RS Global Journals

Scholarly Publisher
RS Global Sp. z O.O.
ISNI: 0000 0004 8495 2390

Dolna 17, Warsaw, Poland 00-773
Tel: +48 226 0 227 03
Email: editorial_office@rsglobal.pl

JOURNAL	World Science
p-ISSN	2413-1032
e-ISSN	2414-6404
PUBLISHER	RS Global Sp. z O.O., Poland

ARTICLE TITLE	AUTOMATING AIR DEFENSE OPERATIONS: METHODS AND TECHNIQUES
AUTHOR(S)	Dungarmaa Tsedendorj, Boldbaatar lkhagva
ARTICLE INFO	Dungarmaa Tsedendorj, Boldbaatar lkhagva. (2024) Automating Air Defense Operations: Methods and Techniques. *World Science*. 2(84). doi: 10.31435/rsglobal_ws/30062024/8195
DOI	https://doi.org/10.31435/rsglobal_ws/30062024/8195
RECEIVED	20 May 2024
ACCEPTED	26 June 2024
PUBLISHED	28 June 2024
LICENSE	This work is licensed under a **Creative Commons Attribution 4.0 International License.**

AUTOMATING AIR DEFENSE OPERATIONS: METHODS AND TECHNIQUES

Dungarmaa Tsedendorj
Ph.D., National Defense University, Mongolia

Boldbaatar lkhagva
Ph.D., Associate Professor, National Defense University, Mongolia

DOI: https://doi.org/10.31435/rsglobal_ws/30062024/8195

ARTICLE INFO

Received: 20 May 2024
Accepted: 26 June 2024
Published: 28 June 2024

KEYWORDS

Automated Control System for Air Defense Operations, Automation.

ABSTRACT

The introduction of an automated control system in the air defense forces will facilitate the management of the actions of troops in collecting, processing, decision-making, planning, conducting and monitoring combat operations, as well as increasing the efficiency of control.

Citation: Dungarmaa Tsedendorj, Boldbaatar lkhagva. (2024) Automating Air Defense Operations: Methods and Techniques. *World Science.* 2(84). doi: 10.31435/rsglobal_ws/30062024/8195

1. The necessity to enhance the management of air defense operations.

Improving the management of air defense operations is essential to ensure the readiness of forces and equipment for combat, prepare for air operations, manage operations efficiently, gather and analyze information, make informed decisions, plan and execute military operations, and monitor performance. Recent changes in the nature of warfare highlight the importance of rapidly managing troops, providing timely information to leadership, ensuring units are prepared for action, and promptly communicating weather updates to personnel.

Automated military control systems will accurately gather, process, and transmit weather information in automatic and automated modes.[1]

The staff operating the automated control system (ACS) includes management, specialists, and equipment operators.[2] Automating AD operations and implementing an automated control system aims to enhance management productivity.

Quantitative and qualitative metrics are utilized to assess the system's effectiveness. Due to its complexity and diverse functions, multiple indicators are employed to evaluate its productivity.

When assessing the productivity of an automated control system, various indicators are used to evaluate the system as a whole, subsystems, and real-time operations. The productivity of the ACS can be evaluated by calculating the increase in combat operations productivity of the unit and sector with the ACS using the formula:[3]

---

[1] "Dictionary of military terms" Institute for Defense Studies. 2014. UB. 359 p

[2] https://encyclopedia.mil.ru/encyclopedia/dictionary/details_rvsn.htm?id=2643 @morfDictionary.

[3] Aerospace Defense Officer's Handbook. (Under the general editorship of S.K. Burmistrov, – Tver: VA PVO, 2006. 512 p. 518.

$$DE = \frac{E_{ACS-E}}{E_{ACS}} * 100\%$$

Here are:

DE – The rate and percentage of productivity increase with the implementation of ACS.

E_{ACS} – Productivity is enhanced by utilizing ACS.

E– Productivity without automated control systems.

