

Landmarks in Romanian History of Anti-Aircraft Artillery: The Anti-Aircraft Gun Director Computer, “Ion Bungescu”

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Abstract

The main purpose of this article is to present the decisive contribution that Brigadier General Ion Bungescu had to the development of anti-aircraft artillery in Romania. To achieve this objective we describe in the paper the evolution of the anti-aircraft gun director computer he invented, as well as its modus operandi. The adopted methods include quantitative and qualitative analyses of documents, manuals and albums published during the considered period, and some published by Brigadier General Ion Bungescu. The results of the article are presented in the context of the accelerated development of military aviation between the two world wars. This development put terrible pressure on the development of anti-aircraft artillery that started with land guns adapted for anti-aircraft firing in 1916 and reached anti-aircraft guns controlled by Gun Director Computer in 1945. We can compare the development of military aviation during that time with the development of information technology over the last 30 years, from connecting computers in the network to the use of artificial intelligence.

Keywords

air defense, anti-aircraft artillery, Gun Director Computer , defense

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1. Introduction

Anti-aircraft artillery includes actions such as active combat actions against an enemy from the air, as well as mitigating actions against its impact on other containment elements, such as chemical defenses, cloaking, and engineering vehicles. All commanders of any type of combat are responsible for auxiliaries in the joint anti-aircraft defense. Romanian air defense appeared around the same period as in more advanced countries at the time and remained at the same level until 1945. This was possible thanks to well-trained world-class officers. Romania is also a country with a great tradition in the field of aircraft construction. It should be noted that the rise of aviation and its entry into the industrial era took place along with the preparations and course of the First World War. The subject of the article concerns the decisive contribution of Brigadier General Ion Bungescu to the development of anti-aircraft artillery in Romania. In order to get an idea of the actions of the Romanian army, it is necessary to look at the methods of combat, including types of anti-aircraft programs during the First World War. The conducted research on the use of quantitative and qualitative analysis on the basis of the collected materials show as well as development of military aviation in the interwar period as well. The purpose of qualitative research is to describe and interpret issues or phenomena systematically from the point of view of the problem being studied, and to generate new concepts and theories. The new era of technologies is very progressive, but knowledge of the research data of already tested equipment is always a necessary foundation in the process of new systems. The article examines the emergence and development of anti-aircraft artillery in Romania from 1915 until the end of the Second World War in 1945. This analysis is not only important from a historical point of view, but also in order to understand how the people of that time managed to find quick solutions to keep up with the extremely rapid development of aviation. Although the officers who established the new specialty in the Romanian Army came mainly from ground artillery, due to good training they were able to adapt easily to the new challenges offered by the development of aviation. Although this study highlights the major contribution that Brigadier General Ion Bungescu made in the emergence and development of anti-aircraft artillery in Romania, the study also highlights the contribution of other officers who have dedicated themselves to this specialization.

In the work *Air defense*, published in 1922, Lieutenant-Colonel Gheorghe Popescu classified the planes in a similar way to the current classifications proving a good understanding of aviation. Lieutenant-Colonel Gabriel Negrei and Lieutenant-Colonel Stefan Burileanu develop anti-aircraft artillery systems from land artillery. At the beginning of his career Brigadier General Ion Bungescu demonstrates the advantage of the transition from decentralized direct firings to centralized indirect firings. At the same time, it developed in successive stages an apparatus for the centralized calculation of the firing elements and had an important contribution to the emergence and development of the school of anti-aircraft artillery officers.

To highlight the good training of these officers we have used quotes from the books published during the period analyzed as many times as possible. From the study of the sources published in the analyzed period of time, it emerged that the good training of these officers was due both the national schools and to the close collaboration with people sharing the same concerns in all the countries of Europe.

The first part of the article presents the extraordinarily fast evolution of aviation since the appearance up to the end of the Second World War in a simplified form. This evolution

is somewhat similar to the evolution of IT systems today. In the next chapter the efforts to establish and develop anti-aircraft artillery in Romania in the period 1915-1925 are highlighted. A special chapter is dedicated to the contribution of Brigadier General Ion Bungescu to the development of anti-aircraft artillery in Romania. In the last chapter the operation of the last type of anti-aircraft gun director computer model Bungescu as shown by the original documentation of the manufacturer is presented.

