MANEUVERABILITY, ONE OF THE MOST IMPORTANT FEATURES OF AIR DEFENCE SYSTEMS

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Abstract: *The basic Surface-to-Air Missile System (SAMS) mission is to combat and destroy the aerial threats on the close and direct ways of access to the defended anti-aircraft objectives, before they fulfil their mission. The main features of Air Defence Systems will aim to increase the effectiveness, Electronic Counter-Counter Measures (ECCM), short reaction time, mobility and stability in work during the day or at night regardless of the weather conditions.*

Keywords: *Long Range Air Defence system forces and means manoeuvring Surface-to-Air Missile System (SAMS).*

1. INTRODUCTION

Integrated Air Defence (AD) involves the engagement of high-performance air platforms, with or without pilots, and technologically advanced aerodynamic and ballistic missiles.

The complex operational environment will include actions in the air, on water and on land carried out by different categories of forces and weapons or joint and coalition forces.

The integrated Air Defence mission will include regional defence, local defence and self-protection, being able to respond quickly to air and missile threats and use combined forces and means.

Area defence is specific to theatres of operations and can be defined as the action of each air defence and anti-missile system to ensure the protection of any other means of combat during military operations. The protected area may include elements to the level of military target groups in a conflict area.

An example of regional defence can be the Aegis system, with the mission of defence against air attacks and potential air threats (*„Anti Air Warfare"/ AAW*) **[Nr.6]**.

Aegis BMD-equipped vessels can transmit their target detection information to the Ground Based Midcourse Defense system and, if needed, engage potential threats using the Standard Missile 3 (SM-3) mid-course interceptors and the Extended Range Block IV (SM-2 Block IV) or Standard Extended Range Active Missile (SM-6) terminal-phase interceptors.**[Nr.21]**

This example includes the requirements for Aegis warships to protect aircraft carriers and other ships in a maritime combat group against any air attack.

Local defense or objectives defense is represented by the mission to protect targets and / or property in the immediate area from air attacks.

This may mean the protection of military or civilian means or smaller populated centres.

An example of a local defense system is the PATRIOT PAC-3 missile system. The local defense also includes self-protection for the own troops and for the combat disposition and its subsystems **[Nr.8]**.

When these strategies are used in combination, the result is a layered defence system in which the systems act successively to eliminate the threat.

Systems that work together can be brought together in a systems architecture and, as such, will act on the same concept of operations (CONOPS). The purpose is to achieve a combat system that destroys the target before it can fulfill its established mission or achieve success by neutralizing or accidentally destroying targets of interest to those defending against their attack.

In this paper we propose to simulate some of the Surface-to-Air Missile (SAM) system manoeuvre of forces and means, as well as to calculate the total time required to execute.

2. THE BASIC ARCHITECTURE OF LONG RANGE AIR DEFENSE SYSTEM

The Long Range SAM system is a set of sensors and components, incorporated regarding action and function through a fire control centre (FDC) into a combat structure which is capable to provide AD with ground-to-air means.

This system is intended to prevent surprise and to take immediate, firm and decisive action to destroy the aggressor, even from the border area, omnidirectional, in the full range of heights in terms of using radio electronic countermeasures.

The main components of the system are:

- C4ISR subsystem which stands for Command, Control, Communications, Computers, Intelligence, Surveillance, and Reconnaissance is the basic element to perform the specific functions of battle management;
- Sensor subsystem: 3D firing and search radars (if appropriate);
- Launching subsystem: launchers with related equipment and ammunition;
- Subsystem of vehicles and transport;
- Logistical support.

2.1 Typology of systems in the AD environement

High-altitude Surface-to-Air Missile (HSAM) systems can be classified according to capabilities, as follows:

1. Surface-to-Air: PATRIOT PAC-2;

The PAC-2 missile has a range of about 160 km. This AD system has four missiles per launcher. Missiles are stored and launched from reinforced aluminum canisters at a fixed angle. Launchers are mounted on trailers or based on 8x8 high mobility chassis. Launchers are self-contained units, fitted with their own powerplants and fuel. During operation these units are unmanned. The launchers are towed by tractor trucks. The mobile version is based on the Man Kat 1, 8x8 high mobility vehicle.

