28N helicopters try to destroy targets by maneuvering quickly. They provide a powerful fire system against both tanks and air defense systems. Ukraine, on the other hand, uses Soviet-made helicopters such as the Mi-8 and Mi-24 supplied by the West. Russia and Ukraine are also trying to integrate new generation drone and helicopter technologies into the battlefield. They feature higher speed, low-altitude flight capabilities, and improved maneuverability. In the Karabakh War (2020), Turkish-made Bayraktar TB2 unmanned aerial vehicles were successfully used by Azerbaijan. They flew at low altitudes and attacked Armenian tank, anti-aircraft missile and artillery systems. Harop kamikaze drones (Israeli-made), hidden from radar, were used to destroy Armenian air defense systems. However, manned aircraft also participated in the battles. In particular, the Azerbaijani Air Force used Su-25 attack aircraft against the Armenians. In turn, the Armenian Air Force had 14 pieces Su-25K and 1 piece Su-25UB aircraft. During this war, the first Su-25 was lost by the Armenian Air Force. After the destruction of the main part of the air defense systems in Karabakh, the Su-25 attack aircraft of the Azerbaijani Air Defense were used to strike the positions of the main enemy forces. In particular, they were used in the direction of Jabrayil. The strikes were carried out from high altitudes with FAB-250 and FAB-500 high-explosive aerial bombs.

Laser-guided munitions were also used. Their Bayraktar unmanned aerial vehicle had the advantage that attack drones could not lift munitions of similar power. During the Second Karabakh War, in addition to aircraft, helicopters were also actively used. LAHAT and SPIKE-NLOS missiles mounted on combat helicopters carried out precise strikes on targets. Active interference with detected air defense systems was also provided by Tigon electronic warfare systems from Mi-17 helicopters. During the fighting, one Mi-17 helicopter was shot down by Armenian air defense. Armenian pilots had extensive experience, having flown in mountainous terrain for a long time. Therefore, using the terrain, they carried out combat sorties on Su-25 aircraft at low and ultra-low altitudes and carried out air strikes on groups of troops of the Azerbaijani army. In total, the Armenian side lost 5 (five) Su-25 aircraft during the fighting[1]. In the war between Azerbaijan and Armenia, it can be concluded that the role of attack aircraft in modern armed conflicts is declining with the advent of attack drones. Aircraft designed to strike targets from low altitudes are vulnerable to an enemy with outdated air defense systems. If the aircraft is damaged, the loss of the pilot is very likely, which often requires the use of attack drones instead of attack aircraft.

During the Syrian civil war, various armed groups and states in Syria and Iraq made extensive use of drones. Armed groups supported by Iran and the Russian military made extensive use of drones for low-altitude attacks. Mi-24 helicopters were one of the main attack aircraft of the Syrian regime. They provided close support to ground troops at low altitudes and played the role of the main weapon against anti-government forces. The Syrian regime used Mi-8 and Mi-17 helicopters to drop barrel bombs on civilian areas. These bombs caused great destruction when dropped from the air, causing civilian casualties. The Russian Air Force used these advanced attack helicopters in military operations in Syria with the Ka-52 Alligator and Mi-28N Night Hunter helicopters. Flying at low altitudes, they carried out effective attacks on tanks, artillery, and armed militants. The Mi-24 and Mi-35 helicopters were also highly maneuverable and provided close fire support to ground troops.

Both the Syrian regime and Russian forces used a variety of reconnaissance drones during the conflict. These drones flew at low altitudes to conduct surveillance and reconnaissance operations on the battlefield. They located militants and weapons systems, and then relayed the information to military aircraft or artillery attacks. Iranian-backed armed groups, particularly Hezbollah and other Shiite militias, have used Iranian-made attack drones. These drones fly at low altitudes and attack opposition forces conducting combat operations against regime forces. Russian Orlan-10 reconnaissance and targeting drones have been used to locate targets and pinpoint coordinates during the conflict in Syria. The drones have been used for airstrikes during the Syrian civil war and for border patrols on Iran's eastern border. Together with the Shahed 129, they are expected to form the backbone of Iran's high-tech drone fleet for at least the next decade. [2] Low-altitude drones were used extensively by Turkey and the United Arab Emirates during the Libyan civil war. Turkish Bayraktar TB2 drones were used by forces supporting the Tripoli government, while the UAE used Chinese Wing Loong drones. At various points in the war, both sides used Mi-24 and Mi-17 helicopters. Electronic defense systems and man-portable air defense systems were used with limited effectiveness against drones and helicopters.