2. The emergence of the air threat and its development until the end of World War II (1900-1945)

Although flying has been mankind's dream since ancient times, it was only at the beginning of the twentieth century the first successes in flying with a heavier-than-air aircraft are recorded. Thus, on December 17th, 1903, the Wilbur brothers and Orville Wrights managed to fly 36.5 m in 12 seconds. Later, as they learned to control the glider, they managed to fly 260 m in 59 seconds. Although recorded as the first controlled flight of a heavier-than-air aircraft, the Wrights 'brothers' plane took off with the help of a rail on the ground and landed on the 'glider's wooden frame.



Figure 1 The Wright 'brothers' glider 1909 Wright Military Flyer, National Air and Space Museum Collection in Washington, (pinrerest.com.).

On March 18, 1906, the history of aviation records the first flight of an aircraft heavier than air, which took off, flew and was landing with the means on board. Thus, on the Montesson plain near Paris, Traian Vuia manages to fly "Vuia I" aircraft over 12 m at a height of 1 m after accelerating with his own means over 50 m. Later, on August 9, 1906, after making some improvements, he managed to fly over 24 m at a height of 2.5m.

After this beginning, aviation experienced an accelerated pace of development, managing to add the vertical dimension to the war in the years of the First World War (1914-1918) (Gheorghiu, 1996).

Some of the authors of this publication are also working on these related projects:

Cfp EAA 2017 - Present identities from the past: providing meaning to modern communities to have an image of aviation from the end of the First World War. For this to occur, it is important to know the classification made by Lieutenant-Colonel Gheorghe Popescu in the work *Air Defense*, published in 1922 at the Military Artillery School from Timișoara Printing House. He classified military aircraft for three types to accomplish in the mission:

- observation aircraft;
- fighters;
- bombers (Popescu, 1922).

Observation aircraft. They are two-seat aircraft (two-seater for the pilot and an observer) with a wide range, and good visibility for observation. They have defensive weapons (machine gun), camera, radio station, missiles, and powerful binoculars. General data:

- the aircrafts have a speed of 35-45 m / s;
- rise in 45 minutes at approximately 1000 m altitude;
- fly at an average speed of 40 m / s;
- and at altitudes of 1000-4000 m.

Fighters have one place (monoplane), high horizontal speed, high ascent speed, high dive speed, maneuverability, powerful weapons. High ceiling (i.e. they can rise at high altitudes). Lifting speed 10-12 minutes at 3000 m altitude. They have a speed of 40-60 m / s. Fighters usually fly at high altitudes, in enemy lines 5-6 km altitude and drop at low altitudes when attacking captive balloons or planes. Ceiling 6000-6500 m. (Popescu, 1922).

Bombers have two to three seats (three-place aircraft), with a long range, large capacity for payload, defensive armament. General data:

- elevation speed of about 20 minutes at 3000 m altitude;
- speed of about 35-40 m / s and they can carry: pilot, observer, possibly another person, about 300 kg bombs, gasoline, oil.

They fly at altitudes of about 2500-3000 m, and when dropping bombs, they can descend to lower altitudes (Popescu, 1922).

Throughout the interwar period and also during the Second World War, military aviation experienced a period of significant development. To better understand the development of aviation, it will keep the same classification with the specification that the role of "observation" aircraft was taken over by the bombers.

Technical performances of a bomber of Boeing B17 Flying Fortress type used in World War II are (Fig. 4):

- heavy bomber with a crew of 10 people, maximum speed of 128 m / s, cruising speed of 81 m / s, range 3219 km with 2700 kg of bombs, maximum flight altitude 10850 m, speed ascending 4.6 m / s.;
- the aircraft had the following types of weapons: 13 Browning M-2 machine guns of 12.7 mm, up to 7800 kg of bombs.



Figure 2 Bomber from World War II, Ike-battered Lone Star Flight Museum moving inland by H. Alexander, H. Chronicle, 2014, ([pinrerest.com.](http://pinrerest.com/)).

The end of World War II marks the appearance of the first jet aircraft Messerschmitt Me 262 Schwalbe fighter-bombing aircraft (Swallow) (Fig.5).

This fighter had the following technical performances:

- monoplane fighter, maximum speed of 250 m / s, range of 1050 km, maximum flight altitude 11450 m, ascending speed 20 m / s.;
- the fighter had the following types of weapons: 4 30 mm MK 108 guns, up to 500 kg of bombs and 24 55 mm missiles.



Figure 3 Fighter-bombing aircraft from World War II., Payerne, Switzerland – September 8, 2014: Messerschmitt Me 262 Luftwaffe World War II jet fighter aircraft, ([dreamsteam.com.](http://dreamsteam.com/)).