2. Air Force Control Automation and Analysis of Automated Control Systems in foreign countries.

The Russian Armed Forces utilize advanced automated air defense control systems such as "Field-E," "Fundamental-1E," "Basis -1E," "Fundamental-2E," "Niva-E," and "Universal-1E" for radar data processing and combat operations control. Additionally, systems like "Baikal-1E" are used for fire control of anti-aircraft missile units, and "Rubezh" systems are employed for directing fighter aircraft in combat operations.

The Russian Armed Forces utilize advanced automated systems for air force management, such as "Field-E," "Fundament-1E," and "Baikal-1E." These systems are designed based on modern science and technology to enhance radar data processing, fire control for anti-aircraft missile units, and combat operations of fighter aircraft.

These systems form the automated military control system for Air and Missile Defense of the Aerospace Forces of the Russian Armed Forces.

BAE Systems corporation of Great Britain is the largest manufacturer and supplier of aerospace control weapons and electronic equipment for military purposes in European countries. The S1850M radar station developed by BAE Systems Corporation is fully automatic and can simultaneously detect and track up to 1,000 air objects within a radius of 400 kilometers. It can also detect ballistic missiles at a distance of 2,000 kilometers and destroy active air defense equipment within 480 kilometers.[1] This radio location station is used by the armed forces of Great Britain, France, and Italy. Table 1 shows a comparative study of the tactical and technical parameters of the automated military control system of the Russian Air Defense Forces.

Table 1. Tactical and technical specifications of Russian Federation's automated military air defense control system.

INDICATOR	Field-E	The basis-1E	Niva-E	Universal-1E	Fundament-3E
Number of cells to monitor	50	120	240	300	300
Cell update frequency (sec)	10	10	10	10	10
Control distance (km)	1600	1600	1600	3200	1500
Control Altitude (km)	40	100	100	100	120
Cell speed (km/h)	4300	6000	6000	6000	7000
Number of connected devices	7	10	16	20	16

Turkey uses air defense equipment from Aselsan, a manufacturer of military electronic equipment in the country.[2] The Turkish Air Defense System "Aselsan" is an advanced, fully automatic

[1] https://www.baesystems.com/en/product/s1850m-long-range-radar.

[2] https://www.aselsan.com.tr/en.

system designed for detecting and intercepting medium-high altitude air attacks. It includes an integrated control network, fire control, and automated guidance system for fighter aircraft. It provides air cover at the corps and brigade level and can work in coordination with allied air defense systems following NATO standards. Turkey supplies Aselsan systems to its own Armed Forces as well as to Azerbaijan, Kazakhstan, Saudi Arabia, and the United Arab Emirates.

In addition to the Russian S-300 (S-400), the most effective air defense system is the US Patriot system. The "Patriot" system was designed not only to combat enemy aircraft but also to intercept ballistic missiles. During the 1991 Persian Gulf War, the United States reportedly destroyed more than 40 Iraq “Scud” surface-to-surface missiles. It proved to be an effective weapon system during the 2003 Iraq War, as well as in the Saudi Arabia-Yemen and Arab-Israeli conflicts. The US "Patriot" missile defense system is used by many countries around the world, including Germany, the Netherlands, Egypt, Israel, the United Arab Emirates, Saudi Arabia, Qatar, Kuwait, Jordan, Japan, South Korea, Taiwan, Greece, and Spain. Additionally, Romania, Poland, and Sweden have also made agreements to purchase the system. The price of the "Patriot" missile complex from Zenit is $3.9-4.7 billion US dollars, depending on the order from the receiving country, the number of launch bases, reserve missiles, Radio Location Stations, and control rooms. The AN/MPQ-53 Radio Location Station in the "Patriot" complex detects, tracks, and controls missiles. The AN/MPQ-53 Radio Location Station is a fully automatic system that automatically obtains cell readings from other stations. It is a complex, multi-purpose model with specific specifications.[1]

Specifications:

- ✓ Target detection distance: missile 70-100 km, fighter 130 km, bomber 180 km.
- ✓ Simultaneous tracking cells: 125.
- ✓ Tracking cell speed: 2200 m/sec.
- ✓ Simultaneously controlled missiles: 6.
- ✓ Cell detection time: 8-10 seconds.
- ✓ Station display time: 25 min.