During the war in Yemen, the Houthis used Iranian-made drones to attack Saudi Arabia's oil infrastructure and military bases.

Saudi Arabia's defensive tactics: Saudi Arabia attempted to counter these attacks using Patriot systems and man-portable air defense systems. Thus, the main advantages of low-flying air attack weapons are their difficulty in detecting radar, their high maneuverability, and their ability to be used effectively in large-scale combat.

Modern radar systems and electronic warfare systems are essential for effective defense against low-altitude aircraft. Mobile anti-aircraft artillery and anti-aircraft missile systems also play an important role in countering low-altitude attacks. New drone technologies and electronic warfare systems are constantly changing the development of these vehicles and the fight against them. Low-altitude aircraft are widely used in modern warfare to provide tactical advantage, and it is important to develop defensive strategies against them.

III. AİR DEFENSE SYSTEMS

One of the main aspects of defeating low-flying supersonic targets is the choice of effective missile systems. Modern anti-aircraft missile systems are equipped with high-precision missiles with integrated guidance and control systems capable of effectively hitting low-flying targets even in conditions of active maneuvering.

"Panser-S1" (Figure 1) is a short-range anti-aircraft missile and gun system mounted on a tracked chassis, a wheeled chassis of a truck, a trailer or installed stationary. Control is carried out by two or three operators. Air defense is carried out by automatic weapons and radio command missiles with infrared and radar tracking. The complex is designed to protect small objects from air attack. In addition, the complex is capable of fighting lightly armored ground targets, as well as enemy manpower. The Pancer-C1 complex is a multi-channel tracking system that creates a continuous target acquisition zone for missile and artillery weapons at ranges from 0 m to 200 m. It is capable of destroying targets at an altitude of up to 15 km and a range of up to 20 km without external support. The fire control system of the Pancer-C1 complex includes detection and tracking radar stations. They provide tracking of both targets and anti-aircraft missiles launched by the complex. The detection range of these radar stations is 32-36 km for targets with an effective reflection area of 2 m2. The maximum detection range of the station is 80 km. In addition to the radar, the fire control system also includes an optical-electronic complex with a long-wave receiver (infrared homing head). The entire system can operate fully automatically [3, 4, 5].

During the military operations in Syria, Turkey took the tactics of using drones to a new level. At the first stage, its target was not the illegal irregular formations of Syria, but the regular army and military equipment. At the second stage, a larger unmanned aerial vehicle, the ANKA complex, equipped with electronic warfare systems, was used to destroy the air defense system as part of the Bayraktar-TB2 unmanned aerial vehicle group. With the help of the electronic warfare systems of the ANKA unmanned aerial vehicle, it was possible to suppress the radar system of the Pancer-C1 complex (Figure 1), which in turn allowed the Bayraktar-TB2 unmanned aerial vehicle to enter the kill zone of the Pancer-C1 complex and strike it [6]. The Zenith-rocket system OSA air defense missile system (Figure 2) is designed to destroy standard air targets at a distance of 1.5–10 km, at an altitude of 25 m to 5 km. The target detection range is up to 45 km. Equipped with 6 anti-aircraft guided missiles. The probability of hitting an air attack vehicle of the "aircraft" type is 0.5 - 0.85. The reaction time is 16-26 seconds [6, 7]. At the same time, the experience of combat use of the zenith-rocket system OSA system in the wars in Yugoslavia and Libya showed that it is ineffective against targets with a small effective reflection area and flying at altitudes of up to 50 m.