In conclusion, it is in less than 30 years that the air means have evolved from a speed of 50 m / s to a speed of 250 m / s and from an altitude of 5000 m to a flight altitude of over 12000 m. This almost explosive development of air means has put a lot of pressure on the development of anti-aircraft means. The problem of meeting the projectile with the target, although it was known from the mathematical model perspective, was extremely difficult to put into practice with the means existing in the same period. In the next chapter, Romania's efforts to develop air defense systems capable of effectively fighting the air force means will be presented.

3. The emergence and development of air defense in Romania between 1915-1925

In Romania, the first actions in terms of creating means of combating aviation took place in 1914. Thus, on December 22, 1914, a contract was signed with the Italian company ““Vickersterni Spezia”” for the import of four 75 mm anti-aircraft guns of the ““Deport”” type, which were received by the Romanian army at the beginning of August 1916. At the same time, measures were taken to use land cannons for anti-aircraft missions without constructive changes and to transform and adapt cannons for anti-aircraft fire. The modification of the 75 mm Md. 1880 guns is part of the second category of measures, made by the Army Arsenal, which was mounted on the platform and intended for fixed firing positions and the modification of 57 mm cannons by lieutenant-colonel Ștefan Burileanu and Gabriel Negrei (Cutoiu, 1984). Lieutenant-Colonel Gabriel Negrei mounted the 57 mm gun on a shielded cannon carriage, without a firing brake. Modified in such a way, the cannon could accompany the maneuvering troops and execute fire vertically up to 90° but with limited possibilities of changing firing direction. Lieutenant-Colonel Ștefan Burileanu mounted the 57 mm gun on a metal pivot and equipped them with a firing brake. In this configuration the cannon had the ability to fire in the direction of 360° and in a vertical position from 0° to 80°. The firing rate of these cannon was of 25 shots/minute. On April 15, 1916, the General Staff decided to establish a “Shooting School for the 75 mm anti-aircraft cannon” and on June 23, 1916 for the 57 mm cannons Burileanu and Negrei system.

On August 9, 1916, immediately after signing the “Military Convention between Romania and the Entente” of August 4, 1916, the General Staff, analyzing the situation of providing anti-aircraft weapons and training of personnel, found that the conditions to establish a new branch in Romanian army were met (Collective, 1996).

Thus, on August 15, 1916, the Anti-Aircraft Defense Corps was established, which in the following period was equipped with cannons, machine guns, projectors, and observation posts for the accomplishment of the assigned missions. The first combat actions took place on the night of August 15-16, 1916, when fire was opened on a Zeppelin airship used on the eastern front (Steven, 2013) that bombed the capital without causing significant damage. These actions repeated almost daily until the night of September 13-14, 1916 when the Z-181 Zeppelin was hit, and it managed to reach Bulgaria. This was also the last attack executed with a Zeppelin airship on Bucharest. Subsequently, the attacks were carried out by aircraft. On September 19, a German aircraft was shot down in the Flamanda region by the “Deport” cannon battery under the command of Lieutenant Constantin Constantin (Collective, 1996).

In the work *Air Defense* published in 1922 at the Military Artillery School Printing House from Timișoara, the author Lieutenant-Colonel Gheorghe Popescu mentioned in the introduction that:

“In anti-aircraft firing, the principle must be rigorously followed: On an aircraft, firing is not regulated but is continuously prepared”.

The problem of anti-aircraft firing is quite complex, the commander is in front of an extremely small and mobile target in space, which involves many variables for shooting, all entering as parameters in the geometric relationships, linking the elements in a moment” (Popescu, 1922, p. 22).

Despite all the difficulties and problems posed by anti-aircraft firing, it was nevertheless solved, initially by calculation tricks and the application of the theory of probability (Michalski & Radomyski, 2020).

It was assumed that during the time required to transmit the coordinates of the target (direction, height, speed, warhead length) and the duration of the trajectory, the aircraft goes in the same direction with constant speed, at the same height, all of which can be called the fundamental hypothesis. Thus, in 1917, the first calculators appeared and a little later, devices were created to measure the height, speed of the target aircraft and central control stations were set up.

Because anti-aircraft cannons came from the adaptation of land ones, only one way of firing was known: decentralized direct firing. In this procedure, each cannon aimed the plane and made the main corrections resulting from the movement of the target through its own devices; a group of devices ensured for the whole platoon or the whole battery the determination of height, speed, and direction. The height was measured with the wired and optical altimeter (Busson); speed was measured rudimentarily with the tachiscope; the cannon-plane distance was measured with the control telemeter and the direction with the Bribard compass.