It takes 30 minutes to prepare the system for firing. A battery of launchers and associated support vehicles can change position up to several times a day.**[Nr 19]**

2. *Surface-to-Air with anti-missile capabilities*: PATRIOT PAC-3 (3rd configuration), Surface-to-Air Missile Platform/Terrain, the system uses a network of sophisticated radars and sensors (SAMP/T), ASTER 30, HQ-9, S-300, S-400;

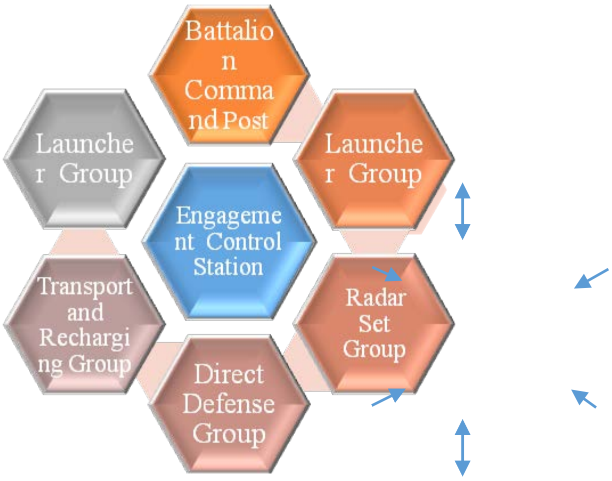

FIG. 1 The basic architecture of a GBAD system

The AN/MPQ-53 and 65 Radars Set from the PATRIOT structure are passive, electronically scanned array radars equipped with IFF(Identification friend or foe), electronic counter-countermeasure (ECCM), and track via missile (TVM) guidance subsystems.

TVM refers to a missile guidancemethod which combines features of semi active radar terminal homming (SARH) and radio command guidance.

The main difference between these two radars is the addition of a second traveling wave tube(TWT)**[Nr.18],** Fig.2, which gives the − 65 radar (PAC-3) increased search, detection, and tracking capability.

Between the two radars, -53 RS supports only PAC-2 units, while the -65 one supports both PAC-2 and PAC-3 units.

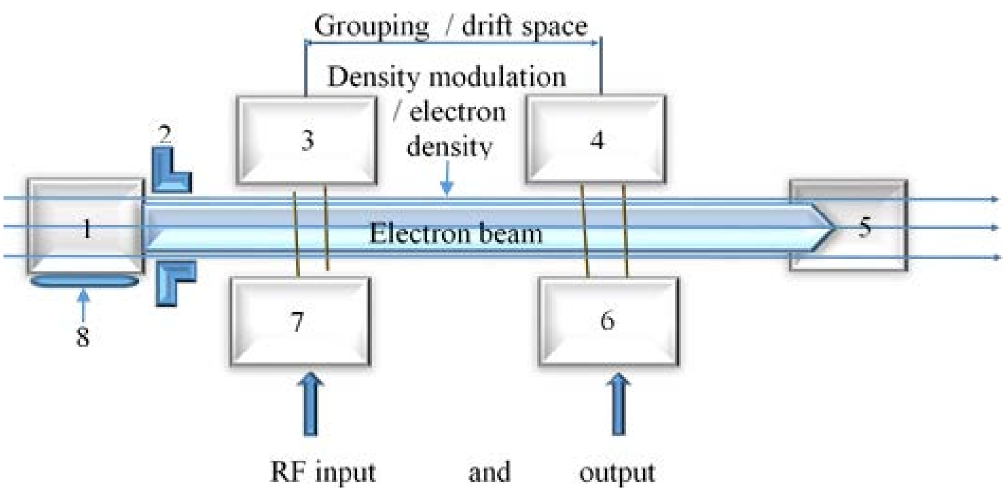

FIG. 2 Cutaway view of a helix TWT. surse [Nr.5]
(1) Filament /Heater(2) Anode; (3, 4) Resonant cavities; (5) Collector;
(6) Microwave input; (7) Microwave output; (8) Cathode

