МІНІСТЕРСТВО ОБОРОНИ УКРАЇНИ
ЗБРОЙНІ СИЛИ УКРАЇНИ
ХАРКІВСЬКИЙ НАЦІОНАЛЬНИЙ УНІВЕРСИТЕТ ПОВІТРЯНИХ СИЛ
ІМЕНІ ІВАНА КОЖЕДУБА

ДВАДЦЯТЬ ПЕРША НАУКОВА КОНФЕРЕНЦІЯ КУРСАНТІВ ТА СТУДЕНТІВ ХАРКІВСЬКОГО НАЦІОНАЛЬНОГО УНІВЕРСИТЕТУ ПОВІТРЯНИХ СИЛ ІМЕНІ ІВАНА КОЖЕДУБА

Тези доповідей

20 – 22 травня 2025 року

Харків
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Затверджено до друку вченою радою Харківського національного університету Повітряних Сил імені Івана Кожедуба, протокол від 27 травня 2025 року № 7

XXI наукова конференція курсантів та студентів Харківського національного університету Повітряних Сил імені Івана Кожедуба: тези доповідей, 20-22 травня 2025 року. – Х.: ХНУПС ім. І. Кожедуба, 2025. – 352 с.

Наведені тези секційних доповідей за теоретичними та практичними результатами наукових досліджень і розробок, які виконані курсантами та студентами Харківського національного університету Повітряних Сил імені Івана Кожедуба.

Для наукових, науково-педагогічних працівників, викладачів, докторантів, ад'юнктів, курсантів, студентів, фахівців в галузі розвитку збройних сил, озброєння та військової техніки.

За достовірність викладених фактів, цитат та інших відомостей відповідальність несе автор.

ЗМІСТ

ВСТУПНЕ СЛОВО
начальника Харківського національного університету Повітряних Сил імені Івана Кожедуба на Двадцять першій науковій конференції курсантів та студентів Харківського національного університету Повітряних Сил імені Івана Кожедуба

Dear participants of the Conference!

Another year, people of Ukraine are fighting for their independence, self-identity, values, and the very existence of the Ukrainian nation. Our soldiers, volunteers, and the entire Ukrainian people were able not only to stop the enemy troops, but also to defeat and shamefully expel them from Kyiv and Kherson, Chernihiv and Kharkiv. The glorious exploits of our heroes demonstrated to the whole world the strength and glory of the Ukrainian army and the superiority of the free democratic people over the empire of weak-willed slaves and treacherous tyrants. The enemy is desperately trying to gain a foothold in the expanses of our State, demonstrating at least some successes to the bewildered peoples of the empire. He is also trying to break the will to resist of our people by unleashing missile and aviation terror against the civilian population, our economy, and infrastructure. And it was the Air Force, our pilots and anti-aircraft gunners, radar operators and electronic warfare specialists, signalmen and engineering and technical personnel, intelligence officers and combat management officers who thwarted the enemy's plans and, despite all objectively negative factors in favor of the enemy, managed to form a reliable air shield over our cities and battle formations of troops.

In this difficult time for the country, it is the Air Force of the Armed Forces of Ukraine that is the unmovable lever and the main tool that primarily restrains the onslaught of enemy forces from the air on each section of the front. The Air Force of the Armed Forces of Ukraine bears full responsibility for the security of our sky throughout the territory of the state, the protection of our country and its citizens from threats from the air.

Effectively increasing the defense capabilities of the Air Force of the Armed Forces of Ukraine is impossible without a critical and comprehensive rethinking of scientific methods, which is confirmed by the complex and heroic experience of our counteraction to the large-scale military aggression of our northern neighbor. The implementation of new scientific approaches, in particular through work with captured weapons and participation in expert and analytical groups, as well as the optimization of automated aviation and air defense control systems, are not only useful, but also extremely necessary. The improvement of military technologies and the integration of international military experience are key to increasing the defense capabilities of the state in modern conditions.

The experience gained by Ukraine during the repulsion of the full-scale armed aggression of the russian federation convincingly demonstrates that the development of the Armed Forces of Ukraine as a whole is not possible today without conducting detailed theoretical research on the development of communication capabilities between all levels of management, increasing the capabilities of modern aviation, the functioning of the air and missile defense system of Ukraine, the creation of the latest information technologies in the military sphere, the development of automated and remotely controlled models of weapons and military equipment of various functional purposes and bases, and the study of problems of training and conducting mobilization deployment of the Armed Forces of Ukraine. In order to develop scientific abilities in cadets and students, the university operates four design bureaus and more than forty scientific circles of cadets and students. All cadets and students studying at the master's educational and qualification level are engaged in scientific work. The best of them are included in the "golden fund" of the university and are candidates for admission to the university's adjunct program.

I am sure that thanks to our cadets and students, we will overcome all the challenges of today and transform into a Euro-Atlantic community.

I wish all participants of the conference to show their best features in the process of work, gain new experience and knowledge, expand their worldview, and form new tasks for themselves, the solutions of which will be implemented in your scientific works in the future for the sustainable development of the Armed Forces of Ukraine. Prosperity to you, harmony and peaceful skies.

Together to victory!

Glory to Ukraine and its Armed Forces!

Начальник Харківського національного університету Повітряних Сил
імені Івана Кожедуба
бригадний генерал Андрій БЕРЕЖНИЙ

ОРГАНІЗАЦІЙНИЙ КОМІТЕТ КОНФЕРЕНЦІЇ

Голова організаційного комітету:

начальник Харківського національного університету Повітряних Сил імені Івана Кожедуба бригадний генерал Андрій БЕРЕЖНИЙ.

Співголова організаційного комітету:

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Секретар:

помічник начальника науково-організаційного відділу Харківського національного університету Повітряних Сил імені Івана Кожедуба капітан Андрій ТІЩЕНКО.

Члени організаційного комітету:

начальник наукового центру Повітряних Сил Харківського національного університету Повітряних Сил імені Івана Кожедуба полковник Олег МІСЮРА;

начальник льотного факультету Харківського національного університету Повітряних Сил імені Івана Кожедуба полковник Віктор ІЩУК;

начальник інженерно-авіаційного факультету Харківського національного університету Повітряних Сил імені Івана Кожедуба полковник Богдан ІВАЩУК;

начальник факультету зенітних ракетних військ Харківського національного університету Повітряних Сил імені Івана Кожедуба полковник Олександр РЕЗНІЧЕНКО;

начальник факультету автоматизованих систем управління та наземного забезпечення польотів авіації Харківського національного університету Повітряних Сил імені Івана Кожедуба полковник Сергій МАКАРОВ;

начальник факультету радіотехнічних військ протиповітряної оборони Харківського національного університету Повітряних Сил імені Івана Кожедуба полковник Сергій КОВАЛЕВСЬКИЙ;

начальник факультету протиповітряної оборони Сухопутних військ Харківського національного університету Повітряних Сил імені Івана Кожедуба полковник Вячеслав МЕГЕЛЬБЕЙ;

начальник факультету післядипломної освіти Харківського національного університету Повітряних Сил імені Івана Кожедуба полковник Ірина БОКЛАГ;

декан факультету підготовки офіцерів запасу за контрактом Харківського національного університету Повітряних Сил імені Івана Кожедуба працівник Збройних Сил України Юрій ОЛІЙНИК;

директор інституту цивільної авіації – заступник начальника університету по роботі зі студентами Харківського національного університету Повітряних Сил імені Івана Кожедуба працівник ЗС України Юрій ШЕВЯКОВ;

командир 141/1 навчальної групи льотного факультету Харківського національного університету Повітряних Сил імені Івана Кожедуба сержант Антоній ҐАВА;

слухач 255 навчальної групи інженерно-авіаційного факультету Харківського національного університету Повітряних Сил імені Івана Кожедуба лейтенант Микита СЕМЕНОВ;

командир 341а навчальної групи факультету зенітних ракетних військ Харківського національного університету Повітряних Сил імені Івана Кожедуба сержант Олексій КЛАССЕН;

курсант 432 навчальної групи факультету автоматизованих систем управління та наземного забезпечення польотів авіації Харківського національного університету Повітряних Сил імені Івана Кожедуба старший солдат Анастасія ПЕРЕШЕВАЙЛО;

курсант 541 групи факультету радіотехнічних військ протиповітряної оборони Харківського національного університету Повітряних Сил імені Івана Кожедуба солдат Катерина ЖЕЛНОВАЧ;

курсант 621 навчальної групи факультету протиповітряної оборони Сухопутних військ Харківського національного університету Повітряних Сил імені Івана Кожедуба солдат Вікторія НАЧОВНА;

студент 721к групи факультету авіаційного транспорту інституту цивільної авіації Харківського національного університету Повітряних Сил імені Івана Кожедуба Сергій КОНОВАЛЕНКО.

СЕКЦІЯ 1

СТАН ТА ПЕРСПЕКТИВИ РОЗВИТКУ ПОВІТРЯНИХ СИЛ

Керівники секції: полковник Олександр ШЕЙГАС
Секретар секції: майор Олексій ШУЛЬГА

IMPROVING THE QUALITY OF PILOT CADETS TRAINING TODAY AND IN THE FUTURE

R. Hladyshko; M. Samoilenko
Ivan Kozhedub Kharkiv National Air Force University

Modern warfare determines the crucial role of air superiority. Achieving this superiority directly depends on the quality of the aircrew training.

A typical flight training programmes should have three stages: primary, basic and advanced flight training, which should come throughout the entire period of flight training.

The main advantages of this training system include the following:

– didactic consistency and quality progressing of skills;
– continuous practical training, minimising the loss of skills;
– gradual mastering of various types of aircraft;
– early career guidance of cadets by field of study – a solid foundation for flight safety.

Cost optimisation of this approach can be achieved by:

– improving the flexibility and quality of training programmes;
– active usage of advanced simulators and immersive technologies;
– prioritising the optimal required flight hours;
– search for opportunities for international cooperation.

Prospects of the system development may be:

– implementation of modern teaching methods;
– consolidation of practical component of the theoretical training;
– involvement in teaching process the experienced combat pilots;
– continuous monitoring and improving of programmes.

FEATURES OF OPERATION OF THE GMK-1AE COURSE SYSTEM

Y. Mikyliak; Y. Tananin
Ivan Kozhedub Kharkiv National Air Force University

The GMK-1AE (magnetic gyrocompass combined) is a classic aviation device that combines gyroscopic stability with the accuracy of a magnetic compass. It is designed to determine the course of an aircraft, particularly in difficult weather conditions or over long distances. Despite its reliability, the device has a number of operational limitations.

In particular, the GMK-1AE requires time to spin up the gyroscope before flight (2-5 minutes), is sensitive to changes in the aircraft's position during parking, and is prone to errors during intensive manoeuvres. In flight, it requires periodic correction and verification with other navigation systems. Operation in areas of magnetic anomalies or under conditions of vibrations can also negatively affect the accuracy of the readings.

In comparison, AHRS (Attitude and Heading Reference System) is a modern electronic spatial orientation system that works on the basis of solid-state sensors: gyroscopes, accelerometers and magnetometers. It provides instant launch, high accuracy in all manoeuvres, automatic correction, reliability and full compatibility with GPS and autopilot.

Suggestions for improving the operation of the MMC-1AE:

Implementation of automatic correction modules with digital feedback to reduce errors during long flights.

Update the gyroscopic unit using modern MEMS technologies without losing the interface with existing aircraft panels.

Development of combined systems such as "MMC-AHRS", which use the MMC as a backup system in case of failure of the electronic unit.

Modernisation of indicators and heading markers to improve the readability of information.

ANALYSIS OF FACTORS CAUSING CRITICAL FLIGHT CONDITIONS AND METHODS FOR AIRCRAFT RECOVERY

D. Mykhailychenko
Ivan Kozhedub Kharkiv National Air Force University

According to statistical data, up to one-third of aviation incidents in transport and commercial aviation are caused by aircraft entering an unusual attitude (UA), which often leads to aerodynamic stall, spin, or loss of control.

The main causes of such situations include adverse weather conditions, technical failures of aircraft systems, and crew errors – particularly the failure to follow flight procedures or loss of spatial orientation.

The challenge of timely recognition of UA and inappropriate crew actions in such scenarios significantly complicates the recovery of the aircraft to controlled flight. Limited knowledge of aircraft and engine behavior at high angles of attack, lack of skills in identifying the onset of stall or spin, as well as the absence of a proper action algorithm – all these contribute to the potential for critical outcomes.

This paper analyzes common crew errors, reviews the main recovery techniques for aircraft in critical flight conditions, and provides rationale for pilot actions in the event of UA, stall, or spin. It also proposes improvements to pilot training through the inclusion of theoretical explanations and expanded simulator practice focused on modeling critical situations.

MODERN APPROACHES TO THE ORGANIZATION AND CONDUCT OF AVIATION SEARCH AND RESCUE OPERATIONS

O. Levkov; O. Pasichnyk
Ivan Kozhedub Kharkiv National Air Force University

Aviation search and rescue is a set of measures aimed at detecting aircraft in distress and providing timely assistance to victims of aviation incidents.

Significant improvements in the effectiveness of aviation search operations can be achieved through the proposed use of a light helicopter equipped with modern surveillance systems, specifically IP cameras. However, installing such equipment requires reliable and stable communication for transmitting video information from the aircraft to the rescue operation command center.