The actual firing was performed by a combat team that, in the case of the 75 mm caliber cannon, was composed of 9 soldiers: cannon leader, direction marksman, elevation marksman, corrector in the direction, corrector in the elevation, warhead regulator, projectiles supplier, loader and shooter. Initially, firings were performed only during the daytime. Later, cannons could fire at night, but in the light of the projectors, it was not possible to speak in these conditions of firing methods and devices.

The operation of the devices is extensively presented by Lieutenant-Colonel Gheorghe Popescu in the work *Air Defense*. In the same paper he lists some firing principles:

- any observation applies to the past. It is valid for the future only as a document which must be interpreted;
- any correction made to the next fire produces its effect, only after a time equal to at least the duration of the trajectory, of the projectile;
- distribution of work;
- judgment in orders;
- continuous measurement of aircraft elements” (Popescu, 1922, p.43).

To have the best possible image of how the anti-aircraft firings were carried out at that time, I will give a detailed overview of the 3rd principle of the distribution of labor as presented in the paper:

“One man ‘can’t do everything, especially in this complicated shooting. For this, the functions were distributed to each device for: tracking the target, recording the device with the necessary calculations, reading, and transmitting the command to another device. Thus, all the elements of the aircraft are measured and recorded, all the firing elements related to those of the target are calculated and recorded, thus making everyone work and compete to complete the work: the departure of the projectile from the barrel, in the best conditions. The situation of the explosion towards the target is the result of ‘everyone’s cooperation, obviously if the target has maintained the same elements from the current position

to the next one. The commander, when the smoke rises from the plane, reaps the fruit of his work in training the personnel" (Popescu, 1922, s. 85).

4. The anti-aircraft gun director computer Bungescu

It is obvious that although the problem of meeting the projectile with the target was solved at a theoretical level, the development of some anti-aircraft cannons, but also of the measuring devices used to determine the target parameters and atmospheric conditions, requires a special attention

Due to the increase in the flight speed of the aircraft, the main direction of improvement of the anti-aircraft systems was the improvement of the cannons and the increase of the projectile muzzle velocities to reduce the time in which the aircraft had to fly in the fundamental hypothesis.

Due to the need to combat air targets at different altitudes, the emphasis was on the diversification of calibers. The classification of artillery in small, medium, and large caliber appears in the specialized literature.

Improvements to measuring devices have experienced a slower improvement, perhaps due to the complexity of the knowledge required.

Under these conditions, the young field artillery officer, Lieutenant Ioan Bungescu, passionate about calculating probabilities, began to study the causes why number of enemy planes shot down by the first anti-aircraft artillery units was quite small during the war. Following the mathematical analyzes made, the officer concluded that this is explained by the lack of synchronization of the shots fired, a lack determined by the large scattering of projectiles fired and their explosions at different times.

To remedy these shortcomings, Lieutenant Ion Bungescu had the brilliant idea of a device that would centrally calculate the firing elements and send them simultaneously to several cannons. This seemingly simple approach brings about a major change in the structure of anti-aircraft artillery subunits. Firings were no longer performed by each individual cannon but were conducted centrally from a single place. The transition was made from decentralized direct firing to centralized indirect firing. This approach is not only an improvement to the existing systems but also a new approach to the organization and execution of anti-aircraft fire with artillery.

For the practical demonstration of the viability of the new approach, Captain Ion Bungescu, promoted in 1926 as commander of the anti-aircraft battery "Skoda" with 76.2 mm caliber cannons, built the first version of the anti-aircraft gun director computer Md. 1925. Later, he used this apparatus in the battery. With the restructured battery, he participated in firings in the firing range from Mamaia, Constanța County, where he destroyed the air target even after the execution of the first salvo.

His years of work has been rewarded by the leadership of the Ministry of National Defense with the "Great Trophy of Precise Shots".

The second perfected model came into operation in 1928. In 1935, the third model known as the "simplified central apparatus" Md. 1935 was created. It was also accompanied by the paper "Memorandum on the central apparatus for preparing and conducting anti-aircraft fire", a paper that met with the favorable appreciation of the members of the specialized technical commission of the Romanian Academy. For this reason, in 1935, the paper was

nominated and awarded by the highest scientific forum in our country - the Romanian Academy. For the same achievement, the Government of our country, under Decree no. 7301935, granted Major Ion Bungescu the scientific order "Cultural merit for science" 2nd Class (Collective, 1996).