The radar antenna array consists of over 5,000 elements that "deflect" the radar beam many times per second. The radar antenna array also contains an IFF interrogator subsystem, a TVM array, and at least one "sidelobe canceller" (SLC), which is a small array designed to decrease interference that might affect the radar.

1. Anti-missile with anti-aircraft capabilities: The Medium Extended Air Defense System (MEADS), DAVID'S SLING, ARROW 2;

The ability to operate at a high level of flexibility ranks the MEADS type systems among the top performing systems, and the "plug and fight" type structure and combat characteristics allow the system to be adapted to a wide range of operations and missions specific to the forms of contemporary struggle. At the same time, the ratio between the firepower of MEADS, extremely high, and the human resource serving the system, relatively low, describes an equation whose solution is efficiency, characterized by the perfect balance between the resources involved, the results obtained and the costs.

The system has subordinated and coordinated structures and subsystems that enable the detection, tracking and engagement of hostile threats. The mode of deployment and combat is established by the command and control structures, those responsible for combat management.

A specific and extremely useful property of these systems is that which allows the command and control of combat elements (launcher, missile) to be taken over and coordinated by another combat subunit, arranged nearby, thus ensuring time for the structure engaged in combat to be able to execute the maneuver of forces and means.

This compatibility with neighboring AD systems gives MEADS systems the ability to conduct autonomous military actions adaptable to the operational environment. Thus, for the minimum provision of the assigned airspace area, a single multifunctional radar, a command center of tactical actions and a launcher with 12 missiles of the PAC-3 MSE type can be used. That elements can be transported and introduced into the area of combat actions with C-5 Galaxy aircraft (in one transport) or C-130 Hercules (in five transport stages).

DAVID'S SLING system is modular, scalable, and flexible to tailor-fit the area and topology to be defended. The Battle Management Center uses information from the multi-mission radar array and infrastructure resources to build an accurate, detailed Air Situation Picture. When interception is required, the planned course is communicated to the launcher via a dedicated data link and the interceptor can be retargeted in real time to eliminate the threat successfully**[Nr 21].**

2. Anti-missile: ARROW3, Theater High Altitude AreaDefense (THAAD).

The THAAD terminal (formerly theatre) is an easily transportable defensive weapon system to protect against hostile incoming threats such as tactical and theatre ballistic missiles at ranges of 200 km and altitudes of up to 150 km.

The system provides the upper tier of a 'layered defensive shield' to protect high-value strategic or tactical sites such as airfields or populations centres. The THAAD missile intercepts exo-atmospheric and endo-atmospheric threats.

The sites would also be protected with lower and medium-tier defensive shield systems such as the Patriot PAC-3, which intercepts hostile incoming missiles at 20 to 100 times lower altitudes.**[Nr 20]**

2.2 Calculation of manoeuvrability

„Nothing is harder than the art of manoeuvring. The difficulty from this point of view, is to make the most direct way in a twisted one, and to change the misfortune into the advantage "- Sun Tzu, The Art of War.

The manoeuvrability represents the unit's ability to respond quickly and timely to requests generated by changes in the enemy's mode of action, the consequences of its attack on the unit and the target to be defended, and the need for AD of other troops and objectives. [Nr. 8]

The manoeuvre is a summary of the planned, organized, coordinated and executed actions, in order to:

– repel the enemy's air attack;

– carry out decisive attacks against the structures of the aerial enemy, deployed on the ground or at sea;
– defend against air attacks and research of own objectives;
– the destruction of the tactical, operative and strategic air landing of the enemy;
– prohibit the supply and evacuation of enemy surrounded forces or carrying out violent actions.