New capabilities for video data transmission from the aircraft have emerged with the introduction of SpaceX technologies. In parallel, the results of aerial search operations can be transmitted via a Starlink satellite relay system.

The ability to directly control drones from the helicopter and receive real-time information greatly enhances aviation search and rescue operations. The search area can be surveyed from different angles – visually from the helicopter or via its technical equipment, as well as from UAVs. If terrain features or urban structures obstruct the helicopter's view, search targets may be hidden. However, by directing the UAV along a trajectory that provides visibility beyond obstacles, the onboard operator effectively "relocates" their sensors while remaining stationary. By accessing the UAV's video feed, the operator can observe different sections of the terrain in real-time to locate victims.

This process is conducted in real-time, ensuring the most efficient and effective execution of search and rescue missions.

INCREASING THE EFFICIENCY OF TACTICAL AND BOMBING AVIATION BY USING UNMANNED AERIAL VEHICLES AS A REPEATER

Y. Sydorov
Ivan Kozhedub Kharkiv National Air Force University

Modern warfare has opened our eyes to many factors of warfare that few people have paid attention to before. For example, we realized the importance and significant advantages of using unmanned aerial vehicles (UAVs). One of the ways UAVs can be used is as a repeater to increase the range of an aircraft's onboard radar.

Modern air combat conditions are based on the use of air-to-air missiles, and while missiles with a longer range can be installed on an aircraft, it is difficult to replace the onboard radar without modifications. Thus, we have considered the advantages of using unmanned repeaters, as well as possible options that already exist and may be used in the near future.

The report covers the following main issues:

Utilization of UAVs as a communication repeater

Bayraktar Akinci as a possible UAV option for the future

The intensive use of UAVs in the future in all industries is a very promising idea. Tactics and strategies are already being developed to help effectively destroy the enemy. So, if we consider this topic scientifically, we hope it will help aviation right now.

CERTIFIED MASTERY OF THE COMMON EUROPEAN AIRSPACE BY GRADUATE CADETS

N. Kabaliuk
Ivan Kozhedub Kharkiv National Air Force University

The implementation of certified training for graduate cadets in the operation of the common European airspace and international aviation regulations is an important step toward Ukraine's integration into the European aviation system. This will contribute to enhancing the professional training of future aviation specialists, ensuring compliance with international flight safety standards, and achieving interoperability of the aviation units of the Armed Forces of Ukraine with the air components of NATO member states.

Certain steps have already been taken in this direction:

Initial flight training for cadet pilots is conducted in aviation training centers under programs that fully comply with the Aviation Regulations of Ukraine and the European Union.

The flight faculty has introduced courses that align with current legislation regarding the preparation and certification of state aviation pilots in Ukraine, as well as an increased number of training hours dedicated to foreign language studies to obtain an aviation English language certificate at ICAO Level IV.

At the same time, the issue of ensuring the necessary volume of practical training remains, particularly flight hours on aircraft and certified aviation simulators. These complex but highly important and relevant issues require detailed discussion during the conference.

TRAINING INSTALLATIONS (SYSTEMS) CAPABILITIES IN RELATION TO THEIR TECHNICAL COMPLEXITY

M. Shkurman
Ivan Kozhedub Kharkiv National Air Force University

The performance potential of modern simulation complexes directly influences the capacity to meet the growing demand for highly skilled flight personnel. These systems are meticulously engineered to emulate real-world scenarios, effectively honing the tactical proficiency essential for executing contemporary aviation missions.

As technology evolves, training platforms frequently exhibit paradoxical performance metrics. Enhancements in realism and simulation accuracy contribute to improved outcomes, yet simultaneously entail a quadratic increase in both initial investment and maintenance expenditures. An analysis of simulator utilization across leading aviation nations reveals distinctive characteristics regarding their function and significance, contingent upon the class and type of simulator employed.

The continuous advancement of modern technologies fosters both quantitative and qualitative improvements in the provisioning of combat training activities through a diverse array of instructional and training tools. These vary in technological complexity, mobility, integration level, and consequently, in the scope and nature of their assigned tasks. Thus, a moderate reduction in simulation complexity can facilitate large-scale deployment while maintaining cost-efficiency and serviceability, without substantially compromising training quality.

Accordingly, rigorous assessment must underpin decision-making, ensuring that each increment in realism yields commensurate gains in operational effectiveness. Striking an equilibrium between the two fundamental dimensions – quality and scalability – remains a cornerstone of contemporary simulator application strategies.

FACTORS THAT CAUSE THE DEVELOPMENT OF WIND SHEAR AND ITS IMPACT ON AIRCRAFT LANDINGS

D. Skochko; A. Kupriienko
Ivan Kozhedub Kharkiv National Air Force University

The research of factors that cause the development of wind shear is one of key and crucial topics concerning flight safety because early detection of these factors allows us to warn the pilots right away and give them more time to prepare, handle or avoid it. Regardless of the developments of civil aviation in the field of dangerous weather warning and detection systems, including wind shear, further development in this field and introduction of these systems into the military aviation, equipping aircraft and airdromes is key for ensuring highest possible flight safety. Because there are many different factors and causes of wind shear, like: cumulonimbus clouds and down bursts, microbursts and gust fronts, mountainous landscapes and leeway rotors, severe turbulence, passing of atmospheric fronts or inversion layers that cause significant temperature gradients in vertical or horizontal profiles, and the difficulties or impossibility of detecting them with current approaches and equipment, research into new possibilities and techniques for developing wind shear detection systems further is substantial. Even though wind shear is a rare event for aircraft to get into, it always causes dangerous or even catastrophic situations because of the aerodynamic effects of sudden change in wind flow speed and direction over aircraft, since it is one of the main components of generating lift.

The presented information could be useful for bringing attention and improving understanding of the wind shear phenomena, factors that can cause the development of wind shear, the extent of its impact on aircraft landing phase of flight and shine some light on the current available wind shear detection approaches and techniques as well as possible ways of improving them.

THE SIGNIFICANCE OF PILOT'S ATTENTION RESERVES IN ENSURING FLIGHT SAFETY

D. Chmelyk; B. Pletskiy
Ivan Kozhedub Kharkiv National Air Force University

Considering flight safety as a complex indicator dependent on numerous factors, it is crucial to note that the professional training of flight crews plays a pivotal role among them. One of the most important aspects of this training is the pilot's ability to effectively distribute and switch attention under conditions of high psychological stress, dynamic changes in flight conditions, and the surrounding environment.

During flight, the pilot faces the need to simultaneously analyze instrument readings, assess the external environment, conduct radio communications, and make operational decisions. In the event of abnormal situations requiring an immediate reaction, this can lead to a time deficit.

In this situation, the pilot's attention reserves come to their aid. These reserves enable the pilot to quickly switch between tasks, facilitate the reception and processing of additional information, maintain focus on critically important elements, and operate effectively even under stressful conditions.

Research in aviation psychology and pedagogy shows that experienced pilots possess greater attention reserves due to their training and the automation of predefined actions. At the same time, attention-related mistakes are the most common causes of aviation incidents, accidents, and catastrophes.

Continuous attention training using aviation simulators, virtual reality simulators, and during training flights reduces the risk of situations where the pilot lacks necessary attention reserves for decision-making and executing correct actions in abnormal situations or when the flight situation becomes complicated.

INTEGRATION OF METEOROLOGICAL MONITORING SENSOR SYSTEMS INTO UAVS: ANALYSIS OF WESTERN SOLUTIONS, PROSPECTS FOR DOMESTIC DEVELOPMENT AND MILITARY APPLICATION

T. Ustymenko
Ivan Kozhedub Kharkiv National Air Force University

The collection of operational meteorological information in combat conditions is critically important for increasing the effectiveness of aviation, artillery, and unmanned systems. UAVs are capable of providing local and accurate meteorological monitoring through the integration of sensor systems for measuring temperature, humidity, pressure, wind speed and direction, as well as advanced atmospheric parameters.

A key stage of the research is the analysis of Western platforms, such as ScanEagle, Puma AE, and others, equipped with meteorological sensors. Technical specifications, types of sensors, level of autonomy, and adaptation to weather conditions are considered. A comparative assessment with modern Ukrainian UAVs, such as "Лелека-100", "Фурія", and "SHARK", has also been conducted from the perspective of the possibility of integrating meteorological sensor systems. Particular attention is paid to the prospects of domestic development of specialized UAVs for meteorological reconnaissance, challenges related to sensor weight, power consumption, real-time data transmission, and the expediency of implementing such solutions in military command and control systems.

The considered/presented information may be useful for scientists, engineers, and representatives of the Armed Forces of Ukraine interested in the development of meteorological monitoring technologies using UAVs.

PROSPECTIVE DIRECTIONS FOR THE DEVELOPMENT OF A SHORT TAKEOFF AND LANDING MILITARY TRANSPORT AIRCRAFT

A. Zakhozhii; M. Tereshchuk
Ivan Kozhedub Kharkiv National Air Force University

The experience of countering Russian aggression has demonstrated that nearly the entire territory of our country is within range of enemy missile strikes, particularly in the operational-tactical depth of the front. Based on this, and taking into account the powerful capabilities of enemy reconnaissance, there is a pressing need for the rapid relocation of airfields. To provide logistical support for temporary base airfields, it is advisable to use military transport aircraft with short takeoff and landing capabilities.

Achieving short takeoff and landing can be made possible by improving the takeoff and landing performance characteristics of transport aircraft. Key directions for enhancing these characteristics in military transport aircraft involve implementing a set of technical and aerodynamic solutions aimed at reducing takeoff and landing distances, as well as increasing safety and operational efficiency under conditions of limited airfield resources. In particular, the modernization of the powerplant and the integration of high-performance thrust units ensure a higher level of thrust during takeoff, enabling a shorter takeoff run. Aerodynamic improvements, such as the use of wing mechanization – including flaps, slats, or innovative adaptive airfoil designs – contribute to increased lift at low speeds.

All of these measures collectively enable takeoff and landing from short or temporary runways, which is critically important in combat conditions and for executing tactical mobility missions.

GENERAL ANALYSIS OF TRAINING COMPLEXES AND SYSTEMS FOR TRAINING FLIGHT PERSONNEL OF THE ARMED FORCES OF THE LEADING COUNTRIES OF THE WORLD

O. Yamchuk; V. Yevtushenko
Ivan Kozhedub Kharkiv National University Air Force

The analysis of training complexes and systems for training flight personnel of the armed forces of leading countries in the world covers modern technologies, training methodologies, organizational approaches, and the integration of the latest developments to ensure a high level of pilot training. Leading countries actively use advanced training complexes to ensure that their aircrews meet the requirements of modern combat operations, including high-precision operations.

Training complexes and flight training systems of the armed forces of the world's leading countries are a key element in ensuring a high level of combat readiness of pilots. These systems allow saving significant costs, increasing training safety, and reproducing complex combat scenarios that meet modern challenges, such as countering high-precision air defense systems and conducting network-centric operations.

Modern simulators vary in complexity and functionality. Full-scale flight simulators, for example, recreate the cockpit of an airplane or helicopter with all the instruments, controls, and visualization of the external environment.

Thus, the training complexes of leading countries are high-tech systems that combine realism, economy and adaptability. They allow to prepare pilots for modern challenges, minimizing risks and costs, and also contribute to the integration of new technologies, such as AI, VR and network simulation, into the training process.

ORGANIZATION OF INFORMATION TRANSMISSION IN REAL TIME, CORRECTION AND SUPPORT OF AIR STRIKES

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In the time of high-maneuver war, the time of updating actual data and accuracy can influence the results and effectiveness of strike on enemy forces, the most effective means of reconnaissance now is unmanned aviation.

Taking into account the conditions described above of conducting modern war we have the conclusion, that with the help of close interaction of unmanned aviation complexes (further UAC) and manned aviation, it is possible to significantly advance in the effectiveness of application of aviation means of destruction (AMD) by means of achieving operational update of information and accuracy of target coordinates.

Moreover, modern complexes are able to directly change the trajectory of flight of an already launched guided missile depending on the change of position of the target or influence of other factors.

The following main questions are considered in the report:

Reconnaissance with the help of UAV

Methods of information transmission

Methods of transmission of information in real time, improvement of combat capabilities of aviation

Optimally suitable unmanned complex for the given task (PD-2)

In case of successful integration of unmanned systems into control of flights and combat application of aviation – this will become a strong push to increase accuracy and timeliness of air strikes. Improvement of these characteristics also can compensate the technical backwardness of our aviation equipment and its armament.

LOGISTICAL SUPPORT OF ARMY AVIATION DURING COMBAT OPERATIONS

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Maintenance and repair of aviation equipment depends on the organization of logistical support. There is an alternative model that allows you to automate the work of technical support for the restoration of aviation equipment at deployment sites. You are invited to explore the ILIAS platform an Integrated Logistics Support System specifically designed to address the unique challenges of modern military operations. Developed by a team of experienced military personnel and IT engineers, ILIAS provides a ready-made solution that ensures mission-driven logistics and real-time asset visibility. The goal is to provide the necessary materials in a timely manner and minimize the cost of their procurement. Case study logistics solutions for mission support and real-time asset visibility are proposed.