It must be said that the 'officer's invention aroused great interest among specialists abroad. The proof of this is the Order "Crown of Yugoslavia" 5th class by Decree no.4235/1935 granted by the Government of Yugoslavia to Major Ion Bungescu. In the fall of 1938, a prototype of anti-aircraft gun director computer "Maior Bungescu Md.1938" was presented. It was approved in 1939. The invention was appreciated and recognized by the specialized commission operating under the Romanian Ministry of Industry and Constructions. The device obtained patent no. 3199/1939. Considered an important event, "Romanian invention for air defense", military commentators and analysts in Romania, France, Germany, and other countries have made extensive comments in the press and periodicals, highlighting both the importance of the invention and the beneficial results in conducting anti-aircraft artillery fire. The officer refused an offer from abroad and handed over the project and all its documentation to the military and civilian specialists from "Resita" factories. They later went on to mass-produce the system, so necessary for the dozens of anti-aircraft artillery batteries in 1939, in the organizational structure of the Romanian Army in the anti-aircraft defense device around Bucharest and in the Prahova Valley.

The original prototype was a world premiere. Since 1931, it was appreciated as a simple, robust, accurate and cheap device compared to other similar foreign devices of very complicated and extremely expensive construction. In Western countries, indirect, centralized firing was not even carried out, while in Romania, the anti-aircraft artillery was fired between 1926 and 1928 with the new device based on the geometric method. All measurements and calculations were performed with the central firing device which, by tele-indication, continuously transmitted the firing elements - elevation, azimuth, and warhead length to the cannons – the sight thus becoming indirect. The device solved the problem of meeting the projectile with the target in the fundamental hypothesis. For Romanian anti-aircraft cannons, caliber 75 mm English Vickers model were also produced.

They worked together with the central fire control device "Predictor Vickers" which used the tachymetric firing method, or with the central fire control device "Bungescu Md. 1938" which used the geometric method. In both devices, the centralized organization of firing was common (Regulations, 1936).

Simultaneously with the technical preoccupations, Major Ion Bungescu also carried out prodigious didactic activities. Concerned with the training of specially trained personnel in the field of defense against aircraft, he pressured the law enforcement agencies and managed, on April 1, 1938, to obtain approval for the establishment of the Training Center for Air Defense, and on December 10, 1939, for the School of Officers for Anti-Aircraft Artillery.

The main objective of the educational center was specified by the commandant of the School of Officers for Anti-Aircraft Artillery, Major Ion Bungescu, when taking the military oath of faith by the first class of students:

"You have started to have a role, a mission to fulfill in the defense of the Romanian borders and sky... Preparing to become active and reserve officers in the anti-aircraft artillery, working every day and learn continuously to handle the anti-aircraft cannon, you must have in mind only one thought, that of serving the country, that of being able to fulfill a high mission: in peacetime training yourself and training others in your turn, in times of war sacrificing yourself while on active duty".

5. Operation of the central apparatus for conducting anti-aircraft artillery fire, Major Bungescu Md. 1938 system

The general characteristics of the anti-aircraft gun director computer Major Bungescu Md. 1938 system, as presented by the manufacturer solves the problem of anti-aircraft fire by a rigorously accurate method.

1. It allows the following firing methods:

a) Indirect firing calculated and transmitted to the guns, continuously: the future azimuth, the total inclination, the future warhead distance.

b) Direct firing in direction, indirect in ascent, transmits to the guns: the total inclination, direction correction (in the horizontal plane of elevation), the future warhead distance.

2. The elements transmitted to the cannons are calculated, where horizontal distance and altitude at which the position of the target is measured in the vertical plan, the speed of the target and the angle of the target's path direction in space are used as variables.

3. It continuously and automatically determines wind and parallax corrections and allows the recording of ballistic and atmospheric corrections.

4. It can shoot unseen aircraft in connection, by remote indication, with aircraft tracking devices.

5. It traces the paths of various planes flying over the AAA batteries, with the double purpose of obtaining graphic data required for reports and the elements necessary for the group commander to lead the shooting of a set of batteries.

6. It allows shooting against aircraft that are defended by using the tail gunner.

7. It can act against the fastest aircraft up to 200 m / s or 720 km / h.

8. The device can be alternatively equipped with the O.P.L. stereoscopic rangefinder, with a removable 5 m base, mounted on the device and forming a system, or with a "Resita" aiming tube mounted on the device and an altimeter of any type installed separately near the device.