In addition to these basic purposes, the manoeuvre will aim at:

– removing their own troops from the air, land or sea enemy attacks;
– restoration of the (combat, strategic and / or operative) district, as a result of the damages caused by the enemy;
– restoration and keeping in the battle and operation of air means;
– surprising the air enemy and the prevention of the surprise by him;
– carrying out actions to demoralize the potential opponent.

Influencing factors:

– general status (war, crisis, peace);
– airspace control index;
– weather conditions, season, as well as relief conditions;
– the technical-tactical characteristics of the fighting forces involved;
– the level of troops and headquarter training;
– the level of logistical support.

Technical factors:

– the gathering time of the equipment;
– framing the fighting team;
– the level of staff training;
– the endowment level of the combat component with means of transport.

Tactical factors:

– intervention in certain districts;
– forces deployment in order to realise the established districts;
– the establishment of new fighting forces or their removal from enemy blows;
– moving to defence in a new district or strengthening the defence;
– change of disposal districts;
– restoration of operational capacity;
– setting up reserves.

When the maneuver is performed in order to ensure the continuity of AD of the troops (objectives), the movement of units (subunits) in the composition of the large Air Defense unit begins when the enemy has reached an alignment located at a distance to allow units (subunits) to timely time from the combat district (shooting positions), or with the target directly defended.

The marching procedures are shown in the Fig. 3:

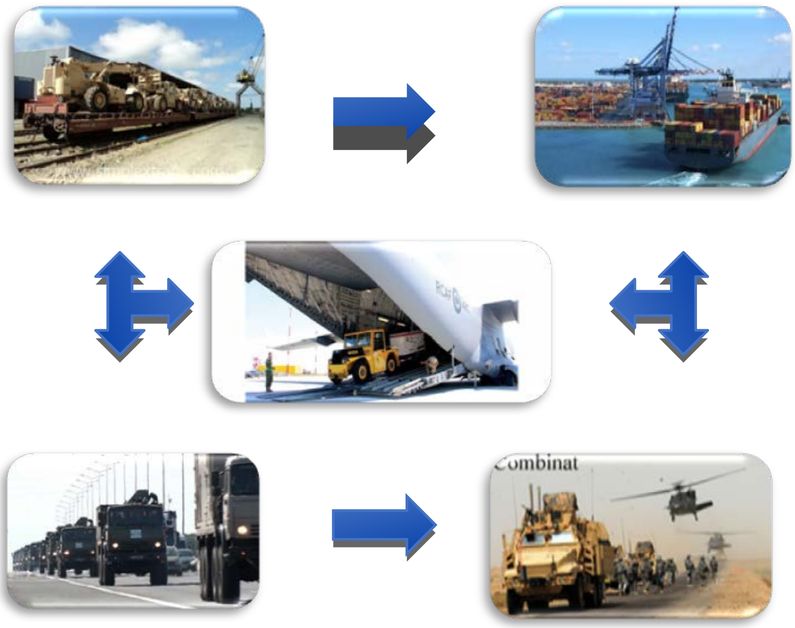

FIG.3 The marching procedures [Nr. 8]

SAM units and subunits can perform manoeuvring forces and means, as well as firing manoeuvre. During the operation, the maneuver of forces and means is performed to strengthen the Air Defense of some troops orobjectives, as well as to change the AD efforts from one direction to another.

During the manoeuvres of forces and means, it is necessary to ensure the continuity of radiolocation research of airspace, as well as the use of combat possibilities of SAM units at maximum capacity, while removing their troops from enemy blows.