The Strela-10 anti-aircraft missile system (Figure 3) can hit air targets at an altitude of 0.01-3.5 km and a range of 0.8-5 km (the probability of hitting with one missile is 0.3–0.6). The reaction time of the system is 7-10 seconds [7].

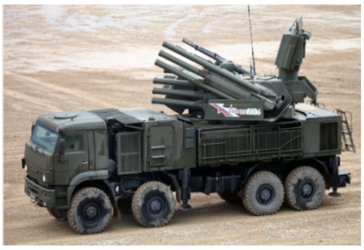

Fig. 1. Pantsir-C1

Fig. 2. Zenith-rocket system OSA

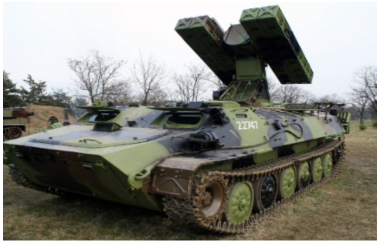

Fig. 3. Anti-aircraft missile complex "Strela-10"

Both of these anti-aircraft missile systems were primarily designed to combat army aircraft and helicopters. Their capabilities against unmanned aerial vehicles were limited. However, during the joint exercises of the Air Defense Forces of Armenia and Russia in June 2020, according to Russian military experts, these air defense systems were recognized as effective against Azerbaijani unmanned aerial vehicles. The reason for such opinions was the successful interception of a single-seat Hermes 900 reconnaissance aircraft by the OSA air defense system [6]. The Patriot-MIM-104 is an American anti-aircraft missile system used by the US Army and the armies of a number of other countries (Figure 4). The system uses universal radars that perform the functions of target detection and tracking, as well as target designation and missile control. The multifunctional radar is designed to detect, track and illuminate targets with a main transmitting phased array diameter of 2.44 meters, track missiles and transmit commands [9]. The wavelength of the system is 5.5 - 6.7 cm, it operates in the range of 4 - 6 GHz, the search mode is from +45 to -45 ° in azimuth, at an elevation angle of 1 ° -73 °, the tracking sector is from +55 to -55 ° in azimuth, at an elevation angle of 1 ° -83 °, the detection range is 70 km with an effective target reflection area of 0.1 m^2 and 180 km at an elevation angle of 10 m^2. It can simultaneously track up to 125 targets and simultaneously control up to 6 missiles. The range of destruction is a minimum of 3 km, maximum 80 km, and the altitude is a minimum of 0.06 km, maximum 25 km [8]. Nasams is a mobile Norwegian anti-aircraft missile complex designed to combat aerodynamic targets maneuvering at low and medium altitudes. He can destroy unmanned aerial vehicles, ballistic missiles, helicopters, airplanes, cruise missiles and other targets. Nasams refers to short- and medium-range air defense systems, and depending on the missiles used, the range of damage can be 20-50 km (Figure 5).