The main advantage of the ILIAS platform during combat operations is the combination of the technical platform of technical personnel with the possibility of providing them with repair units from the industry. This approach takes this concept to a new level, seamlessly combining the aviation component of the force structures with the capabilities of industry.

The report provides a structure of the logistics structure on the platform ILIAS.

An algorithm for planning technical support and recovery of damaged aircraft using the ILIAS platform is provided.

This approach supports each stage of deployment through a single source of logistics, ensuring the accuracy and consistency of technical personnel's actions to restore aircraft during combat damage. The ILIAS platform fully complies with STANAG 2406 requirements.

ANALYSIS OF TYPICAL PILOTING ERRORS IN HELICOPTER FLIGHT TECHNIQUE AND DEVELOPMENT OF RECOMMENDATIONS FOR PREVENTION AND AVOIDANCE OF ERRORS IN THE INITIAL TRAINING OF HELICOPTER CADETS IN CIVIL AVIATION SCHOOLS

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One of the key tasks in aviation safety is minimizing errors during flight, particularly during the initial stages of training. Despite technological advancements, human factors continue to play a significant role in aviation incidents. This article presents the results of an analysis of typical piloting errors made by cadets during training flights on the Robinson R-44 Raven II helicopter at the GLOBAL Civil Aviation Flight School. The study involved six hours of flight training, during which errors were recorded at each stage of the training process.were grouped into three main categories: technical errors (violations of flight parameters, instability in hovering, and uncoordinated control inputs), psychophysiological errors (muscle tension, delayed reactions, and lack of fine motor control), and psychological errors (failure to recognize mistakes, difficulty in managing attention, and issues with communication). The most significant difficulties were observed during the first hour of training, although issues persisted throughout the training session. An individualized approach was applied, taking into account weather conditions and incorporating exercises to improve spatial awareness and coordination.

A set of methodological recommendations was developed, including additional exercises to improve motor skills, reduce psychological stress, and progressively increase the complexity of flight tasks. The analysis of performance over time showed an improvement in practical piloting skills, especially among cadets with weaker theoretical knowledge. This suggests that a comprehensive training approach is crucial, combining theoretical learning, practical flight experience, and psychological resilience as essential factors for developing professional pilots.

FEATURES OF THE NATO SPEED NOMENCLATURE AND ITS APPLICATION IN AVIATION

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Ukraine's active progress towards NATO membership and the gradual introduction of military aviation equipment manufactured and used by NATO member states into the Ukrainian Air Force requires the study and integration of military standards in aviation. The key systems for ensuring full functional interaction between the Ukrainian Air Force and NATO aircraft include the speed nomenclature. Therefore, there is a need to study aviation equipment, namely the principles of determining and constructing speed indicators used in the above-mentioned equipment.

The report provides theoretical information on the definition and establishment of the speed nomenclature based on Zhukovsky curves. The speed nomenclature used by NATO member states is considered, and it is established that the military transport aviation of the Alliance member states adheres to international aviation standards. The article also presents the results of a study of one of the types of speed indicators used in NATO aviation.

The results of the study of the characteristics of speed indicators used on some aircraft of the Ukrainian Armed Forces and NATO member states, namely KUS-730/1100 and LUN-1107, show that speed indicators similar to LUN-1107 serve as a better tool for using the NATO speed nomenclature due to their adaptability to this nomenclature, compared to KUS-730/1100 or similar indicators used in Ukrainian aviation.

A COMPARATIVE STUDY OF L-39 AND ALPHA JET TRAINING AIRCRAFT: CURRENT REALITIES AND FUTURE OUTLOOK

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The ongoing transition of the Ukrainian Air Force to Western aircraft such as the F-16 and Mirage 2000-5F, the selection of effective training platforms has become a strategically significant issue. These platforms are essential for ensuring the successful adaptation of pilots to new operational standards, advanced technologies, and doctrines.

This report offers a comparative analysis of the L-39 and Alpha Jet training aircraft. The L-39 represents Soviet-era design philosophy, while the Alpha Jet exemplifies a Western approach to aerospace engineering, especially to avionics, weapons systems, and flight performance parameters.

The L-39, powered by a single AI-25TL turbojet engine, is characterized by its structural simplicity, operational reliability, and relatively low maintenance costs, making it available option for basic flight training. Nevertheless, its analog avionics and exclusive use of the metric system hinder its effectiveness in preparing cadets for transition to NATO-standard platforms.

In contrast, the Alpha Jet, equipped with dual Larzac engines, incorporates digital avionics and the imperial measurement system, thereby aligning more closely with the systems and protocols of Western combat aircraft such as the F-16 and Mirage 2000-5F. Moreover, the Alpha Jet offers enhanced maneuverability, survivability, and interoperability with modern pilot training program.

In conclusion, this comparative assessment suggests that, moving forward, Ukraine’s military and political leadership should prioritize the adaptation of NATO training aircraft such as the Alpha Jet, or alternatively, invest in the development of a next-generation training platform that integrates advanced Western technologies.

METHODS OF USING COMBAT UAVs FOR STRIKES ON ENEMY TARGETS IN THE OPERATIONAL-TACTICAL DEPTH

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This report presents the results of a study on the feasibility of integrated use of tactical techniques in overcoming enemy air defense systems when delivering airstrikes with combat UAVs on enemy trgets in the operational-tactical depth.

In the context of the development of electronic warfare systems and the increasing density of air defense systems, an effective way to enhance the efficiency of combat UAVs is by changing their application tactics, namely:

– Using UAVs mainly at low and extremely low altitudes, leveraging complex terrain features, which ensures their concealment and reduces the impact of enemy EW assets;

– Employing highly maneuverable flight modes (such as "zigzag" and "jerky" movements with periodic hovering or sharp deceleration, making detection more difficult);

– Utilizing primarily one-time-use combat UAVs for strikes, which are capable of loitering in a designated area, identifying a target, and diving into it;

– Flying in radio silence mode in the final phase of the flight using inertial navigation systems;

– Group application of UAVs, use of decoy UAVs equipped with active and passive signature and radar cross-section simulators of various aerial objects, in conjunction with manned aviation.

HELICOPTERS AS CARRIERS OF UNMANNED AIRCRAFT: POTENTIAL AND PRACTICAL APPLICATION IN THE ARMED FORCES OF UKRAINE

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The integration of helicopters as platforms for launching unmanned aerial vehicles (UAV) is a promising direction in the development of army aviation, especially in the conditions of the modern war in Ukraine. This approach allows combining the mobility of a helicopter with the accuracy and safety of remote use of drones, increasing the effectiveness of combat operations. Helicopters can act as carriers for reconnaissance UAV, kamikaze drones, or communications repeaters. This makes it possible to launch drones from a safe distance, quickly obtain intelligence information, and deliver pinpoint strikes without directly entering the enemy's air defense zone. Technically, this requires equipping the helicopter with appropriate launchers, UAV control systems, and stable communication channels. The advantages of this approach include greater flexibility in combat conditions, reduced risk to the crew, and increased tactical initiative of units. However, there are challenges – the need to modernize the helicopter fleet, ensure system interoperability, and develop appropriate tactics for use. The introduction of UAV carrier helicopters into the Armed Forces of Ukraine can significantly increase the combat capability of aviation units. To this end, it is advisable to conduct experimental developments, field tests, and active cooperation with domestic UAV manufacturers.

UNMANNED AERIAL VEHICLES WITH FIBER-OPTIC CONTROL

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Traditional UAVs rely on radio communication, which makes them vulnerable to EW. A fiber-optic channel provides secure, interception-proof communication with low data transmission latency. In modern warfare, dominated by EW and cyber threats, such systems enable reconnaissance, targeting, and coordination without loss of control.

Fiber optics add weight and air resistance, requiring an optimized design:

Use of lightweight materials (composites, carbon fiber);

Extended wing for increased aerodynamic efficiency;

Reduced engine load due to balanced center of mass.

Reducing electronic equipment (by eliminating RF components) helps offset the cable's weight.

Advantages:

Immune to EW jamming;

High transmission speed and signal stability;

Reduced interception risk.

Disadvantages:

Range limited by cable length;

Susceptible to mechanical damage;

Maneuvering complexity due to obstacle avoidance.

Fiber-optic UAVs are difficult to detect due to the absence of RF emissions.

This makes fiber-optic UAVs a highly promising solution for missions in contested and electronically hostile environments.

ANALYSIS OF FACTORS CAUSING CRITICAL FLIGHT CONDITIONS AND METHODS FOR AIRCRAFT RECOVERY

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According to statistical data, up to one-third of aviation incidents in transport and commercial aviation are caused by aircraft entering an unusual attitude (UA), which often leads to aerodynamic stall, spin, or loss of control.

The main causes of such situations include adverse weather conditions, technical failures of aircraft systems, and crew errors – particularly the failure to follow flight procedures or loss of spatial orientation.

The challenge of timely recognition of UA and inappropriate crew actions in such scenarios significantly complicates the recovery of the aircraft to controlled flight. Limited knowledge of aircraft and engine behavior at high angles of attack, lack of skills in identifying the onset of stall or spin, as well as the absence of a proper action algorithm – all these contribute to the potential for critical outcomes.

This paper analyzes common crew errors, reviews the main recovery techniques for aircraft in critical flight conditions, and provides rationale for pilot actions in the event of UA, stall, or spin. It also proposes improvements to pilot training through the inclusion of theoretical explanations and expanded simulator practice focused on modeling critical situations.

THE SUPERHEAVY AIRCRAFT AN-225 "MRIYA" – A SYMBOL OF UKRAINIAN AVIATION

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The Antonov Design Bureau has always been known for its unconventional approaches and engineering boldness in aircraft construction. In 1984, the bureau began the development of the heavy cargo aircraft An-225 "Mriya", which was intended to transport the Buran space shuttle and components of the "Energia" launch vehicle.

The An-225 was a deep modification of the An-124. The main structural differences included a lengthened fuselage, six engines, a twin-fin vertical tail for stability with external cargo, and the presence of mounting units for the Buran on the fuselage, which the An-124 did not have. These solutions allowed the creation of a platform for transporting oversized and super-heavy objects. Due to the mass of the aircraft 250 tons and its cargo, the An-225 could take off only from specific airfields with reinforced runways and a length of over 3.5 km – among them were Hostomel, Leipzig/Galile, Luxembourg, and Prešov. After the end of the "Buran" program, the aircraft was temporarily preserved, but since 2001, the An-225 has been actively used in commercial transport. It became indispensable in the transport of energy equipment, transformers, generators, and also in humanitarian missions – especially during the COVID-19 pandemic, where it enabled the fast transport of medical cargo. Despite the destruction of the aircraft in 2022, the An-225 remains a symbol of engineering power. Its uniqueness lies not only in its record-breaking characteristics but also in its flexibility in performing non-standard logistics tasks.

COMPARATIVE ANALYSIS OF FLIGHT PERFORMANCE AND MANEUVERABILITY CHARACTERISTICS OF F-16 AND MIG-29 AIRCRAFT

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The study of combat effectiveness of fighter jets primarily involves analyzing their aerodynamic and flight performance characteristics. Aerodynamic characteristics are a decisive factor in the combat effectiveness of fighters, significantly influencing their maneuverability, flight stability, and their capability to fully utilize available thrust-to-weight ratios and execute complex tactical missions. Given the demands of modern aerial combat, the aerodynamic design of fighters must achieve an optimal balance of lift, drag, and controllability across a wide range of speeds and altitudes.

Modern fourth-generation fighters exhibit high aerodynamic performance, enabling operations at high speeds and altitudes. They possess excellent acceleration characteristics, facilitating rapid speed gain and seamless transition between various flight modes according to tactical scenarios.

The report presents the calculated results of flight performance and maneuvering capabilities of MiG-29 and F-16 fighters, along with conclusions on their operational effectiveness in specific situations.

The research demonstrates that the fighters generally have similar aerodynamic characteristics, particularly regarding angular turn rate and acceleration dynamics. However, at different speeds, one of the aircraft may exhibit localized advantages in maneuverability: the F-16 shows superior performance in certain flight regimes, while the MiG-29 excels in others. Acceleration characteristics of both fighters remain largely comparable. Consequently, the outcome in close air combat scenarios primarily depends on the pilot’s skill.

UAVS "BOBER" AND "GERAN-2"

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In the current stage of modern warfare, UAVs have come to play a significant role. There is a need to develop more powerful and advanced systems capable of striking the enemy.

This report presents the results of a study on a Ukrainian development in the field of long-range unmanned systems, namely the detailed analysis of the "Bober" UAV, as well as an investigation of the enemy's UAV used in the war – the Shahed-136 (Geran-2). The characteristics of both UAVs were examined, and promising development directions were identified.

"Bober" is an entirely Ukrainian development that began to be used in 2023. It demonstrates Ukraine's ambition to create a high-precision, autonomous platform for deep strikes on key strategic enemy targets through advanced electronics, the ability to bypass air defense systems, and adaptive flight paths.

"Geran-2" is a Russian-modified Iranian Shahed-136 used in the war. This UAV is a cheaper, simpler weapon to produce, which compensates for its relative technical primitiveness through mass deployment in swarms to exhaust air defense systems and carry out large-scale strikes on cities and infrastructure.