The fire maneuver consists of the simultaneous or successive concentration of SAM fire on the most important air targets. It shall be carried out in accordance with the intensity of combat operations, the procedures used by the enemy air force to strike groups of troops and targets, their maneuvering against air strikes, the amount of ammunition and SAM available and the mode of cooperation with other AD. fighter aviation. The fire maneuver, by successive concentration of fire from one air target to another, is called fire transport. [Nr. 5]

The maneuver of forces and means is organized by the officers designated to ensure air security based on the decision of the operative group commander, taking into account: the general concept of conducting the defense operation; the situation and the operative district of the operative grouping; the availability of the communication means necessary for the organized movement of the AD troops performing the maneuver; ensuring the conduct of the fight with the air enemy; level of logistical support.

The maneuver of AD forces and means is materialized in the Air Defense Plan, on variants of action as well as in the successive action orders (combat dispositions) of the officer in charge of AD, given during the defense operation.

Table 1 presents the main characteristics of the missile subunits that influence the efficiency of the maneuver performed to participate in the battle with the air landing during transport and landing.

Table 1 - Estimated technical-tactical characteristics of SAM ssubunits

Nr. crt.	SAM	Details				
		Gathering time [min]	Deployment and preparing for shooting[min]	Total [min]	March speed [km/h]	Interval between launches [sec]
1.	PATRIOT PAC-3	≈50	≈30	≈80	≈50-60	≈3

For example, we will illustrate the simulation of the forces and means manoeuvre by a battery of SAM. In order to execute it, we chose the PATRIOT PAC-3 missile system.

We set out to determine the total time required to execute the manoeuvre with a subunit of this type. The manoeuvre of forces and means with the PATRIOT Surface-to-Air Missile battery will be performed both on land and in air, on the following itinerary:

FIG. 4 March itinerary

Table 2 – Technical data on the components of the missile battery that will be deployed

Patriot components	Gauge characteristics of transport means				Transport means
	Lenght: [m]	Width: [m]	Height: [m]	Weight:[t]	
Engagement Control Station (ECS)	10,29	2,50	3,38	31,8	Truck M927-5 ton 6x6
Radar Set	14,72	2,78	3,54	30,3	Truck M983-10 ton 8x8
Antena Mast Group(AMG)	7,6	2,50	2,85	24,8	Truck M942-5 ton 6x6
Launchers (4 x 16 missiles)	10,12	2,70	2,48	37,8	Truck M983-10 ton 8x8
Electric Power Plant (EPP)	10	2,7	2,8	33,7	Truck M927-5 ton 6x6

The manoeuvre of forces and means will be carried out in a tactical exercise. In this perspective, the air transport will be performed with C-17 Globemaster aircraft, considering that the military transport aircraft (C-27 J Spartan or C-130 Hercules) are required to perform other missions.

In Table 3 there are presented some comparative data on the transport possibilities of the three aircraft mentioned above.

Table 3 – The aircrafts transport capacity

Gauge data, UM / Typeof plane	C-27 J Spartan	C-130 Hercules	C-17 Globemaster
Lenght: [m]	7,8	12,2	26
Width: [m]	3,29	2,69	5,48
Height: [m]	2,23	2,74	3,76
Capacity of transport: [t]	11,4	10, 3	76

Initial situation:

Four C-17 Globemaster aircraft are required to carry out the air transport of the equipment of a PATRIOT PAC-3 SAM battery. The arrangement of the subunit equipment will be done as follows:

-Commamd Post and Electric Power Plant (total weight = 66,2 t) in the first aircraft;

-Radar Set and Antena Mast Group (total weight = 55,8 t) in the second aircraft;

-Two launchers with 4 missiles each (total weight = 76 t) in the third aircraft;

-The others two launchers with the same weight in the fourth aircraft.

Taking into account that the movement on wheels between Military Base and Air Base1 (AB_1) respectively Air Base 2 (AB_2) and new combat district is done with an average speed of 60 km / h, the resulting ratio between march speed and distance travelled is reflected in time T_2 and T_6.