Table No. 2 shows the tactical-technical parameters of US Radio Location Stations and compares them with the tactical-technical parameters of anti-aircraft missile complexes from foreign armies in Table No. 3.

Table 2. Tactical-Technical Specifications of US Radio Location Stations. The following are the tactical-technical specifications of US radio location stations.

INDICATOR	AN/TPS-59	AN/FPS-117	AN/TPS-77	TPS-77 MRR
Frequency	1200-1400MHz	1200-1400MHz	1200-1400MHz	1200-1400MHz
Control distance (km)	10-740	10-470	10-470	10-463
Control Altitude (km)	0-350	30.5	30.5	30.5
Accuracy of measurement (m)	30 meters in distance 300 meters in height.	50 meters in distance and 762 meters in height.	50 meters in distance and 915 meters in height.	50 meters in distance and 915 meters in height.
Number of tracking cells	100	100	100	100
Time to transition from campaign to combat (min)	30	45	45	45

[1] https://www.radartutorial.eu/19.kartei/06.missile/karte003.en.html.

Table 3. Tactical-technical specifications of the foreign military army anti-aircraft missile complex system.

Specifications	C-300 PMU-1 (Russia)	CA-75 (China)	PATRIOT (USA)
A distant reflection	0,4-150	10-34	5-100
Kill height	0,01-27	0,5-27	0,06-24
Number of cells to delete at once	6	2	8
Display time	5	-	30
Unit complex price (million USD)	117,6	-	123

The "Patriot" complex uses 3 types of missiles depending on the characteristics of the target. MIM-104A for anti-aircraft or aerodynamic targets, MIM-104B for anti-interceptor and anti-radar purposes, and MIM-104C for combating ballistic missiles.

Specifications of rockets:

- ✓ Ballistic missile destruction range: 3-20 km;
- ✓ Distance to destroy an aerodynamic cell/plane: 3-80 km;
- ✓ Height of destruction of cell: 0.06-25 km;
- ✓ MIM-104A and MIM-104B rocket speed: 3M[1] (3 times faster than sound);
- ✓ MIM-104C missile speed: 5M (5 times faster than sound);
- ✓ Duration of the rocket engine: 11.5 seconds.

The main manufacturer of air defense control and reconnaissance radar stations in the United States is Lockheed Martin. The technical specifications of the Radio Location Stations of this company are shown in Table 2.

The Germany, Italy, Canada, Finland, Sweden, Switzerland, India, Iran, Israel, Japan, Pakistan, and China have developed their own air defense weapons, combat equipment, and automated control systems for defense purposes. As evidenced by the ongoing world wars, armed conflicts, and terrorist operations, the rapidly advancing speed and destructive capabilities of air attack equipment necessitate the enhancement of air and space control by countries. This includes the establishment of a unified management system and the swift exchange of information for effective management. In recent years, China has developed the "Dongfeng-41" (DF-41) missile with a speed 10 times that of sound, while Russia has adopted the "Avangard" ballistic missiles with a speed 20 times that of sound.

3. Introducing automated systems for managing air defense operations.

As of today, the traditional "Tablet" method of receiving, processing, and transmitting airtime information used in the management offices of the Radio Engineering Department is outdated. The amount of time lost and allowable errors in the operation exceeds current requirements. For example, it takes several minutes to make a decision on one cell's data through many (more than ten) stages. Modern aircraft travel 50-100 km, and the accuracy of determining the cell's position is half the error of the small square of the tablet or 1-5 km. Due to the high traffic density of today, there is a significant lack of correct decision-making in airspace.

The results of experiments and research on the development of the management structure of the Mongolian Armed Forces Air Force and the implementation of an automated control system were studied. A scenario for the introduction of an automated system in the management of air defense operations was developed.

[1] MAX - "Mach speed" 330 m/s

One. The intelligence and information subsystem.

The intelligence and information subsystem consists of radio engineering units and branches with the primary function of receiving, processing, and transmitting radar information, as well as disseminating combat and intelligence information.