The comparative analysis leads to the conclusion that both systems have their strengths: "Bober" excels in precision and technological sophistication, while "Geran-2" stands out for its simplicity and mass deployment. Based on combat experience, both drones are continuously being improved, particularly in terms of reduced detectability, increased autonomy, and resistance to electronic warfare. The further development of such UAVs will be crucial in shaping the strategies of future wars. Research on these drones not only enhances the effectiveness of domestic weaponry but also improves adaptation to emerging challenges on the battlefield.

PROTECTION OF AIRCRAFT ENGINES FROM FOREIGN OBJECTS

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Today, the issue of birds, foreign objects, dust, and dirt getting into aircraft gas turbine engines is an acute one, and, as a result, the destruction and abrasive wear of the engine compressor blades, as well as the subsequent impact on the power and stability of the engine. The study was conducted on the example of helicopter engine protection. The importance and effectiveness of using different types of dust protection devices were determined.

The natural, climatic and operational features of helicopter operation are analyzed. The use of helicopters in conditions of military conflict, the need to fly at extremely low altitudes, taking cover from the terrain, is studied. The issues of reliability of aviation equipment and safe performance of flight missions in conditions of active combat operations are also considered. Advanced technologies and innovations in the field of aviation equipment are studied, aimed at improving the quality of operation of helicopter engines and maintaining their performance. The results of the work can be useful for developing strategies and policies for using helicopters to perform various missions in various natural and climatic conditions.

The operation of helicopters without an installed dust protection device and with a standard dust protection device installed was analyzed.

It is proposed to modernize the helicopter with the installation of PALL 120 PUREair dust protection devices to reduce the possibility of birds, foreign objects, dust and dirt entering the helicopter's gas turbine engine.

PROBLEMS OF SPATIAL DISORIENTATION DURING HELICOPTER FLIGHT AT ULTRA-LOW ALTITUDES

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The paper addresses a pressing issue in modern warfare – spatial disorientation experienced by helicopter crews during flights at ultra-low altitudes in combat environments. The study analyzes the impact of various factors on navigation accuracy, including: electronic warfare (EW) measures employed by both enemy and friendly forces; enemy air defense systems; the use of spoofed signals targeting GPS receivers; and the influence of environmental and weather conditions.

An overview is provided of the most common orientation methods and modern navigation systems, including: map-based navigation, aerometric position determination, inertial, Doppler, and astronomical systems, as well as innovative solutions involving artificial intelligence. The advantages and disadvantages of each approach are identified in the context of modern combat scenarios.

The paper outlines key requirements for a prospective navigation system suited to contemporary warfare: autonomy, resilience to EW measures, adaptability to real combat conditions, ease of use, affordability for mass deployment, functionality in GPS-denied environments, minimal cognitive load on the crew, and sufficient accuracy under complex operational conditions.

A conceptual model of an advanced navigation system is proposed. It features high autonomy, resistance to interference, and integration of artificial intelligence, enabling accurate position determination even in the absence of GPS signals. An example is provided of practical implementation of coordinate estimation algorithms based on flight parameters obtained from onboard navigation instruments, using the DCS simulator.

COMPARATIVE ANALYSIS OF FLIGHT PERFORMANCE CHARACTERISTICS OF HELICOPTERS MI-8MSB AND SH-3 SEA KING

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The flight performance characteristics (FPC) of military transport helicopters determine their ability to perform missions both in combat and peacetime conditions. This report presents a comparative analysis of the FPCs of the Mi-8MSB and SH-3 SeaKing helicopters.

Calculations of Zhukovsky curves were carried out, and the theoretical and operational ranges of flight speeds and altitudes for both helicopters were determined under the condition of their maximum take-off weight. Analysis of the calculated data shows that the SH-3 SeaKing can fly at speeds ranging from 0 to 252 km/h, adjusting them depending on altitude – up to 4500 meters. The maximum flight altitude is achieved at a horizontal speed of 118-152 km/h, while the Mi-8MSB develops a horizontal speed of up to 232 km/h at various altitudes and reaches a maximum altitude of 2500 m at horizontal flight speeds of 88–173 km/h. This is explained by the ratio of required power to the weight of each helicopter: the Mi-8MSB is equipped with two TS3-117 engines with a power of 1618 hp each and a maximum take-off weight of 13,500 kg, while the SH-3 SeaKing is equipped with two T58-GE-8B engines with a power of 1250 hp and a maximum weight of 9300 kg. In addition, the SeaKing has a more streamlined fuselage to achieve higher horizontal speeds, as it was designed for anti-submarine warfare. The Mi-8 has a less streamlined fuselage, as it prioritizes a larger internal volume for transporting more cargo.

The SH-3 SeaKing helicopter is intended for operations over the sea at higher speeds and altitudes, while the Mi-8MSB has a smaller range of altitudes and speeds but is more cargo-capable.

INTRODUCTION OF AEROBATIC CATEGORY AIRCRAFT INTO THE SYSTEM OF FLIGHT TRAINING OF CADETS-PILOTS

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Flight training for cadet pilots is based on the principle of "from simple to complex" and is carried out in a graduated system: initial flight training on light aircraft and basic training on L-39 jet trainers. These are very important steps on the way to becoming a future military pilot who will later have to fly combat aircraft such as MiG-29, Su-27, Mirage-2000 and F-16 in the entire range of altitudes and speeds. Therefore, both initial and even more so basic training should include practicing aerobatic piloting techniques and elements of combat maneuvering.

The existing fleet of light aircraft on which cadets begin their journey to the sky satisfies the need to master the basic elements of piloting techniques: takeoff, landing, circling, route, and performing simple aerobatics. However, training future fighter pilots in aerobatics is one of the most effective methods of developing cadets' professional skills and spatial orientation in the performance of certain aerobatics with higher overloads and in a wider range of speeds.

To achieve this, we need to meet the need for aircraft that are affordable and, most importantly, meet flight safety requirements. The best way to do this is to develop (purchase) a promising Ukrainian airplane of the aerobatic category and introduce it into the cadet flight training system.

INFLUENCE OF THE HUMAN FACTOR ON FLIGHT SAFETY DURING AIR TRAFFIC CONTROL

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An air traffic control system is a complex, hierarchical and multi-level human-technical system that includes information gathering and processing facilities, computing facilities, information display systems, communication facilities, and contains an obligatory ergatic element – a human operator, which closes the system into a single continuous control loop. The object of control in such systems is the aircraft operating in the control area.

The flight management team constantly analyses available information, processes it, makes decisions and communicates these decisions to the crew. The successful operation of air traffic control depends on the quality of the system as a whole, i.e. ensuring complete flight safety during air traffic control.

Therefore, it is extremely important to study and improve the content and structure of the work of flight management team members. The processes of perceiving and processing information, preparing options for resolving situations, and making informed, responsible decisions in the face of information uncertainty in a fast-moving airspace are particularly important. Variable, often critical workloads and time pressure also have a significant impact. That is why it is vital to take into account the human factor, psychophysiological capabilities and motivational interests of the flight control team members working in such systems.

METHODS OF TRAINING AND WORK OF THE ADVANCED AIR GUNNER WHEN GUIDING ARMY AIRCRAFT TO GROUND TARGETS

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In combat operations, forward air controllers will play a significant role in solving the tasks of aviation support for ground forces.

In order to increase the efficiency of crew management during the performance of a combat mission, the processes of an aircraft gunner's activity at the stage of preparation and during the performance of a combat mission were investigated. The study developed a model of an aircraft gunner's activity at the stage of preparation for a combat mission. This made it possible to identify labour-intensive processes in his work, the implementation of which requires a large amount of time.

One of the options for improving the efficiency of an air gunner's combat mission is the use of a decision support system.

The software complex implements the following tasks: the choice of background of the area of hostilities; the choice of preliminary location of the post of surveillance of the aircraft agent without taking into account, and taking into account the zones of visual visibility of objects and land goals; the choice and introduction of coordinates of landmarks for targeting when giving on a ground target; determination and introduction of land goals; calculation of areas of damage to air defense; Preparation and transmission of combat information about the land target on board the aircraft using television channels.

IMPROVING THE EFECTIVENESS OF JTAC IN PERFORMING AIRCRAFT CONTROL

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The study of the process of formation of aircraft flowing in a circle showed that it is not always possible to create between aircraft on the flight area before the start of the turn on a landing course of a set or design distance at flight at different speeds. This is associated with a number of random values related to the actions of crews, a group of flight management and external influences, refusals of control systems.

The creation of algorithms for the automated control system allowed the head of the near area to evaluate the air situation and make decisions based on the indication and graphical display of the calculated quantities, which allows to exclude a number of errors related to the eye definition of parameters.

It can be concluded that the automated control system has clarity, promptness and timeliness of submission of the necessary information for persons of a group of flight management when forming a flux of aircraft. The use of the algorithm in the formation of the flow of aircraft coming to land, significantly reduces the influence of the subjective factor and improves the likelihood of process characteristics. This leads to an increase in flight safety, fuel savings from 10 to 28 and more percent and reducing the psychological burden on persons of the flight management group. Hence the conclusion about the rationality of the use of this algorithm and the development of technology of its use throughout the complex of automation of air traffic control processes.

BASICS OF TRAINING AND PROCEDURES FOR AIR GUNNERS AND STRIKE GROUP CREWS WHEN ENGAGING GROUND TARGETS

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The experience of the Russian-Ukrainian war shows that one of the main features of the management of army aviation crews and units is the complexity of their deployment, guidance and targeting of targets. In modern operations, the organisation and management of helicopter crews and units is a complex dynamic process. The crew of an aircraft directly controls the flight, and the outcome of a combat flight depends on the correctness of their actions in destroying the enemy. The air traffic controller is responsible for issuing competent and reasonable recommendations and instructions to the aircraft crew. The final decision is made by the aircraft commander, but a timely and correct tip from the air traffic controller can prevent the situation from developing into a catastrophic one.

In today's warfare environment, it is necessary to improve the process of training an air gunner. At present, this can be done by automating the process of training an air gunner using special software. This software will help to achieve the following results: a 20% reduction in the time required to prepare a map and perform targeting; selection of the air gunner's location during the guidance process, taking into account the terrain; the ability to guide helicopter crews to ground targets in radio silence mode; and a reduction in the possibility of detecting the air gunner's location by the enemy at the stage of direct guidance.

METHODOLOGY OF WORK OF THE FLIGHT CONTROL TEAM MEMBERS TO PREVENT CONFLICTS BETWEEN AIRCRAFT BASED ON THE AIR SITUATION FORECAST

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The experience of the Russian-Ukrainian war shows that, given the capabilities of aviation systems to reach targets, advanced airfields are usually used to reduce flight time when striking targets and conducting aerial reconnaissance. The flight control group is tasked with forming a flow of aircraft flying combat training flights and those flying combat missions. The latter aircraft have priority in landing at the airfield over others. When returning from a combat mission, aircraft may be damaged, which in turn leads to non-standard situations in the air, which complicates the actions of flight control personnel and leads to conflict situations in the air.

The paper develops an algorithm of actions of the flight management group when choosing a rational approach method, which will reduce the workload on the management group and reduce the time required to identify a potentially dangerous situation and reduce the time shortage for decision-making.

Thus, the use of the automated workstation model greatly simplifies the analysis of the air situation, forecasting of conflict situations, prevention of conflict situations, situation analysis and decision-making by flight control team members.

LASER GYROSCOPES IN MILITARY AVIATION. PRINCIPLES OF OPERATION, APPLICATIONS, AND DEVELOPMENT PROSPECTS

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Modern military aircraft require precise navigation systems to ensure autonomous flight capabilities. Laser gyroscopes serve as a fundamental component of advanced military navigation systems, providing high-accuracy positioning without reliance on GPS. Their implementation enhances both the precision and autonomy of combat aircraft.

A laser gyroscope is an optical instrument designed to measure angular velocity. Gyroscopes play a crucial role in aviation, navigation, and astronautics. Contemporary laser gyroscopes (LGs) achieve exceptional accuracy in measuring angular velocities without the use of moving parts, ensuring reliability and long-term operational stability.

The operating principle of a laser gyroscope is based on the Sagnac effect.

Its primary function is to support the navigation of moving platforms, such as aircraft and missiles. Additionally, laser gyroscopes find applications in fundamental scientific research and precision measurements.

Key advantages of laser gyroscopes include their digital output signal and rapid operational readiness. They are indispensable optical devices for measuring angular velocity, particularly within inertial navigation systems.

Laser gyroscopes remain an essential element of modern navigation frameworks. Their reliability, accuracy, and resistance to mechanical wear make them indispensable in military and civilian aviation, astronautics, and the defense industry.

GROUND STATIONS FOR CONTROLLING FPV DRONES

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Repeater for FPV drone is a critically important tool for combat operations using kamikaze/bomber/aerial reconnaissance drones. The FPV ground station creates optimal conditions for solving important combat missions, ensuring the maximum level of control over the operation of quadcopters and the pilot's safety in conditions when a real hunt is being conducted behind the UAV piloting groups. Providing the best conditions for the drone operator performing a combat mission is an extremely important factor affecting the effectiveness of his work. Drone operators must be able to make decisions quickly and accurately in conditions of stress and danger. They must be well aware of the situation on the battlefield, receiving a high-quality image without interference. The FPV ground station effectively solves all these problems, contributing to increasing the operator's efficiency and reducing losses among personnel. Let us note the main advantages of using a combat quadcopter control station: – the maximum possible flight range of the drone; – the risk of the pilot being attacked on the bearing is significantly reduced; – a repeater for kamikaze drones FPV increases the accuracy of targeting and image stability during rapid attacks on fast-moving enemy equipment. This high-tech equipment allowed operators to make instant decisions based on objective information.