9. The device is transported on a two-wheeled trailer that ensures great tactical and strategic mobility. The wheels are foldable to be able to place the platform - the chassis/carriage on the ground. The horizontality of the platform is obtained with the help of four adjustable jacks. The actual platform has folding sides for placing the servants. The turret is provided with a series of circular contacts that ensure tele-indication and telephone transmission with the battery, the rangefinder (in the case of the separate rangefinder), the tracking devices and the battery commander. Thanks to the transmission system and the parallax corrector, the central device can be installed up to 2 km away from the battery, in the current situation of the electric remote indication up to 250 m. The device (including the rangefinder) is used by nine servants. The maneuver is easy, requiring quite simple operations from the servants. During the action, the servants are placed on chairs mounted on the platform and are trained in the movement of the device by means of the turret.

10. The device can be used on any cannon, being sufficient to provide it with the abacus set corresponding to the respective material. For this purpose, ballistic abacuses in focal length, inclination and travel time are easily removable (Regulations, 1941).

By reading these technical-tactical characteristics, we can appreciate the fact that the device offered a top solution worldwide, perfectly adapted to the specific level of development until 1945. Obviously, with the advent of jets with speeds over 200 m / s, this system becomes morally obsolete. We must not forget, however, that between 1926 and 1945, the hard work of the future Brigadier General Ion Bungescu held Romania among the elite of countries capable of producing and being equipped with the most advanced anti-aircraft artillery systems.

The central apparatus anti-aircraft gun director computer Major Bungescu Md. 1938 system consists of the following large parts: an O.P.L stereoscopic altimeter, mechanism box., turret with circular platform, and a two-wheeled car trailer.

The personnel necessary for the maneuvering of the Central Apparatus Major Bungescu Md. 1938 System, consists of a chief of staff and nine servants appointed as follows (Fig 4):

- No. 1 telemetry height operator;
- No. 2 azimuth marksman;
- No. 3 elevation marksman;
- No. 4 horizontal distance recorder;
- No. 5 speed and road angle measurer;
- No. 6 speed recorder, road angle, wind and altitude reader;
- No. 7 trip length and altitude recorder;
- No. 8 tilt recorder;
- No. 9 focal length recorder.