Radio engineering units and branches will detect air cells with the help of radar stations, determine the coordinates of the cells, establish their nationality, acquire, process, transmit, and disseminate information about air traffic status. The combat capability of a radio engineering unit or branch is the ability to conduct radar reconnaissance under any weather conditions and transmit intelligence and combat information to the command and troops within a specified period of time.[1] The combat effectiveness of radio engineering units and branches depends on spatial and informational factors. Spatial parameters are expressed by the detection distance of the cell at a certain height, the upper and lower limits of the height of the detection cell, the size of the covered radar area, and the overlapping of the detection zone. Information parameters are expressed by the quality of the radio location data and the capacity of the transmitted data (speed of data transmission of the cell). The combat potential greatly depends on the tactical-technical parameters of the Radio Location Station and communication equipment used.

As of today, the radio technical committee finds it challenging to receive and process radar intelligence simultaneously with radio location information (RLI). This issue hampers the promptness of management and slows down the transmission of radio location information. To address this, existing radar companies will be divided into parts to create battalions. The radio technical committee will be integrated into the battalion structure and enhanced as an intelligence subsystem.

When establishing a new battalion, three additional Russian "NEBO", CASTA-2, and radio location stations will be placed, and a closed radar area will be created at an altitude of 3000-6000 meters, which will improve the air border and radar control of Mongolia. These radar complex stations are shown in Figure 1, and their tactical and technical specifications are shown in Table 4.

In the command post of each radio technical committee and battalion, certain equipment of the automated control system will be installed and used. This equipment will be able to process and transmit radio location information quickly and reliably provide active fire equipment with combat information.

NEBO-UE

CASTA-2

NEBO-ST

Figure 1. Radar Complex Stations.

[1] Aerospace Defense Officer's Handbook. (Under the general editorship of S.K. Burmistrov, - Tver: VA PVO, 2006. 512 p. 433

Table 4. Tactical specifications of radar complex stations.

№	Tactical specifications	NEBO-UE	CASTA-2	NEBO-ST
1	Detection distance, km	400	150	300
2	Height, km	60	6	30
3	Accuracy of coordinate determination: distance, meter	400	100	400
4	Azimuth, min	24	40	40
5	Height, meters	750	900	-
6	Wave range	meter	decimeter	meter
7	Time and date of display, /collection/	22	0.33	0.75
8	Power consumption, kw	100	3	29

Two. The Covering Subsystem.

The anti-aircraft missile defense in Ulaanbaatar will be managed by the anti-aircraft missile committee using Pechora-2M and C-300 models. The air defense system will cover all altitudes and areas around the city. It is also possible to enhance the cover by including the mobile "Pantsir" anti-aircraft missile complex in the arsenal of the ground military brigade. Fighter aircraft cover will be provided by fighter aircraft squadrons equipped with modern fighter jets to ensure compliance with flight rules and regulations in Mongolia's airspace and borders, prevent violations, and deter potential air attacks.

The Zenith missile committee and fighter aircraft squadron control rooms will be provided, and these systems will be able to receive commands and signals from the automated control system of the Air Force Central Command building. They will also exchange information with the adjacent radio technical committee and the automated control system of the battalion control building. Two options for automating the management of air defense operations are proposed.

The first option (The introduction of the automated control system in the Russian Federation).

The first proposed option for automating the control of air defense operations is to directly adopt the automated control system used by the Russian armed forces and integrate it into the Air Force arsenal. A schematic diagram of this version is shown in Figure 2.