Military operations require accuracy, speed and coordination of actions. Ground stations – repeaters for drones FPV allow for reconnaissance, monitoring and targeting of weapons on targets with high accuracy, minimizing risks to own personnel.

SIMULATOR TRAINING – A UNIVERSAL MEANS OF TRAINING CADETS

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The development and use of modern simulator technologies allow to increase the readiness of those who are trained to act in real combat flight conditions by simulating various combat missions, significantly ensuring the safety of flight training. New generation simulators have significant advantages compared to previous ones. During the simulation, realistic visual effects can be created against the background of real areas of the terrain, recreated on the basis of electronic maps. At the same time, simulators virtually simulate flight conditions that are as close as possible to combat ones, when aircraft weapons hit the board of an airplane or helicopter, equipment fails, the control system does not work, etc. For this purpose, training equipment is used, which allows the most realistic, practically by 95%–97%, to simulate the visual and acoustic environment both in the cockpit of the aircraft and outside it, in the airspace and on the ground. That is, modern simulator training in the system of education and training of pilot cadets has become an indispensable element in the formation of skills necessary in real combat conditions. Modern simulators are a universal means of comprehensive training of flight personnel for combat flight.

CLASSIFICATION OF UNMANNED AIRCRAFT

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Unmanned aerial vehicles (UAVs) currently provide various opportunities for units to conduct aerial reconnaissance, surveillance and reconnaissance, tactical air support, and destroy specific objects, ensuring, almost in real time, the fulfillment of assigned tasks. Classification of UAVs by main features. Combat radius. Micro (tactical) take-off weight < 2 kg to 5 km (line of sight) micro Mini (tactical battlefields) 2 kg ≤ take-off weight ≤ 15 kg more than 5 km (line of sight) mini. Small (tactical) take-off weight > 15 kg more than 25 km (line of sight) small. Classification of UAVs UAVs by purpose as: 1) Combat UAVs: situational awareness, reconnaissance, for fire correction, strike multiple and single use, combined purpose; 2) Special UAVs – designed to perform special tasks as repeaters, electronic warfare equipment and targets, etc. Classification of UAVs: 1) By type of aircraft: aircraft type, helicopter type, multirotor; 2) By location: land-based, river (sea), air-based. 3) By takeoff method: aircraft-based, helicopter-based, using launch vehicles (catapult, launcher, hand-held, combined; 4) By landing method: aircraft-based, helicopter-based, using landing vehicles (parachute, braking device, etc.); 5) By type of flight control system: autonomous, manned, with a combined control system.

INERTIAL NAVIGATION SYSTEMS USED IN MODERN UAVS

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Unmanned aerial vehicles have become an integral part of modern warfare. However, today most UAVs cannot independently perform all of the above operations, being, in fact, remotely controlled aircraft. The use of inertial navigation tools is a necessary condition for the use of UAVs in conditions of active radio-electronic countermeasures from the enemy; they will allow UAVs to perform reconnaissance and strike missions even in the event of a complete loss of communication with the control center and the absence of signals from ground and satellite navigation systems. The only reliable solution for preserving UAVs in conditions of countermeasures by modern electronic warfare is to install a platform-free inertial navigation system (BINS) on board, integrated with special devices that recognize interference in the control of the device and transfer it to a completely autonomous mode. In this case, navigation is carried out using the coordinates issued by the BINS, and the device continues to perform a pre-programmed task – for example, flying over certain points for reconnaissance of the area. The device includes accelerometers that track acceleration and gyroscopes that measure the angles of rotation and tilt.

Using this data, the on-board computing complex calculates the route from a certain point, which can be the exact coordinate of the launch site or the last reliable coordinate obtained by the satellite navigation system. The BINS has the necessary accuracy for a sufficiently long flight, which is based on the use of a laser or fiber-optic gyroscope.

TARGETING ON A LARGE-SCALE MAP WITH A RADAR SIGHT ON A RADAR LANDMARK

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As practice shows, the accuracy of airborne landing largely depends on the accuracy of determining the aiming parameters, the aiming method, and the skills of the crew.

Analysis of the situation in the area of the landing site allows you to correctly and reasonably choose the aiming method, on which the accuracy of the combat mission will depend. At the landing site, it is not always possible to choose a characteristic visual landmark on the line of a given combat path, and since we are talking about a combat zone, it is not always possible to mark the aiming point with a radar beacon.

Analyzing the methods of aiming by KVM and radio beacon, the only autonomous method will be aiming on a large-scale map with a radar sight by a radar landmark.

The relevance of the aiming method lies in the fact that the proposed method combines two previously known aiming methods into one – combined (Aiming by KVM with a radar sight by a radar landmark). This method does not depend on the time of day and meteorological conditions, does not require the involvement of personnel from the commandant's office of airborne support to mark the aiming point. In modern conditions of combat operations, autonomy gives the crew the opportunity to carry out the landing almost covertly.

СЕКЦІЯ 2

АВІАЦІЙНИЙ ТРАНСПОРТ

Керівники секції: к.т.н. полковник Юрій ВОЛКОВ
Секретар секції: лейтенант Микита СЕМЕНОВ

RESEARCH ON WAYS TO IMPROVE THE PERFORMANCE OF UNMANNED AERIAL VEHICLE ENGINES

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In modern conditions, unmanned aerial vehicles (UAVs) play a key role in reconnaissance, fire adjustment, cargo delivery, and strikes on enemy targets. Their effectiveness directly depends on the reliability and performance of powerplants, which determine flight duration, payload capacity, resistance to external factors, and the ability to perform missions under complex conditions.

The aim of this research is to analyze the current state of UAV engines, identify their limitations, and develop recommendations for improving designs to enhance performance.

The study examines internal combustion engines, electric motors, and hybrid power systems. Special attention is given to ROTAX 912 iS engines used in UAVs such as the Bayraktar TB2. These engines offer advantages in terms of fuel efficiency and reliability but are limited in power, which reduces the UAV's operational capabilities.

Based on modeling and analysis of operational characteristics, the following improvement directions were identified:

– reduction of engine weight and dimensions;
– increased power output without reducing efficiency;
– implementation of active cooling systems;
– use of alternative energy sources such as hydrogen or fuel cells;
– integration of intelligent engine control systems to adapt to flight conditions.

The research results can be applied to the modernization of existing UAVs or the development of new generations of drones with expanded operational capabilities.

DEVELOPMENT OF RECOMMENDATIONS FOR REDUCING AIRCRAFT MAINTENANCE COSTS

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Development of Recommendations for Reducing Aircraft Maintenance Costs

Ensuring the airworthiness and operational readiness of aircraft requires regular and often costly maintenance. In the context of increasing operational demands and limited defense budgets, the development of cost-saving strategies becomes a crucial task for aviation enterprises.

This study focuses on analyzing the main cost drivers in aircraft maintenance and proposes practical recommendations for their optimization. These include the implementation of predictive maintenance technologies based on real-time monitoring systems, standardization of repair procedures, optimization of spare parts logistics, and the use of modular design approaches for more efficient component replacement.

The integration of digital maintenance tracking systems and data analytics can help identify trends, prevent breakdowns before they occur, and significantly reduce unplanned downtime. Additionally, training personnel in efficient diagnostic methods and adopting international best practices can further lower maintenance costs.

Reducing maintenance costs without compromising safety and reliability contributes to extending the operational lifespan of aircraft and enhancing the overall efficiency of air force logistics.

DEVELOPMENT OF A SITUATIONAL NAVIGATION FIELD FOR GROUP UNMANNED AERIAL VEHICLE MISSIONS

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Ensuring flight safety of unmanned aerial vehicle (UAV) operations, particularly in group formations, is a key objective of air traffic management systems. The high density of flight paths in launch and landing zones necessitates precise control over the relative positioning of UAVs. To coordinate and synchronize group flights, an optical inter-aircraft navigation system is proposed. This system enables accurate determination of relative positions, generation of navigation commands, and maintains low observability in contrast to less precise radio-based systems.

The situational navigation field is generated as a set of digital images in the visible or infrared spectrum. Each fragment of the situational navigation field represents a portion of the overall scene, where gradient-based methods are employed to detect object contours and their angular coordinates. The situational navigation field is treated as a matrix composed of all segment elements, with its dimensionality determined by the number and size of the individual fragments. The positions of navigation reference points, defined in the UAV's coordinate system, are converted into azimuth and elevation angles to support coordinated movement.

The central point of the UAV’s coordinate system is defined through the optical sensor’s field of view (FOV), which is divided into segments corresponding to elements of situational navigation field. The FOV for each element is calculated separately in terms of azimuth and elevation, accounting for the non-uniformity of FOVs across the hemispheres. Navigation points detected through machine vision are identified by their position within the situational navigation field and their angular deviation from the central point, thereby enabling precise group navigation.

STUDY AND DEVELOPMENT OF IMPROVEMENT METHODS FOR UAV ENGINE PERFORMANCE

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The growing importance of unmanned aerial vehicles (UAVs) in modern warfare requires not only the evaluation of flight performance and mission capability but also the improvement of critical systems such as propulsion. The Bayraktar TB2 UAV, known for its success in various military operations, employs a ROTAX 912 piston engine, which provides solid fuel efficiency and reliability. However, operational experience reveals several technical challenges related to engine performance:

Overheating during prolonged missions at low altitudes or high ambient temperatures;

Limited power output affecting payload capacity and maneuverability;

Insufficient thermal management under increased load conditions.

These limitations suggest the need for engine system modernization to enhance performance, durability, and mission flexibility. Research shows several possible directions for improvement:

Optimization of the engine cooling system to reduce the risk of thermal overload;

Use of advanced lightweight materials to reduce engine weight and improve heat dissipation;

Implementation of hybrid propulsion systems to enhance fuel efficiency and operational range.

The study involves computational modeling of thermal dynamics, experimental analysis of heat dissipation methods, and evaluation of alternative design configurations. The objective is to propose viable engineering solutions that reduce heat-related losses, extend engine life, and ensure stable UAV operation in complex environments.

Engine modernization is expected to significantly increase the tactical capabilities of the Bayraktar TB2, making it more resistant to intensive mission loads and better suited for the demands of modern warfare.

RESEARCH OF INFORMATION TRANSMISSION METHODS IN THE RADIO TELEMETRY CHANNEL OF THE THIRD CLASS UNMANNED AERIAL VEHICLE

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The development of unmanned air-based systems, namely unmanned aerial vehicles (UAVs), is moving in the direction of complicating the control system in favor of improving operational characteristics.

One of the key tasks in the development of control systems for UAVs is the need to ensure maneuverability of flight when performing military and special tasks.

The development of technologies of unmanned systems leads to an increase in the volume of observed parameters and software complications and, as a result, a decrease in its reliability when transmitting information from the board of unmanned aerial vehicles a large amount of data.

Determining the direction of the approach to the organization of the process of transmitting telemetry information, as well as solving the relevant technical problems, is one of the most pressing issues in the creation of unmanned air-based systems.

One of the most effective approaches is the use of LoRa modulation, the key feature of which is its high immunity to interference.

Thus, the use of LoRa technology will significantly increase the reliability, secrecy and reliability of transmitted information.

DEVELOPMENT OF METHODOLOGICAL RECOMMENDATIONS FOR IMPROVING THE EFFICIENCY OF THE ACTIVE INTERFERENCE STATION FOR UNMANNED AERIAL VEHICLES

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During the armed aggression of the Russian Federation unmanned aerial vehicles have become an integral part of combat operations, performing reconnaissance, fire correction and strike tasks. The use of unmanned aerial vehicles equipped with active jamming stations is becoming critical in modern military conflicts. The high level of technological development of enemy electronic warfare systems creates significant challenges for the effective functioning of UAVs, including Bayraktar TB2. The integration of AJS, such as the ANTIDOT module, allows not only to protect UAVs from suppression of control and navigation signals, but also to interfere with enemy radars, FPV drones and air defense systems.

Prospects for the development of UAVs with integrated AJS are associated with the improvement of their autonomy, modularity and adaptability to dynamic combat conditions. The development of artificial intelligence algorithms for automatic analysis of the electronic environment and adaptive tuning of interference will increase the effectiveness of counteracting modern radar and air defense systems with frequency jumps. In addition, the group use of UAVs with AJS, coordinated using methods similar to the Dubins algorithm, opens up opportunities for creating "swarm" systems that can form interference zones and provide comprehensive protection.

RESEARCH INTO MODERNIZATION PATHWAYS FOR THE MAIN ROTOR OF A MILITARY TRANSPORT HELICOPTER

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The growing role of army aviation in modern armed conflicts necessitates the improvement of key helicopter components. One of the most critical elements is the main rotor, which determines the primary flight characteristics of the aircraft.

The main rotor provides lift, maneuverability, and flight stability; therefore, modernization of its design directly impacts the combat effectiveness of the helicopter. Current challenges include noise reduction, increased service life, reduced weight and vibrations, as well as improved resistance to combat damage.