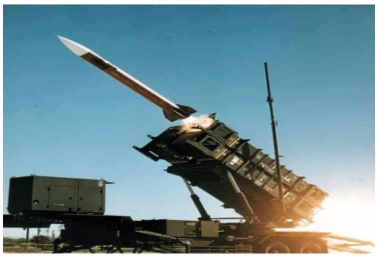

Figure 4. Anti-aircraft missile complex Patriot MIM-104

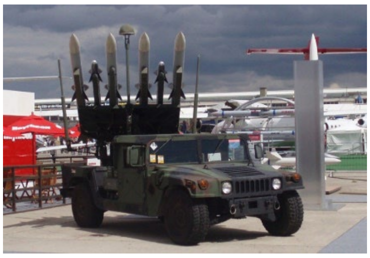

Figure 5. Anti-aircraft missile complex Nasams-III

Let's consider the tactical and technical characteristics of the means of fire defense, intended for defeating unmanned aerial vehicles. According to Russian manufacturers, the following types of weapons are effective against unmanned aerial vehicles: anti-aircraft missile systems "TOR-M1", "TOR-M2E", "BUK-M2E", "BUK-M3", "Morpheus", "Vityaz", anti-aircraft missile guns "Pantsir C1" and "Sosna". Versatıle counteractıve complex "TOR" is considered effective against hard-to-detect targets, as it is designed to combat high-precision weapons and cruise missiles. Anti-aircraft missile complex "TOR-M1" detects and accompanies 48 targets at a distance of up to 27 km, at an altitude of 0.01-9 km and destroys them at a distance of 1–12 km. The number of simultaneously fired targets - 2. The reaction time of the complex -7.4 seconds. Modification "TOP-M2Э" now shoots 4 targets simultaneously. In the "TOP-M2У" variant, the combat kit is increased from 8 rockets to 16 rockets.

The results of the 44-day war between Azerbaijan and Armenia in 2020 are still being studied, and the experience of tactics implemented by Azerbaijan is used all over the world. Thus, from the beginning of the conflict, among the air defense systems of Armenia were such systems as zenith missile system "Osa-AK(M)", "Krug", "Kub", S-125, S-300PS and "TOR-M2KM". With the help of these systems, the Armed Forces of Armenia fulfilled the task of protecting the airspace in the Karabakh region of Azerbaijan. However, the high maneuverability, low-altitude capabilities and accurate weapons of the Azerbaijani Bayraktar TB2 unmanned aerial vehicles allowed them to gain an advantage over the Armenian air defense systems. The effective use of unmanned aerial vehicles by the Azerbaijani army reduced the effectiveness of Armenia's air defense systems. Although, according to Russian military experts, the joint exercises of the Armenian-Russian air defense forces in June 2020 made it possible to draw conclusions about the high combat qualities of this air defense system[9].

Armed forces of Azerbaijan, taking into account the experience of local wars, started the war in Karabakh with the use of a large group of unmanned aerial vehicles. In the first days of the war, it became clear that Armenia is completely unprepared for anti-aircraft defense with the intensive use of unmanned aerial vehicles. This led to the almost complete destruction of the Armenian zenith missile system "Osa-AK(M)" in Karabakh during the first days. On the first days of the military operation, more than 60% of Karabakh air defense systems (14 pieces "Osa-AK(M)") were disabled by pre-prepared strikes on air defense systems. At the same time, since such Armenian air defense systems as "S-300PS" and "S-300PT" were not designed to fight unmanned aerial vehicles, these systems were not effectively used to protect against new threats on the first day of the war. In addition, as a result of a successful operation planned by the Air Force of Azerbaijan, the air defense system "S-300PS" was destroyed by an unmanned aerial vehicle. The outcome of this war shows that the effectiveness of the above-mentioned air defense systems against unmanned aerial vehicles, which are modern means of air attack, is low.

IV. STUDY OF THE DESTRUCTİON OF AİR ATTACK WEAPONS OPERATİNG AT LOW ALTİTUDES

Let us assume that the values of the conditional coefficients characterizing the effectiveness of the use of the S-125 2TM, BUK-MB, Barak-8, S-300 PMU2, TOR-M2KM, Patriot MIM-104, Pantsir S-1, Nasams-III, IGLA-S, Strela-10 and OSA-AK(M) air defense systems against low-altitude air targets such as fighters, helicopters, cruise missiles, unmanned aerial vehicles, armed unmanned aerial vehicles, drones and kamikazes are given in Table 1. To study the effectiveness of the use of the S-125 2TM, BUK-MB, Barak-8, S-300 PMU2, TOR-M2KM, Patriot MIM-104, Pantsir S-1, Nasams-III, Igla-S, Strela-10 and OSA-AK(M) against low-flying air attack weapons such as fighters, helicopters, cruise missiles, unmanned aerial vehicles, armed unmanned aerial vehicles, drones and kamikazes, we consider air defense systems as the first side, and air attack weapons as the second side. Then the problem can be considered as a game of two players. The solution to the problem can be obtained using the simplex method [10, 11, 12, 13, 14]. Using the above methodology and Table 1, the lower $\alpha = \max_i \min_j a_{ij} = 0.721 = 0.721$ and the upper $\beta = \min_j \max_i a_{ij} = 0.833$ values of the effectiveness of air defense weapons against air attack weapons are obtained.