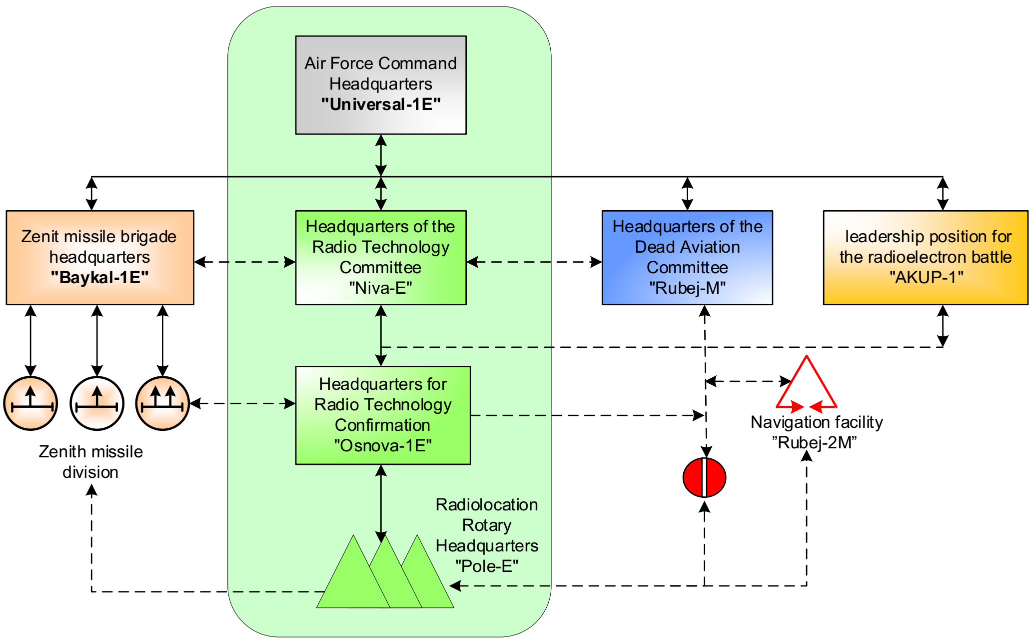

Figure 2. Introduction of the automated control system for the "Universal-1E" model of the Air Defense Forces of the Russian Federation to the Mongolian Armed Forces.

In this version, the automated control system (air defense connection) of the "Universal-1E" model of the Air Defense Forces of the Russian Federation is being discussed. This system, which was introduced into the arsenal in 1998, belongs to the category[1] of third-generation automated control systems and is currently considered the latest model. This system is designed to control air defense and modern weapons (anti-aircraft missiles, anti-aircraft guns, radio electronic warfare equipment).[2]

In Figure 2, the areas surrounded by green squares represent the systems for acquiring, processing, and transmitting radio location information. The continuous arrow lines depict the channels through which the message is transmitted, while the dashed arrow lines represent the active means of fire and the channels providing combat information to the Radio-Electronics Combat Branch, respectively.

As can be seen from the picture of the introduction of the automated control system of the "Universal-1E" model, only a one-level automated control system is used to control the combat operations of anti-aircraft missiles, anti-aircraft, and radio electronic combat units and branches, while a three-level system is used for radio engineering units and branches: company, battalion, and regiment. This is due to the characteristics of radio location data acquisition, processing, and transmission, which highlights the importance, complexity, and cumbersome nature of the operation.

Let's calculate how the combat potential of the radio engineering division and branch will increase with the introduction of the proposed first version into the arsenal by using some indicators.

1. **Cell data transmission speed.** The "Pole-E" automated control system monitors 50 cells simultaneously and updates the data of each cell every 10 seconds. Therefore, it can be concluded that the communication channel of the "Pole-E" automated control system can transmit 50 cell messages per 10 seconds.

Then the system will calculate $50 * \frac{60\ \text{sec}}{10\ \text{sec}} = 300$ the number of text messages transmitted per minute. In this case, let's evaluate the increase in the productivity of cellular communication using the formula (1) above:

$$\Delta Э1 = \frac{300-7}{300} * 100\% = \mathbf{97.6\%},\quad \Delta Э2 = \frac{300-14}{300} * 100\% = \mathbf{95.3\%}$$

Note: The number of cells transmitted per minute by the tablet method is calculated as 7 for one channel and 14 for two channels.

2. **Number of Cells to Track Simultaneously.** When using the tablet method, the Radio Locator Company HQ can track 12 cells simultaneously, while the Pole-E Control Automated System can track 50 cells simultaneously.