An analysis of existing designs shows that the extensive use of composite materials can significantly reduce the rotor’s weight while maintaining or even enhancing its strength characteristics. A promising direction is the implementation of adaptive blade control systems that allow geometry changes during flight depending on conditions.

Mathematical modeling and CFD analysis enable optimization of blade shapes to achieve better aerodynamic performance. Additionally, bench testing and operational trials are essential stages for confirming the effectiveness of proposed changes.

Key modernization directions include:

– implementation of next-generation composite blades;

– aerodynamic optimization of blade shapes;

– reduction of acoustic pollution;
– increased maintainability and rotor service life;
– implementation of active blade control systems.

Modernization of the main rotor will improve payload capacity, flight range, fuel efficiency, and overall performance of military transport helicopters in demanding combat environments.

RESEARCH ON THE POSSIBILITIES AND WAYS TO IMPROVE THE OPERATIONAL CHARACTERISTICS OF UAVS

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During Russia’s full-scale war against Ukraine, unmanned aerial vehicles (UAVs) have proven their critical role in the tactical and operational dimensions of warfare. The constantly changing conditions of combat, the widespread use of enemy electronic warfare (EW) systems, and the need to operate deep behind enemy lines require ongoing improvement of Ukrainian drones.

One of the promising directions for enhancing UAV performance is the modernization of the "Vampire" strike-reconnaissance drone by integrating a modular electronic warfare system. The proposed technical solution involves equipping the drone with a special detachable module that can be remotely dropped in areas where the enemy is present. Such a device is capable of temporarily suppressing radio communication, navigation, and control signals while remaining inconspicuous and autonomous after deployment.

Thus, this study aims to assess the technical feasibility, effectiveness, and potential of incorporating drop-off EW modules into the design of the "Vampire" UAV. This approach could become an element of an asymmetric strategy to counter the enemy's superiority in EW and air defense systems. The research holds practical significance for the development of Ukrainian unmanned technologies in the context of modern warfare.

Installing a deployable mini-EW module will enable the "Vampire" to perform both classic combat tasks (reconnaissance, strikes, artillery correction) and functions of active informational impact – temporary jamming of enemy drones, suppression of control channels, or disruption of air defense systems. This significantly enhances the combat versatility of the platform while ensuring the safety of the UAV itself – the module continues to operate after being dropped, allowing the UAV to return to base.

IMPROVING THE METHODOLOGY FOR CONDUCTING RECONNAISSANCE WITH MODERN UAVS IN COMBAT CONDITIONS

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In the context of the full-scale war launched by russia against Ukraine, unmanned aerial vehicles (UAVs) have become critically important tools for tactical and strategic reconnaissance. Their use significantly improves operational decision-making, enhances the accuracy of fire missions, and minimizes risks to personnel. The realities of modern warfare have demonstrated that classical approaches to UAV deployment require significant adaptation.

Objective of the study. To analyze current approaches to UAV reconnaissance and determine the key areas for improving methodologies in the context of high-intensity combat operations.

Main directions for improvement:

Integration of Artificial Intelligence. The application of machine learning algorithms for automated target detection, classification, and tracking in video feeds allows operators to focus on decision-making rather than manual data analysis.

Adaptive Route Planning. The use of dynamic trajectory algorithms that respond to real-time changes in the battlefield (e.g., enemy air defenses, weather conditions, no-fly zones) helps reduce UAV losses and improve mission flexibility.

Optimization of Surveillance Modes. The implementation of algorithms for switching between visual and thermal imaging enhances the probability of detecting targets under varying visibility and camouflage conditions.

Secure Communication Channels. Development of jamming-resistant data and control channels, including satellite communication (SATCOM), extends UAV operational range and reduces vulnerability to electronic warfare.

MODERNIZATION OF THE MI-8 COMBAT HELICOPTER FOR TRANSPORTING THE ALTIUS-600 MINI-UAV

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Currently, there is an urgent need for the Armed Forces and other military formations to conduct aerial reconnaissance, battlefield surveillance, and target designation to guide both manned and unmanned strike air assets to identified targets. One of the key tools for these tasks has become unmanned aerial vehicles (UAVs), which, during military conflicts, have proven significantly more effective than manned aircraft in conducting aerial reconnaissance and performing other combat support tasks, as well as delivering strikes against the enemy.

The aim of the study is to enhance the effectiveness of UAVs by employing them in conjunction with a carrier helicopter, the Mi-8, and to identify potential directions for their use in the development and combat training of the Armed Forces of Ukraine.

Based on the requirements for tactical UAVs, the use of a container-launched UAV, named the "ALTIUS-600" manufactured in the USA, has been proposed.

By transporting the UAV via the Mi-8 helicopter, the effective operational radius of the ALTIUS-600 has increased from 440 km to 540 km, limited only by the characteristics of the receiving and transmitting devices.

DEVELOPMENT OF MEASURES TO REDUCE FUEL CONSUMPTION WHEN OPERATING THE BAYRAKTAR TB2

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In the context of the armed conflict between Russia and Ukraine, the use of various types of UAVs has proven to be both appropriate and promising. Since the beginning of the full-scale invasion, the Bayraktar TB2 has established itself as an effective operational-tactical level UAV.

The Bayraktar TB2 has become not only a physical weapon but also a psychological one. It struck enemy vehicle convoys at unexpected moments, especially when they lacked protection in the form of MANPADS or larger air defense systems.

The main factor behind its successful use was the absence of enemy air defense systems and the lack of awareness among enemy personnel.

Currently, various types and sizes of UAVs are widely used in Ukraine. Different versions of the Mavic are employed for both aerial reconnaissance and precision strikes against equipment, personnel, and electronic warfare systems. Additionally, FPV drones of various configurations are used due to their structural advantages, being faster and more maneuverable compared to the Mavic.

As the enemy has now deployed air defense systems, the use of the Bayraktar TB2 for strike missions has become nearly impossible.

The focus of this research is on improving fuel efficiency to reduce fuel consumption of the Bayraktar TB2 UAV.

The subject of the research is the Rotax 912 is engine.

Currently, the Bayraktar TB2 is primarily used for aerial reconnaissance. Therefore, increasing engine efficiency will lead to longer flight times, resulting in extended patrol durations and more thorough reconnaissance operations.

DEVELOPMENT OF MEASURES TO OPTIMIZE FUEL EFFICIENCY DURING MI-8 HELICOPTER OPERATIONS

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The full-scale war unleashed by the russian federation has significantly complicated the supply of fuel to the Ukrainian military aviation due to strikes on fuel infrastructure. The Mi-8 helicopters, which are crucial for tactical transport, medical evacuation, and logistics, require fuel consumption optimization in conditions of limited resources to maintain operational efficiency. One of the methods to address this issue is replacing the standard dual-channel injectors with multi-jet injectors, which improves fuel atomization and combustion stability, thereby reducing specific fuel consumption. This is essential for ensuring longer flight times and reducing refueling frequency.

Additionally, the implementation of a dual-flow swirler reduces the fuel droplet size, enhancing the air-fuel mixture and combustion, which leads to increased engine power and improved altitude-speed performance. Reducing the temperature in local combustion zones helps to lower harmful emissions, such as nitrogen oxides (NO_x) and carbon monoxide (CO). The main advantage of multi-jet injectors is that, due to the modern fuel atomization scheme, the temperature only increases slightly, allowing the engine to remain in the optimal temperature zone typical for low-emission combustion chambers.

The aim of this research is to justify the effectiveness of using multi-jet fuel injectors and a dual-flow swirler to improve fuel efficiency, reduce fuel consumption, and enhance engine performance on Mi-8 helicopters during real combat operations. It is expected that these technologies will reduce fuel consumption by 5–10%, increase operational autonomy, and reduce refueling frequency, thereby improving mobility and combat effectiveness.

RESEARCH ON WAYS TO IMPROVE THE REPAIR TECHNOLOGY OF THE STRUCTURAL FRAMEWORK OF A FIGHTER AIRCRAFT AIRFRAME, TAKING INTO ACCOUNT COMBAT EXPERIENCE

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The relevance of this topic is determined by the fact that during combat operations, as well as during the operation of aircraft, frequent damage to the skin and structural framework of the airframe is observed. Damage to these components negatively affects load-bearing capacity, and consequently – the safety and effectiveness of the aircraft's combat use. Therefore, there is a need not only for effective maintenance but also for rapid and high-quality repair of these structures.

To restore aircraft that have sustained operational or combat damage or have made emergency landings on a highway, field, or alternate airfield, it is proposed to develop a mobile aircraft repair complex. This airmobile repair complex would be equipped with modern, compact repair tools and equipment, as well as outfitted with spare components and consumable materials for all relevant specialties.

Timely and thorough repair of aircraft is one of the key factors in preventing flight incidents and ensuring high post-repair reliability and flight safety. This complex enables aircraft repairs to be carried out in the shortest possible time at the sites of their forced landings.

DEVELOPMENT OF A PROPOSAL FOR MODERNIZING THE PERFORMANCE MONITORING SYSTEM OF AIRCRAFT RADIO COMMUNICATION EQUIPMENT IN ACCORDANCE WITH NATO STANDARDS

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Enhancing the reliability of aircraft radio communication equipment is a critical task to ensure the competitiveness of aviation on the global market and maintain a high level of combat readiness. An analysis of radio communication equipment failures in a tactical aviation brigade, conducted following the onset of the Russian Federation's large-scale invasion of Ukraine, identified inadequate maintenance quality as the primary cause of malfunctions.

A promising direction for modernizing the performance monitoring system of radio communication equipment is the development and integration of a software-hardware complex compliant with NATO standards. This complex is designed for rapid, effective, and standardized diagnostics of onboard communication systems. The proposal includes the creation of a multi-platform, high-speed, interactive fault detection system that ensures high-quality technical diagnostics in minimal time with limited involvement of engineering and technical personnel.

The advantages of this approach lie in a simplified diagnostic process that does not require highly qualified specialists with in-depth knowledge of equipment design specifics. The software complex, developed in accordance with NATO standards, enables rapid fault detection even by personnel with lower qualifications, ensuring compatibility with international requirements and enhancing the efficiency of maintenance operations.

THE MI-8 HELICOPTER PROTECTION SYSTEM WHEN ENCOUNTERING OBSTACLES SUCH AS POWER LINES BY USING SPECIAL DEVICES

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The Air Force of the Armed Forces of Ukraine is actively involved in the protection of the territorial integrity and sovereignty of the country in the conditions of a military conflict with Russian aggression. They play an important role in providing defense capabilities of the country and the performance of tasks to remove enemy threats and aggression. The modernization of the Air Force of the Armed Forces plays a key role in strengthening the country's defense and ensuring that its military capabilities meet the requirements of the modern military situation.

Therefore, the main task of the work is to improve the characteristics of Mi-8, which are often used in various fields. Collision with obstacles such as power lines can cause serious damage to helicopters threats to the lives of the crew and passengers. Therefore, solving this problem is of great importance for the safety of aviation operations.

In this work, we research and develop an optimized protection system for the Mi-8 helicopter, which will ensure its safety when encountering power line obstacles. The system will include the development of new technologies and methods for detecting and avoiding obstacles, as well as improving existing protection systems.

The main areas of research will include:

research into current protection systems, their limitations and opportunities for improvement.

study and development of new technologies and methods for detecting and classifying obstacles.

development of new algorithms and methods for effective avoidance of collision with obstacles.

carrying out various tests to verify the effectiveness of the new protection system.

The basis of this research is the development of an effective protection system that will be able to significantly reduce the risk of the Mi-8 helicopter colliding with power line obstacles, thereby increasing flight safety and mission efficiency.

NEW TECHNOLOGIES FOR SERVICING THE SU-27 AIRCRAFT

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In modern warfare conditions, advanced technologies for the maintenance of combat aircraft, particularly Su-27 fighter jets, are of critical importance. This fourth-generation multirole fighter remains the backbone of the air fleet of many countries even today, which makes the implementation of innovative maintenance approaches increasingly relevant.

The introduction of automated diagnostic systems allows real-time assessment of the condition of the aircraft's main components, timely detection of potential malfunctions, and prediction of the timeframes for their elimination. Such systems are based, in particular, on the use of sensor networks, vibration analysis, ultrasonic inspection, and computerized data processing. This significantly reduces human error and shortens the duration of scheduled inspections.

Another promising technology is additive manufacturing (3D printing), which enables the production of scarce or non-standard parts directly at the location of the aircraft. This significantly accelerates repair and restoration work, reduces spare parts logistics costs, and ensures a high level of aircraft operational readiness.

In addition, the use of nanotechnological coatings for aviation components contributes to reduced wear, improved corrosion resistance, and enhanced thermal endurance of airframe and engine elements. Such materials extend the service life of units and assemblies, which is critically important for combat aircraft operating under challenging conditions.

Thus, the integration of cutting-edge maintenance technologies for the Su-27 contributes to enhancing the aircraft’s operational efficiency, extending its service life, optimizing costs, and ensuring a high level of combat readiness. These directions are key to modernizing the aviation sector and maintaining the state's defense capabilities.