Knowing that the C-17 Globemaster aircraft flies at an average speed of 830 km / h, and the distance in a straight line between $AB_1$and $AB_2$is 270 km, it results, by calculation, that the approximate flight time (T_4) will be 20 minutes, plus the time required for the take-off procedure (5-7 minutes) and the landing one (5-7 minutes). Therefore, it takes about 30 minutes to perform the manoeuvre in the air.

FIG. 5 Flight and road itinerary

To calculate the total maneuvre time it is necessary to determine the fractions of time for every operation:

-time for gathering and preparing for march (T_1);

-time to march on the road from the gathering area to plane boarding area(T_2);

-boarding time(T_3);

-flight time to the deployment area to which is added the landing and take off time(T_4);

-landing time from the plane(T_5);

-time to march to the deployment area(T_6);

-puttimg into service time(T_7);

-total manoeuvring time(T_{TM}).

$$T_{TM} = T_1 + T_2 + T_3 + T_4 + T_5 + T_6 + T_7 \quad (2.1)$$

The values of the time fractions necessary for the SAM forces and means manoeuvring, against the air landing, are presented in Fig. 6.

With the development of decisive aviation actions, most armies are conducting studies and forecasting for the modernization of AD, the introduction of new types of weapons and military equipment, the modernization of existing ones and the improvement of tactical procedures and concepts of use in combat and operation, starting from the principle of maintaining a high level of combat capability of SAM units.

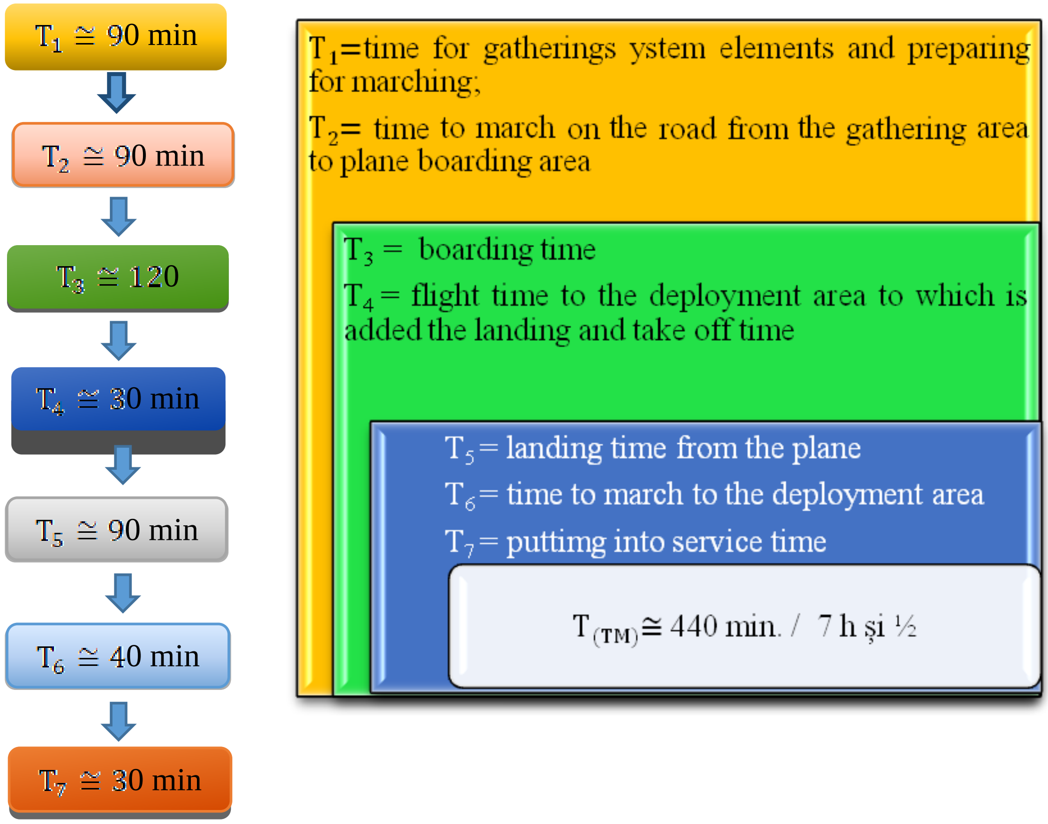

FIG. 6 Calculation of total manoeuvring time

3. CONCLUSIONS

It has been considered that the lines of evolution of an air defence system must meet the following conditions of efficiency:

- to be organized and led in a unitary conception, since peacetime, and to include the entire area of responsibility;
- to ensure the research, the opportune discovery and the continuous pursuit of the opponent's means so as to avoid surprise;
- to have the capacity to carry out combat actions against the air adversary in all probable directions of his action, in the space corresponding to the area of responsibility;
- to be permanently ready to fight with all forces and means;
- to achieve a shorter reaction time than available and to be stable in operation, even in complex conditions;

- ➢ to be made, constructively, on an advanced technology, with possibilities for modernization in perspective;
- ➢ to ensure the use to the maximum capabilities of the fighting technique, to allow the efficient cooperation between the component elements, as well as the other fighting systems in the area;
- ➢ to allow the standardization of the means of AD and their constitution in efficient mixed structures;
- ➢ to ensure compatibility and interoperability with other modern air response systems;
- ➢ to be able to act both in integrated and independent systems. [Nr. 5]

The prefigured AD systems for the future are designed to meet the following more important requirements:

- ➢ the possibility to fight against a wide range of aerial targets (from unmanned aerial vehicles to Long-Range Ballistic Missiles);
- ➢ discovery of aerial targets from a distance at least double from the range of the means of fire they serve;
- ➢ engagement in the fight with aerial targets at altitudes between 2000-30,000 m, with a probability of destruction of 80%, below 2000 m will act the specialized means for fighting at low altitudes;
- ➢ engagement in the fight against aerial targets that fly at altitudes between 2000-30000 m, with a kill probability equal to 0,8 (80%);until 2000 m will act the specialized means for fighting at low altitudes;
- ➢ short time to change firing positions;
- ➢ permanent airspace research;
- ➢ system operation time at least 20-30 years, with the possibility of successive update.

There are two dominant main trends in the development of SAM systems, namely: the creation of new systems for counteracting shocks and research from the air or from outer space; modernization of existing systems and endowment with high-efficiency missiles.

Taking into account the defensive nature of the AD, the triggering of impact systems must be ensured as soon as possible depending on the permanent threat situation. In this perspective, the researched airspace must be much larger than the defended area.

It is estimated that in the case of a SAM system, the search of airspace must comprise an almost double distance from the range of the missiles. In principle, airspace surveillance is based on the area of defense established on the basis of tactical considerations.

In the field, the limitations determined by the coverage angle and the influence of the blindspot of the long-range radar means shall be taken into account.

To discover targets that fly at low altitudes, studies have been conducted to increase the effectiveness of certain radiolocation antennas (folding arm or telescopic).

Studies in this field are still ongoing and aim to build radio stations, which have the ability to determine the shapes of air targets and even their dimensions, which would lead to a more accurate assessment of the aerial enemy and the adoption of measures effective in combating these threats.

The improvement of the IFF equipment is constantly increasing, thus obtaining the possibility of efficient correlation on the actions of SAM systems with the actions of its own aviation troops, under the conditions of the enemy's electronic countermeasures or a complex air situation.

Regarding the development of SAM, military specialists consider the following:

- – the continuous information technology improvement and the wide use of microprocessors that will increase the accuracy of the combat components;

– creating smaller, simpler and more secure means for the automatic discovery, identification and tracking of targets;
– an optimal conception regarding the weight of the combat components, with programmed proximity warhead, which allows the optimal determination of the explosion moment.
– the realization of some means smaller, simpler and more secure for automatic detection, identification and tracking of targets;

It can be concluded that improvements to AD systems are an important direction towards automating activities and increasing effectiveness in the fight against aerial threats.

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