Then, if the increase in the potential productivity of the radio locator company data is evaluated by the formula (1):

$$\Delta Э1 = \frac{50-12}{50} * 100\% = \mathbf{76.0\%}$$

3. **Accuracy of cell coordinate determination.** The accuracy of cell position determination using the tablet method is half of the small square of the tablet, or 1-5 km. By utilizing the automated management system, this error is eliminated, and the coordinate accuracy does not decrease from the accuracy measured by the radio location station.

The introduction of the automated control system of the "Universal-1E" model in the Air Defense Forces of the Russian Federation has the following advantages:

✓ Mongolian Air Force uses Russian-manufactured weapons and equipment, allowing for direct connection of the new automated control system without intermediate switches.

[1] The automated control system of the 1st generation is based on a lamp element, the automated control system of the 2nd generation is based on a transistor element, while the automated control system of the 3rd generation is based on an integrated microcircuit and is faster, more capacious, and more reliable than before.

[2] Morenkov V., Tezikov A., Historical aspect of the development of air defense automated control systems. Magazine “Aerospace Defense”, 2015, No. 1.

✓ There is no cost for designing and testing the automated control system, which has been proven reliable through years of testing in the Russian Air Defense Forces.

✓ Integration with the unified air defense system of the Russian Federation will not require extensive technical and technological reforms in the long run.

✓ The automated control system will significantly improve data transmission efficiency, increase information availability

✓ From the Radio Locator Company by 76%, and eliminate loss of precision in Cell Coordinates caused by the tablet.

Adopting and using ready-made systems from foreign countries has drawbacks, including:

✓ Dependency on foreign countries due to lack of knowledge about the system's algorithms and techniques.

✓ Increased costs for the Air Force from acquiring new technology and training specialists to operate it.

Conclusion: It is estimated that by eliminating the radio locator company cell data transmission tablet method and implementing the "Pole-E" automated control system, the productivity of the company's cell data transmission will increase by 95.3-97.6 percent. Additionally, the tablet's effect on reducing the accuracy of cell coordinates will be completely eliminated.

Option Two: Build and use your country's Automated Management System.

The Air Force Command of the Armed Forces plans to implement the "Automation of the Central Command Building Management System" in four stages. The total cost of automation is 950 million MNT, making it more cost-effective than purchasing a similar system from abroad. Let's calculate how the combat potential of the radio engineering division and branch will increase with the introduction of the second option into the arsenal, using some indicators.

1. **Cell data transmission speed.** Five communication systems will be used for transmitting radio location information in the desert, including fiber optic cable, radio relay, microwave, communication network, and space communication. Short-wave radio communication will be used as a representative system to calculate data transmission possibilities. The calculations were made based on the example of the RF-5800H-MP radio station from the American company Harris, which is used by the Armed Forces of Mongolia. The station is capable of transmitting data at a speed of up to 2400 bps.[12] The cellular data is converted to binary for transmission through this digital communication station. A total of 101 bits are required to transfer the complete data of the cell to the binary number system. It is assumed that some official codes will be added to it, and cell data will be packaged and introduced in 128 bits to facilitate conversion in the binary number system.

Then the Harris RF-5800H-MP radio station can transmit $\frac{2400}{128} = 18.7$ or 18 cell messages per second. If you calculate the number of text messages transmitted per minute, it is: 18 * 60 = 1080. The increase in the productivity of cellular communication is estimated by the formula (1):

$$\Delta Э1 = \frac{1080-7}{1080} * 100\% = \mathbf{99.3\%} \qquad \Delta Э2 = \frac{1080-14}{1080} * 100\% = \mathbf{98.7\%}$$

Note: The number of cells transmitted per minute by the tablet method is 7 with one channel and 14 with two channels.

2. The number of cells transmitted per minute by the tablet method is 7 with one channel and 14 with two channels. By utilizing an automated control system, this error is eliminated, ensuring that the accuracy of the coordinates remains consistent with the measurements obtained from the Radio Location Station.

Advantages of implementing an in domestic automated control system include:

✓ Low cost in terms of costs and expenses

✓ Cost-effectiveness and control over software customization and error detection

✓ 99.3% increase in efficiency of cell information transmission from the radio locator company.