SHAPING THE CONFIGURATION AND GENERAL TECHNICAL REQUIREMENTS OF A PROSPECTIVE LIGHT TACTICAL RECONNAISSANCE AIRCRAFT

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The thesis substantiates methodological approaches to shaping the aerodynamic configuration and general technical requirements of a prospective light tactical reconnaissance aircraft, taking into account combat experience in tactical reconnaissance operations. The influence of operational-tactical tasks on the determination of flight performance characteristics – such as speed, maneuverability, flight endurance, operational ceiling, range, and stealth features – is examined. Requirements for the airframe design, powerplant, onboard systems, and reconnaissance equipment are analyzed. Fundamental technical criteria are formulated as a basis for the design of an aircraft capable of effectively performing reconnaissance missions in dynamic combat environments

DIRECTIONS FOR INCREASING THE BOMB LOAD OF A STRIKE UAV BASED ON THE L-39 TRAINING AIRCRAFT

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The modernization of the L-39 training aircraft for use as a strike unmanned aerial vehicle requires the optimization of methods for placing the combat load. One of the key directions for increasing strike potential is the use of FAB-500 or FAB-250 aerial bombs, which can be mounted on external pylons using beam bomb racks. This involves reducing the aircraft’s own weight by removing unnecessary systems, including the ejection seat, avionics, part of the hydraulic system, and other piloting modules that are no longer needed in the unmanned configuration.

An additional improvement direction is the placement of the payload inside the fuselage. Since the L-39 in its unmanned variant does not require a cockpit, the space previously occupied by the pilot can be used to install an aerial bomb or explosive charges (e.g., TNT or other powerful explosive mixtures). This approach allows an increase in the total combat load weight without significantly affecting the aircraft's aerodynamics.

The optimization of the center of gravity and balance of the strike UAV with such modifications is critically important to maintain its controllability and stability during flight. Calculating mass characteristics and conducting additional verification tests will help determine the optimal options for suspension and internal placement of munitions.

In general, the implementation of these changes will significantly increase the combat potential of the L-39 in an unmanned configuration, turning it into an effective means of delivering high-precision strikes against enemy strategic targets.

WAYS TO IMPROVE THE ENERGY EFFICIENCY OF THE TV3-117 ENGINE BY OPTIMIZING THE FUEL SYSTEM

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In this paper, we investigate topical issues of improving the energy efficiency of the TV3-117 turbofan aircraft engine by optimizing its fuel system. In the current conditions of intensive operation of aircraft, especially military aircraft, improving energy efficiency is becoming one of the key areas for reducing fuel consumption, improving environmental performance, and increasing combat readiness. The TV3-117 engine, which is widely used in domestic and foreign helicopters, has significant potential for improvement, in particular through the modernization of its fuel system.

Based on the analysis, the paper proposes a number of technical solutions aimed at eliminating the identified shortcomings. In particular, we are talking about the introduction of automatic fuel supply control systems using electronic control modules, the use of the latest injectors with improved spray characteristics, and the modernization of the fuel consumption control system by integrating modern sensors and data processing algorithms.

The feasibility study has shown that the implementation of the proposed changes can reduce fuel consumption by 6-8%, which in turn helps to reduce operating costs, increase engine life, reduce environmental impact and increase the overall efficiency of aircraft. The solutions proposed in this work are of practical importance and can be implemented both in the modernization of the existing fleet of aircraft engines and in the development of new models of aircraft.

MODERNIZATION OF THE FRONT-END DEVICE OF THE COMBUSTION CHAMBER

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One of the key tasks in the development of combat aviation is the creation of technologies aimed at improving the economic characteristics of engines and increasing their power. One of the priority directions is the development of measures that ensure the improved functioning of the front-end section of the combustion chamber.

For effective combat operations, reliable and combat-ready equipment is required, with minimal losses and maximum safety for personnel. During the operation of Mi-24PU1 helicopters, technical malfunctions related to the operation of combustion chambers are encountered.

An analysis of the combustion chamber unit damage revealed defects in the outer casing and flame tube, opening up opportunities for the implementation of modern technologies in this field. The modernization of the front section involves replacing the traditional 12 dual-channel centrifugal nozzles with the same number of multi-flame nozzles, which will optimize the combustion process of the fuel-air mixture and improve the quality of fuel atomization in the combustion zone. This allows for a reduction in the diameter of the atomized fuel droplet.

According to thermogas dynamic calculations and the geometry of the new fuel nozzle's orifice, it can be concluded that the diameter of droplets passing through the new nozzle will be significantly smaller compared to the dual-channel centrifugal nozzle. This will improve fuel atomization quality without significantly increasing the temperature.

Improving the quality of atomization contributes to an increase in combustion temperature in the chamber by 30°C, which in turn will allow for an increase in effective power by 6% and a reduction in specific fuel consumption by 2%.

RESEARCH ON THE FUEL EFFICIENCY OF THE IL-76 MILITARY TRANSPORT AIRCRAFT

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The analysis of fuel efficiency in transport aircraft from 1960 to 2020 highlights the need to extend flight range and improve fuel economy. Given rapid advancements in aviation technologies, optimizing fuel consumption is a critical goal.

This study focuses on the Il-76 aircraft, assessing its current performance and modernization potential. Particular attention is given to enhancing fuel efficiency through engine upgrades and technical recalculations under maximum load.

The proposed approach enables precise assessment of operational limits and suggests effective ways to extend flight range, improve performance, and broaden the aircraft's application in modern conditions.

ANALYSIS OF AIRCRAFT COMPONENT FAILURES TO JUSTIFY THE FEASIBILITY OF RESEARCH ON EXTENDING THEIR SERVICE LIFE

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The issues of improving flight safety are directly related to extending the service life of aircraft. The lifespan of many aircraft components depends on the wear resistance of friction pairs. Such components include power unit drive gearboxes, transmission assemblies, reducers, gear pumps of various systems, and many others. Their service life is mainly determined by the contact fatigue strength of the gear teeth that make up their design.Currently, advanced methods for increasing the contact fatigue strength of friction pair surfaces are being actively developed, offering significant advantages over traditional techniques. To determine the operational characteristics (including service life) of structural materials strengthened by these new methods, long-term and costly fatigue strength tests must be conducted using friction machines that simulate the operation of aviation components.This situation limits the number of studies on the impact of new strengthening methods on contact fatigue strength, particularly ion-plasma nitriding techniques. In today's conditions, decisions regarding long-term and expensive research – despite their potential to extend aircraft service life and enhance flight safety – cannot be made without thoroughly assessing their relevance and necessity.This underscores the importance of conducting research on the analysis of failures and malfunctions of aviation components to determine the share caused by contact fatigue wear. Such an analysis can provide a justified assessment of the feasibility and necessity of conducting long-term and costly testing of advanced surface-hardening methods for gear wheels to extend their service life.

CONCEPT OF AN AUTONOMOUS STRIKE UAV WITH ADAPTIVE TACTICAL BEHAVIOR FOR DEEP OPERATIONS BEHIND ENEMY LINES

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Taking into account the experience of modern warfare and the growing demands for autonomy and efficiency of combat UAVs, a concept is proposed for a strike UAV capable of performing combat missions with minimal operator involvement. This refers to a UAV that can independently navigate in complex environments, make decisions on its own, adapt to changes on the battlefield, and engage designated targets without continuous control from the ground. This approach not only reduces the workload on operators but also lowers the risk of losing control due to enemy electronic warfare systems.

This UAV is equipped with modern sensors – optical, infrared, and, if necessary, radar – which enable it to receive detailed information about its surroundings. Using specialized onboard systems, it is capable of detecting objects and recognizing them based on certain features (for example, distinguishing armored vehicles from regular cars). This allows the UAV to operate effectively even in dynamic and high-threat combat conditions.

Another key feature is the use of a digital terrain map, which can be preloaded with information about known or suspected enemy air defense positions, terrain features, supply routes, and more. By combining this data with real-time reconnaissance input, the UAV can autonomously plan the safest routes to its target.

A critical element is the UAV's ability to coordinate with other unmanned platforms. This enables joint operations by multiple units acting in a synchronized manner and sharing data among themselves. Such an approach allows for massed strikes, reconnaissance by one unit with target data relayed to a strike UAV, and generally improves system survivability – as the loss of one UAV does not compromise the entire mission.

In this way, the development of such a UAV opens new possibilities for conducting modern combat operations – from deep penetration into enemy territory to precision strikes in fully autonomous or semi-controlled modes. Its use combines high accuracy with reduced management time and a lower risk of detection by enemy electronic warfare systems.

THE INFLUENCE OF OPERATIONAL FACTORS ON THE DYNAMIC CHARACTERISTICS OF THE MI-8 HELICOPTER

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Under modern conditions of intensive operation of aviation equipment – particularly the versatile Mi-8 helicopter – the issue of ensuring a high level of flight reliability, controllability, and safety under varying and sometimes extreme conditions becomes especially relevant. The Mi-8 helicopter, being one of the most widespread and multifunctional rotorcraft, is used in a wide range of missions, from cargo and personnel transportation to search and rescue operations, which demands stable performance of its dynamic systems across diverse environments.

One of the key factors in mission effectiveness and flight safety is the helicopter's dynamic characteristics, specifically stability, controllability, and maneuverability, which are significantly affected by a complex of operational influences. This research examines the primary factors impacting flight dynamics: changes in weight and center of gravity depending on payload distribution; external meteorological conditions such as air temperature, atmospheric pressure, air density, and wind; and the technical condition of specific components – particularly the main and tail rotor systems, transmission units, and control mechanisms.

The study also considers the influence of mission-specific factors: low-altitude flights, operations in mountainous terrain, limited visibility, or flights under maximum takeoff weight conditions. Particular attention is given to analyzing how these factors affect the helicopter's response to pilot inputs, behavior during transient modes, and the likelihood of hazardous scenarios such as loss of control or structural overload.

The analysis of operational factors and their impact on the Mi-8's flight performance provides a deeper understanding of the nature of changes in helicopter dynamics. It also supports the development of a systematic approach to risk assessment during flight planning and promotes optimization of maintenance procedures based on real-world operating conditions.

STUDY OF THE OPERATIONAL CHARACTERISTICS OF THE BAYRAKTAR TB2 UAV BASED ON COMBAT EXPERIENCE

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The increasing role of unmanned aerial vehicles (UAVs) in modern armed conflicts necessitates a thorough analysis of their operational characteristics. The Bayraktar TB2 UAV has proven to be an effective tool for reconnaissance and strike missions in conflicts such as those in Ukraine, Syria, Libya, and Nagorno-Karabakh.

The Bayraktar TB2 has demonstrated its value in engaging lightly armored targets, command posts, and mobile anti-aircraft systems. However, operational experience has also revealed certain drawbacks:

Dependence on weather conditions;

Range limitations in the event of signal loss;

Vulnerability to modern electronic warfare (EW) and air defense systems.

The Bayraktar TB2 is equipped with a ROTAX 912 is four-stroke piston engine. This engine is known for its high fuel efficiency, low vibration levels, and reliability during extended missions. However, its limited power output restricts the UAV's payload capacity and flight speed.

Based on an analysis of operational characteristics and combat experience, several areas for improvement can be identified:

Optimization of the airframe's aerodynamics to reduce drag;

Use of satellite communication channels (SATCOM) to extend control range;

Engine modernization – potentially switching to a different engine to achieve increased power, greater range and endurance, higher altitude, and enhanced capability to counter modern EW and air defense systems, as well as to reduce maintenance costs.

While the use of the ROTAX 912 engine is effective, it is also resource-limited. To expand the capabilities of the Bayraktar TB2, efforts should focus on modernizing the powerplant and integrating energy-efficient technologies. All these factors will enhance the UAV's effectiveness and flexibility in modern combat scenarios.

RESEARCH ON IMPROVEMENTS TO THE TAIL ROTOR OF THE Mi-24V ATTACK HELICOPTER

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In modern combat conditions, particularly in the context of the full-scale war ongoing since 2022, ensuring the technical reliability and effectiveness of aircraft components is of critical importance. The Mi-24V attack helicopter remains one of the main means of fire support for the Ground Forces of the Armed Forces of Ukraine. A crucial component that affects the controllability, stability, and maneuverability of the helicopter is the tail rotor.

An analysis of the Mi-24V helicopter's tail rotor design has revealed several key shortcomings: a high noise level, insufficient efficiency during hovering and low-speed maneuvers, and significant stress on the transmission system. Based on the analysis, several directions for modernization of the tail rotor have been proposed: the use of composite materials, optimization of the blade's aerodynamic profile, and improvement of the pitch control system.

The expected outcomes of these improvements include enhanced controllability, reduced acoustic signature, extended tail rotor lifespan, and overall enhancement of the helicopter's flight performance. These upgrades, in turn, will contribute to increased combat effectiveness and survivability of the helicopter in active combat operations.

MODERNIZATION OF THE AN-26 WITH THE REPLACEMENT OF THE AI-24VT ENGINE WITH THE PRATT & WHITNEY CANADA PW150A ENGINE

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The AI-24VT engine is a reliable unit, but it was developed several decades ago and no longer meets modern requirements for fuel efficiency and environmental friendliness. The installation of the PW150A, which is a representative of the latest generation of turboprop engines, offers significant benefits:

– Reduced fuel consumption: The PW150A demonstrates significantly lower specific fuel consumption compared to the AI-24WT. This will lead to lower operating fuel costs, which is an important factor in today's economic climate.

– Increased environmental friendliness: The modern design of the PW150A results in significantly lower emissions of harmful substances such as nitrogen and carbon oxides, which meets more stringent environmental standards.