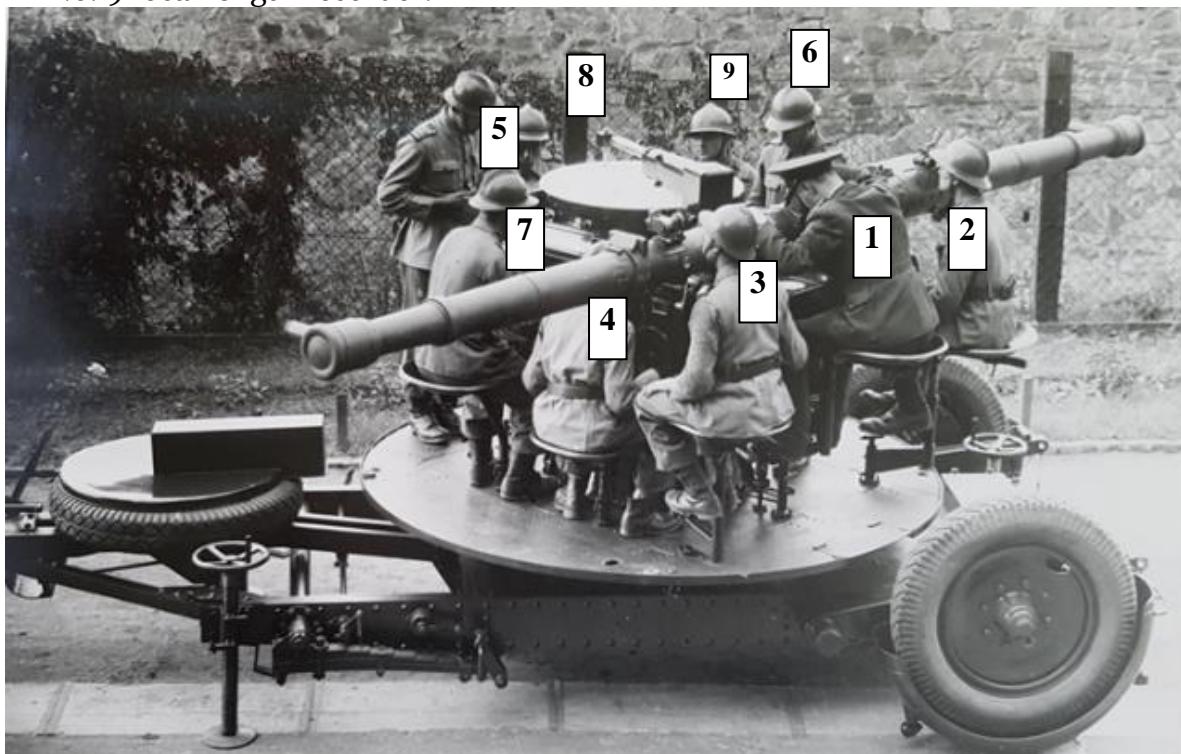


Figure 4. The place of servants on the Central Apparatus for preparing and conduct of anti-aircraft firing equipped with a stereoscopic altimeter with a base of 5 m. (Regulations, 1944).

The main duties of the telemetry height operator no. 1:

- executing height and distance adjustments;
- handling the steering wheel of the search movement. When a target appears from a different direction from those of the device, he uses the search movement with the help of the search wheel;
- controlling the approximate sight, and giving instructions to servants 2 and 3 for maneuvering the aiming mechanisms.

The main duties of the servant no. 2 direction marksman and recorder:

- when aiming at a visible aircraft, performing the approximate and precise shooting in azimuth;
- when aiming at a heard aircraft, recording the alignment division on the azimuth receiver or records the azimuth transmitted from the sound tracking section.

The main duties of servant no. 3 elevation marksman and recorder:

- when shooting a visible aircraft, executing the approximate and precise aiming in elevation;
- when the aircraft is heard, recording the alignment division on the lift receiver or records the lift angle transmitted from the sound tracking section.

The main duties of servant no. 4, horizontal distance recorder:

- recording the horizontal distance as follows: either by extending the indices of the angle dial by rotating the steering wheel of the horizontal distance, or by keeping the reticle of the rear-view mirror of the horizontal distance device on the target by rotating the steering wheel of the horizontal distance.

The main duties of servant no. 5, speed, and road angle measurer:

- putting the pencil in the drawing position;
- orienting the road and measures the speed of the target.

The main duties of servant no. 6, speed, and road angle recorder:

- recording the altitude ballistic correction;
- reading the altitude;
- recording the wind direction and speed;
- recording the target speed;
- recording the road angle;
- stalling the azimuth;
- recording the percentage speed correction;
- handling the crank for clutching the recording movement;
- orienting the crown offset by the direction of the wind;
- handling the steering wheel to orient the parallax.

The main duties of servant no. 7 altitude and time recorder:

- recording the altitude on the altitude dial;
- recording the trajectory time;
- recording the parallax;
- turning the lights on and off at night.

The main duties of servant no. 8 tilt recorder is the total tilt.

The main duties of servant no. 9 warhead length recorder:

- recording the warhead length;
- recording the ballistic correction of warheads (Regulations, 1944, p. 26).

With the evolution of anti-aircraft artillery systems, it is the turn of aviation to adapt to the new conditions of the battlefield. Thus, to reduce losses, aviation plans missions especially at night when the accuracy of anti-aircraft artillery systems is the lowest. Referring to the attacks of aviation during the night, Lieutenant-Colonel Ion Bungescu mentioned, in the book Anti-Aircraft Artillery Firings Vol Iv edited by the Anti-Aircraft Artillery Training Center, Officers School in 1942, the following:

The problem of locating aircraft during the night is very up to date and of great importance. The attack of bombers during the night takes a widespread form in the current air war, especially in the case of distant and well-defended targets. The great advances made in the field of air navigation, give the bombing aviation, a great freedom of action and a great precision in the attack of the objectives during the night.

In the current state of the means, the sound reconnaissance is the basis of the action of the anti-aircraft artillery during the night, both in firing on the "illuminated plane" with the help of projectors, and in firing on the "heard plane" (Bungescu, 1942).

The action of anti-aircraft artillery during the night, being much more complicated than during the day, involves a special organization with sound tracking devices and a complex instruction.

Based on the experience of the current war, it is often the case that the action of the anti-aircraft artillery combined with that of the projectors (firing on an illuminated plane) is difficult or inapplicable. Therefore, the other form of action, shooting on an “unseen plane” is indispensable. Therefore, it is essential to practice and apply the sound measuring technology to the maximum of its capacity, both in terms of maneuvering with the projectors and shooting with the use of the sound target localization before new devices for target localization are introduced (Bungescu, 1942).