✓ Elimination of the need for expensive training abroad.

[1] http://www.railce.com/cw/casc/harris/harris.htm

[2] https://military.trcvr.ru/2015/09/06/radiostancija-rf-5800h-mp.

Disadvantages of the system include:

- ✓ Potential challenges during testing and commissioning due to the new design.
- ✓ Incompatibility with the Russian Air Defense System in the future.
- ✓ Lack of experience in manufacturing and using automated management systems at the factory level.

Conclusion. Implementing the "Automation of the Central Command Building Management System" project is expected to significantly improve productivity and eliminate accuracy issues in cell data transmission.

CONCLUSION.

The following conclusion is made regarding the automation of the management of air defense operations of the Armed Forces of Mongolia. It includes:

1. The entire weaponry, equipment, airspace control, and management system used by the Air Force of the Armed Forces of Mongolia are outdated in terms of operational methods, techniques, and technology and are no longer viable.
2. It is high time to transition the development of the Radio Locator stations used by the Armed Forces Air Force to digital technology, phase out obsolete Radio Locator stations, eliminate the outdated manual operation of the cell data transmission tablet, and promptly implement an automated system for the control of air defense operations.
3. The goal of automating the management of air defense operations in the Air Force of the Mongolian Armed Forces will be achieved in two ways: 1) purchasing a ready-made automated control system from Russia or creating a unified air defense system in cooperation with the country, and 2) developing and introducing a national automated control system.

RECOMMENDATIONS.

1. Develop an automated military management system and a national secret communication-management-information system based on Mongolian engineers' expertise and domestic resources. Learn from past mistakes, avoid repetition, and scientifically reduce risks.
2. The General Directorate of Civil Aviation's proposal to allocate up to 17% of air navigation service revenue for the "Integrated Airspace Control Network" and "Technical Innovation of Mongolia's Airspace Control" has been approved by the President, Commander-in-Chief of the Armed Forces, and Prime Minister of Mongolia.
3. Begin the phased replacement of Radio Locator stations used by Air Force radio engineering units and branches of the Armed Forces immediately, aiming to complete the process within 10-15 years. Transition some stations to digital technology to save time, while purchasing and deploying 1-2 new stations annually.

Evaluate all planned armament and technical modernization work for the state's airspace control using the "Combat Readiness Coefficient." Only proceed with projects if the coefficient has increased or remained stable for the next 5 years. Ensure timely, quality completion of all planned work.

REFERENCES

1. Dashzeveg Ts., Fundamentals of military management, UB, Soyombo Printing, 2003, 170 p.
2. Palamdorj Sh., Theoretical-practical analysis of military management, Proceedings of the theoretical-practical conference, 2010, UB, ISBN 978-99962-50-05-7.
3. Palamdorj Sh., Evolution, changes, and analysis of the theory and practice of military management, Proceedings of the Russian Academy of Sciences on the topic of analysis of the theory and practice of military management, BHIS, UB, 2010, 118 p., ISBN 978-99962-50-05-7.
4. Ravjaa B., Some issues of the theory and practice of automation of military management, Proceedings of the SSC on the analysis of the theory and practice of military management, BHIS, UB, 2010, 118 p., ISBN-978-99962-50-05-7.
5. Military reform, UB, 2007, No. 2, pp. 9-11. Works in Russian and English.
6. Namsrai T., Projections of some approaches to modernization of the armament and military equipment of the Armed Forces of Mongolia // Security and Defense Studies, UB, 2019, No. 27, p. 91-108.
7. Zimin G.V., Burmistrov S.K., et al. Handbook of an air defense officer. 2nd ed., revised and expanded. Moscow: Voenizdat, 1987, 512 p.

8. Morenkov V., Tezikov A., Historical aspect of the development of air defense automated control systems. Aerospace Defense, 2015, No. 1..
9. Tactics of the Air Force Radio Engineering Troops: Fundamentals of the combat use of radio engineering formations and units. Tver, 2003.