Table 1. The coefficients of effectiveness of defense means for targets operating at low altitudes are given conditionally

Serial number	Air Defense Systems	Low altitude targets							
		Fighter	Helicopter	Cruise missile	Unmanned aerial vehicle	Armed unmanned aerial vehicle	Drone	Kamikaze	$\alpha_i = \min_j a_{ij}$
1	S-125 2TM	0.652	0.853	0.454	0.801	0.791	0	0	0
2	BUK-MB	0.711	0.891	0.651	0.871	0.852	0	0	0
3	Barak-8	0.971	0.981	0.956	0.972	0.981	0	0	0
4	S-300 PMU2	0.892	0.952	0.882	0.982	0.973	0	0	0
5	TOR M2KM	0.731	0.752	0.721	0.861	0.853	0.842	0.833	0.721
6	Patriot MIM-104	0.724	0.854	0.681	0.843	0.834	0.813	0.824	0.681
7	Pantsir S-1	0.704	0.784	0.684	0.754	0.734	0.684	0.694	0.684
8	Nasams-III	0.784	0.879	0.769	0.849	0.839	0	0	0
9	Igla-S	0.539	0.648	0	0.527	0.519	0.501	0.509	0
10	Strela-10	0.538	0.629	0	0.387	0.379	0.369	0.346	0
11	OSA-AK(M)	0.536	0.686	0	0.667	0.658	0.638	0.645	0
$\beta_j = \max_i a_{ij}$		0.971	0.981	0.956	0.982	0.981	0.842	0.833	

That is, in this case $\alpha \neq \beta$, determining the effectiveness of using air defense systems against air attack systems is reduced to solving the following conjugate linear programming problems:

Objective function:

$$f(x) = \sum_{i=1}^{m} x_i \to min \qquad (1)$$

Restriction conditions:

$$A^T \cdot x \geq b \qquad (2)$$

$$x \geq 0. \qquad (3)$$

$$p_i = x_i \cdot v, p_i \geq 0,\ i = 1, 2, \dots, m \qquad (4)$$

$$v = \frac{1}{fmin(x)},\ \ v > 0. \qquad (5)$$

Objective function:

$$z(y) = \sum_{i=1}^{n} y_i \to max \qquad (6)$$

Restriction conditions:

$$A \cdot y \leq b \qquad (7)$$

$$y \geq 0. \qquad (8)$$

$$q_j = y_j \cdot v, q_j \geq 0,\ j = 1, 2, \dots, n \qquad (9)$$

$$v = \frac{1}{Zmax(y)},\ \ v > 0. (10)$$

Where m - is the number of air defense systems, n – is the number of air attack systems, p_i - is the probability of using the i-th air defense system, q_j -is the probability of using the j-th air attack system, v - is the numerical value of air defense systems from air attack systems,

$x_i = p_i/v, \quad i = 1, 2, \ldots., m, \qquad y_j = q_j/v, \quad i = 1, 2, \ldots., n$

A -is the matrix of efficiency coefficients with m rows and n columns, A^T - is the transposed matrix of matrix A. Thus, the use of air targets such as fighters, helicopters, cruise missiles, unmanned aerial vehicles, armed unmanned aerial vehicles, drones and kamikazes operating at low altitudes, and the effective use of air defense systems such as the S-125 2TM, BUK-MB, Barak-8, S-300 PMU2, TOR M2KM, Patriot MİM-104, Pantsir S-1, Nasams-III, Igla-S, Strela-10 and OSA-AK(M) in relation to them can be refined based on finding the values $q_j \geq 0, \ i = 1, 2, \ldots., n$ and $p_i \geq 0, \ i = 1, 2, \ldots., m$. For this purpose, the following results were obtained by solving problems (1) - (3) and (6) - (9) using the simplex method [15, 16, 17]:

$x = (0, 0, 0.141, 0, 1.2, 0, 0, 0, 0, 0, 0), \quad fmin(x) = 1.341, \ v = 0.75,$

$p = (0, 0, 0.105, 0, 0.895, 0, 0, 0, 0, 0, 0);$

$y = (0, 0, 1.046, 0, 0, 0, 0.295), \quad Zmax(y) = 1.341, \ v = 0.75,$

$q = (0, 0, 0.780, 0, 0, 0, 0.220).$

The obtained results show that the probability of using the TOR zenith missile system is 0.895. This means that during combat operations it is advisable to use the TOR zenith missile system first. The Barak-8 zenith missile system can also be used during combat operations, the probability of using which is 0.105. Since among air attack weapons the probability of using a cruise missile is 0.780, and the probability of using a kamikaze is 0.220, it is expected that the cruise missile will be used first, and then the kamikaze during combat operations. In a particular case, we will also consider the use of air targets such as low-altitude fighters, helicopters, cruise missiles, unmanned aerial vehicles and armed unmanned aerial vehicles, the effectiveness coefficients of which are given in Table 2, and the effective use of air defense systems against them, such as the S-125 2TM, BUK-MB, Barak-8, S-300 PMU2, TOR, Patriot, Pantsir S-1 and Nasams-III. Using the above methodology and Table 2, we obtained the lower $\alpha = \max_i \min_j a_{ij} = 0.956$ and the upper $\beta = \min_j \max_i a_{ij} = 0.956$ values of the effectiveness of using air defense systems against air attack weapons [15, 16, 17, 18, 19, 29, 21, 22]. This means that an air target operating at low altitudes could be a cruise missile, and it would be appropriate to use the Barak-8 air defense missile system against

it.

Table 2. The efficiency coefficients of specially selected means of protection against targets operating at low altitudes are given conditionally.

Serial Number	Air Defense Systems	Low altitude targets					
		Fighter	Helicopter	Cruise missile	Unmanned aerial vehicle	Armed unm aerial vehicl	$\alpha_i = \min_j a_{ij}$
1	S-125 2TM	0.652	0.853	0.454	0.801	0.791	0.454
2	BUK-MB	0.711	0.891	0.651	0.871	0.852	0.651
3	Barak-8	0.971	0.981	0.956	0.972	0.981	0.956
4	S-300 PMU2	0.892	0.952	0.882	0.982	0.973	0.892
5	TOR M2KM	0.731	0.752	0.721	0.861	0.853	0.721
6	Patriot MIM-104	0.724	0.854	0.681	0.843	0.834	0.681
7	Pansır S-1	0.704	0.784	0.684	0.754	0.734	0.684
8	Nasams-III	0.784	0.879	0.769	0.849	0.839	0.769
$\beta_j = \max_i a_{ij}$		0.971	0.981	0.956	0.982	0.981	

V. CONCLUSİON

Thus, it is necessary to pay special attention to these results in effective planning when using zenith missile systems against low-altitude air attack weapons. Thus, in modern wars, in order to achieve and constantly maintain air superiority and maintain it, it is necessary to take into account all the parameters of anti-aircraft missile systems, and effective planning can be carried out as a result of minimizing value. The results show that since the probability of using the TOR-M2KM zenith missile system is 0.895, it is advisable to use it primarily against fighter aircraft, helicopters, unmanned aerial vehicles, armed unmanned aerial vehicles and drones during combat operations. The Barak-8 defense system with a deployment probability of 0.105 can also be used in combat. Since the deployment probability of cruise missiles is 0.780 and the deployment probability of kamikazes is 0.220, it is expected that cruise missiles will be used primarily in combat, with kamikazes also being used for air strikes. In a specific case, based on the data given in Table 2, a low-altitude air target may be a cruise missile, and it is appropriate to use the Barak-8 as an air defense against it.

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