Also, in the same work, the author recognizes the limits of determining the position of airplanes with the help of sound waves. At the same time, however, he is aware of the research that was done in different countries to find more efficient solutions for locating airplanes.

It is interesting from a historical perspective how an anti-aircraft specialist looked at the development directions of aircraft location systems.

The first category of devices originally used the aircraft sound source as well, but the ear as a receiving organ was replaced by special instruments.

Another category of locating devices uses a different energy source than the acoustic one. In America, a method has been developed that has led to the construction of an instrument that allows perceiving the heat radiated by aircraft engines. It is believed that the results obtained are exceptionally good, but the tool/instrument seems impractical due to the narrowness of the field.

In France and England, there was talk before the war of devices using rays or radiation spreading at the speed of light. In Germany, a lot of work is being done in the same direction and we can speak of some especially important achievements. The devices using the electromagnetic waves emitted by the plane are being generalized (Bungescu, 1942).

6. Conclusions

In conclusion, Romanian air defense appeared in the same period as in the more advanced states of the time and remained until 1945 at the same level as them. This was possible due to the existence of well-trained officers able to understand the complexity of anti-aircraft artillery firing. The quality of officers' education was also high because they benefited from courses and training periods abroad and thus were up to date with the latest advances in the field. This quality could be maintained owing to the establishment and development of weapons education in Romania. The quality of training of anti-aircraft artillery officers allowed Captain Ion Bungescu to radically change the firing, from decentralized direct fire to centralized indirect fire, which was much more effective. It also allowed him to make the first mechanical firing computer for anti-aircraft artillery in our country and among the first in the world. The domestic industry was able to produce both the central firing apparatus and the anti-aircraft artillery pieces. After 100 years of anti-aircraft defense in Romania (G. Visan, 2017), the history of anti-aircraft artillery can strengthen *l'esprit de corps* of elite officers. They were able, at different times in history, to succeed with the means at their disposal to maintain the air defense at the level of those existing in the most advanced states. This analysis highlights the importance of education in preparing those who will have to find solutions to future problems. Thorough education and cooperation are the prerequisites for future development.

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References

1. Bungescu, I.(1942), *Tragerile Artileriei Antiaeriene Vol. IV*, Centrul de Instrucție al Artileriei Antiaeriene, Școala de Ofițeri, București, Romania.
2. Comandamentul Artileriei Antiaeriene (1944), *Instructiuni referitoare la Variația elementelor determinante de Aparatul Central de Tragere sistem*.
3. Colectiv (1996) *Istoria Artileriei și Rachetelor Antiaeriene Române Vol. I* – Editura Modelism, București, Romania.
4. Cutoiu, V., (1984), *Istoria apărării antiaeriene a teritoriului României*, Editura militară, București, Romania.
5. Deheleanu, A.(2011), *The beginnings of Romanian aviation*, Incas bulletin, Romania.
6. Michalski, D., Radomyski, A. (2020). *Counting the Uncountable. Safety & Defense*, 6(2),100-112. <https://doi.org/10.37105/sd.91>.
7. Popescu, I. (1977) *Colectiv - Istoria artilleriei române*, Editura Militară, Bucuresti, Romania.
8. Rudeanu, I. V. (1931) *Tragerile de noapte ale Artileriei Antiaeriene* – Tipografia ”Dorneanu”, București, Romania.
9. Regulament provizoriu asupra nomenclaturii, descrierii, funcționării, manevrei și întreținerii tunului a.a. cal. 75 mm sistem Vickers Md. 1936.
10. Regulament asupra descrierii, funcționării și manevrei aparatului central de tragere simplificat sistem Major Bungescu I. Md. 1941.
11. Steven, J. M., (2013) *Major-General G. V. Burman and the Creation and Development of Russia's Air Defense System in World War I*, The Journal of Slavic Military Studies,26:3,439-461, DOI: 10.1080/13518046.2013.812486.
12. Leitz, Ch.(1997), *Arms as Levers: Materiel and Raw Materials in Germany's Trade with Romania in the 1930..*, The International History Review, XIX, <https://doi.org/10.1080/07075332.1997.9640786>.
13. Visan, G. (2017) *Romania on Course to Revamp Its Air Defenses*, Eurasia Daily Monitor, 14(1).