– Increased power and improved flight performance: The PW150A has more power than the AI-24WT.

– Lower noise levels: Modern engines generally have lower noise levels.

– Improved reliability and reduced maintenance costs: The PW150A has a more modern design and technology, which can lead to increased reliability and lower maintenance costs in the long term.

Of course, the integration of the new engine will require significant engineering developments, including the design of new pylons, engine control systems and adaptation of existing aircraft systems. It will also require certification of the upgraded aircraft.

Nevertheless, the potential benefits of this modernisation are significant. The AN-26 will be given a second life, become more fuel-efficient, environmentally friendly and have improved performance.

MODERNIZATION OF IL-76 WITH THE REPLACEMENT OF D-30KP ENGINES WITH D-18T ENGINES

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The D-30KP engine is reliable but was developed in the last century. Installing the more modern D-18T engine, which is used on An-124 "Ruslan" aircraft, offers significant advantages for the Il-76:

increased payload and flight range: the d-18t has significantly higher thrust compared to the d-30kp. this will allow the il-76 to carry larger loads over significantly longer distances without refueling.

improved take-off and landing performance: increased thrust will contribute to a reduction in take-off run and landing distance, which will expand the possibilities for using airfields.

increased cruising speed and flight altitude: more powerful engines will allow the aircraft to operate at higher altitudes with a greater cruising speed, which will increase the efficiency of transportation.

potential reduction in fuel consumption: although the d-18t is more powerful, its more modern design may provide better fuel efficiency in certain flight regimes, especially over long distances.

increased service life and reliability: the d-18t is a more modern engine, which can positively affect its service life and time between overhauls.

Of course, such a deep modernization will require significant engineering work, including the design of new pylons, engine mounting systems, fuel and control systems. Recertification of the aircraft will also be necessary.

However, the implementation of D-18T engines can significantly expand the capabilities of the Il-76 aircraft, making it more efficient, with a higher payload capacity and longer range, which is critical for military transport aviation.

RESEARCH ON WAYS TO EXPAND THE COMBAT CAPABILITIES OF THE Mi-8 TYPE HELICOPTER

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The experience of our country's armed confrontation with the armed forces of the Russian Federation demonstrates the active use of enemy unmanned strike drones of the Shahed type to destroy both military targets and civilian energy and other infrastructure facilities. Countering slow-moving UAVs is a relevant issue and is carried out comprehensively through the use of mobile fire teams, air defense missile systems, fighter aircraft, and army aviation helicopters.

This study analyzes ways to expand the combat capabilities of Mi-8 type helicopters in terms of intercepting and destroying slow-moving aerial targets. A proposal is made for the stationary installation of lightweight 7.62 mm PKM machine guns on the left and right sides of the helicopter.

The feasibility of implementing the proposed measures is substantiated based on an analysis of the helicopter's flight and technical characteristics and the calculation of the aircraft's existence equation. Structural strength calculations were performed on the helicopter's load-bearing elements at the points where additional weapons would be mounted.

Following the helicopter's modernization, an increase in its effectiveness in combating aerial targets and providing fire support during ground operations is expected. An analysis of technical compatibility, onboard shooting ergonomics, and calculation of the effective engagement sector will allow for conclusions to be drawn regarding the feasibility of such armament and its potential for deployment in combat conditions.

ENSURING STABLE OPERATION OF THE AI-450V ENGINE COMPRESSOR

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The combat experience gained by the Armed Forces of Ukraine in countering the armed aggression of the Russian Federation has demonstrated the critical importance of aviation and air superiority. Since 2022, helicopter aviation has been actively employed in the eastern operational zone.

The powerplant of the Mi-2MSB helicopter includes the AI-450V engine. During flight operations – particularly under yaw maneuvers and hovering – there is a risk of compressor surge, characterized by loud bangs and unstable compressor operation.

Analysis of this phenomenon has shown that one of the causes of compressor surge is the close proximity of the exhaust diffuser to the engine air intake, leading to the recirculation of exhaust gases back into the engine compressor.

The objective of this work is to ensure stable compressor operation through modernization of the exhaust system.

The proposed engineering solutions, in particular the installation of an extension pipe with an ejector, significantly improve compressor operating conditions and reduce the risk of surge.

Additional technical measures, such as the use of a splined joint and various ejector types, contribute to enhanced reliability, structural unification, and stable exhaust gas discharge.

The implementation of modernized exhaust nozzles also reduces infrared emissions and decreases acoustic load, which is critical for operating aircraft in combat environments.

Therefore, the proposed technical improvements ensure stable and efficient operation of the AI-450V engine compressor across various flight regimes of the Mi-2MSB helicopter.

RESEARCH INTO DIRECTIONS FOR MODERNIZATION OF FIGHTER AIRCRAFT TO REDUCE OBSERVABILITY INDICATORS

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The experience of the full-scale war in Ukraine has shown that the effectiveness of combat aircraft is significantly reduced in conditions of intense air defence, especially when the enemy uses modern radar detection equipment. In such conditions, the stealthiness of the aircraft becomes a critical advantage. The MiG-29 fighter is a highly manoeuvrable aircraft, but its visibility remains a vulnerable factor in combat missions. Reducing the radar visibility of a fighter jet is a key task in the face of densely deployed detection and air defence systems.

One of the key factors in detecting an aircraft is the radar signature of its nozzles. In particular, the RD-33 axial circular nozzles, which are used in the MiG-29 base version, have a high effective radar scattering area, which creates an increased risk when entering the range of enemy radars or air defence radars.

A promising area of MiG-29 modernisation is the replacement of the standard axial nozzle with a flat nozzle. Due to its geometry, such a nozzle reduces the effective radar reflection area, which makes it difficult to detect the aircraft.

The relevance of the topic is driven by the need to increase the survivability of the aircraft in today's confrontation with high-tech detection and destruction equipment. Modernisation of the MiG-29 by installing a stealthy nozzle increases the chances of successful combat missions and the safety of the crew.

DESIGN MEASURES TO IMPROVE COMBUSTION CHAMBER EFFICIENCY

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In the context of the full-scale war in Ukraine, the intensity of aircraft operation has significantly increased, which has led to the urgent need to enhance the service life, fuel efficiency, and overall reliability of powerplants.

This study examines promising approaches to improving the powerplant of the Mi-2MSB light multipurpose helicopter, which is based on the use of the AI-450V gas turbine engine. Particular attention is paid to two key components: the fuel supply system and the thermal protection coating of the combustion chamber elements.

The first direction of improvement involves modernizing the fuel nozzles. Instead of a single-channel, single-orifice nozzle, a dual-channel, dual-orifice design is proposed. This configuration enables efficient fuel atomization over a wide range of engine operating modes. Such an approach improves starting conditions, reduces the risk of flameout, decreases the likelihood of coking, and promotes more complete fuel combustion.

The second direction involves the application of heat-resistant coatings, in particular aluminum oxide (Al_2O_3), deposited using the Atomic Layer Deposition (ALD) method, to protect the inner surfaces of the combustion chamber. This coating reduces the rate of oxidation and thermal degradation of the material, increases the service life of the combustion liners, and ensures stable operation under prolonged high-temperature exposure. ALD films have a uniform structure, high density, and the ability to protect even complex internal surfaces of components.

The implementation of these solutions makes it possible to reduce specific fuel consumption by up to 2–3%, increase the combustion chamber service life by 10–15%, and improve engine start-up reliability.

STUDY OF DIRECTIONS FOR SOLVING THE PROBLEM OF UNSUCCESSFUL LAUNCH OF MI-8MSB HELICOPTER ENGINES

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Based on the results of the analysis of the experience of using helicopter aviation in the course of hostilities during the full-scale armed aggression of the Russian Federation, the problem of starting the engines of the power plant of the Mi-8MSB helicopter when based outside the airfield was identified.

The main reason for the unsuccessful launch of the Mi-8MSB helicopter engines was the lack of sufficient air in the helicopter's air system.

Currently, the Mi-8MSB helicopter, developed by Motor Sich on the basis of the Mi-8 helicopter, is widely used as a multi-purpose helicopter.

Based on the design features of the Mi-8MSB helicopter, namely, the change of the launch system from air to electric, the problem of the inability to start the helicopter engines when there is no air in the air system is becoming relevant.

The paper proposes to upgrade the air system of the Mi-8MSB helicopter by integrating an additional air cylinder with air to start the engines. To calculate the amount of air for starting and the volume of the air cylinder, the requirements for ensuring 3 consecutive engine starts were selected. As a result of the calculations, it was determined that the volume of the cylinder that must be installed in the air system to provide additional air volume is Vaac = 0,00884 m^3.

The results of the research allow us to improve the helicopter's autonomy characteristics when off-airfield.

IMPROVEMENT OF THE FUEL SYSTEM TO ENHANCE THE FLIGHT PERFORMANCE CHARACTERISTICS OF A TRANSPORT HELICOPTER

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The Role of Army Aviation in Offensive and Defensive Operations, as a Means of Providing Air Support to Combined Arms and Armored Units, Has Significantly Increased. It has become the primary component of aviation support. During combat operations, helicopters play a critical role in mission execution.

The flight range and endurance depend on the amount of fuel on board at takeoff and the efficiency of its consumption. A pressing task is to improve the flight performance of the Mi-8MSB helicopter, specifically to enhance its flight range.

To increase flight range and endurance, it is proposed to expand the capacity of the external fuel tanks. Design calculations of the helicopter's takeoff weight and center of gravity have been conducted, and a fundamentally new layout for the external fuel tanks has been developed.

The results of the calculations provide a comparative analysis of flight range before and after the modification. The modified helicopter demonstrates a 53% increase in range and a 54.5% increase in flight endurance. This significantly expands the helicopter's tactical operational radius and opens new mission capabilities.

For Mi-8-type helicopters, the presence of additional fuel tanks inside the cargo compartment presents a serious drawback, limiting available space for payload and personnel. The proposed technical solution addresses this issue by relocating the additional fuel tanks outside the cargo compartment, thereby improving the efficiency of internal space utilization and enabling quick reconfiguration of the helicopter depending on mission requirements.

THE IMPACT OF OPERATIONAL AND COMBAT DAMAGE ON THE LOAD OF THE TRANSMISSION SYSTEM OF THE MI-8 TYPE HELICOPTER

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The transmission system of the Mi-8 helicopter is one of the most critical components that significantly affects flight safety. Transmission failure or destruction usually leads to catastrophic consequences. Therefore, increasing the structural reliability of the transmission becomes a key issue.

The primary loads acting on the transmission are the torques transmitted through the transmission shafts. In addition, bending and torsional vibrations of the shafts also occur. During transmission operation, there are strict requirements for operational limitations.

The first aspect is the occurrence of torsional vibrations in the shafts, which are associated with the transmission of torque to the tail rotor. During flight, the tail rotor constantly changes its angle of attack, thereby changing the rotational resistance moment. This leads to a variable torque.

Another relevant issue is the investigation of transverse vibrations of the transmission shaft. These transverse vibrations may cause additional bending stresses in the shaft. All these factors contribute to the failure of both the shafts and their bearings.

In condition-based operation, it is essential to determine the levels of loads and stresses in order to assess the rate of resource consumption.

During operation, combat damage may also occur, which can significantly affect the transmission's performance.

A relevant approach is the development of a transmission with an operating rotation frequency higher than the critical frequency. This would allow the system to avoid resonance oscillations of the transmission shaft.

DIRECTIONS OF IMPROVEMENT OF FUEL EFFICIENCY (ECONOMY) OF TRANSPORT AIRCRAFT

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The combat experience gained during the war has demonstrated the extremely important role of transport aircraft in ensuring the mobility of troops, delivery of cargo and evacuation of the wounded. In these conditions, it is of particular importance to improve the fuel efficiency of transport aircraft, which directly affects their ability to perform tasks with minimal resource consumption.

One of the ways to increase efficiency is to modernise powerplants. The use of modern turboprop or turbojet engines of the new generation can reduce specific fuel consumption, improve reliability and reduce maintenance.

In addition, one of the most promising areas is improving the shape and streamlining of the aircraft. For example, the use of new wings with variable shapes or smoother surfaces made of modern materials helps to reduce air resistance and thus fuel consumption. Also, the use of lightweight composite materials for the body and other parts of the aircraft reduces its weight without sacrificing strength and reliability.

The paper examines how the AN-26 and C-130 transport aircraft were used during combat operations. It is shown that the upgrade of their engines and the introduction of fuel-saving technologies help to significantly increase the flight range without the need for refuelling, reduce dependence on ground supplies and increase efficiency.

IMPROVEMENT OF TACTICAL CHARACTERISTICS OF THE AN-26 AIRCRAFT

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Renewal of the transport aircraft fleet of the Air Force of Ukraine is crucial for ensuring the defense capability of the state. The experience of combat operations in the armed conflict with the aggressor country makes it obvious that there is an urgent need for fast, mobile and efficient transportation of goods in conditions of limited resources.

One of the key areas for improving the tactical effectiveness of the AN-26 is the modernization of its fuel system. Improvements in fuel supply, storage and management systems will significantly improve the tactical performance, increase the range and duration of the flight, and improve the reliability of the aircraft in combat and logistics missions.

The main modernization measures include the introduction of modern fuel pumps and filters, adaptive fuel consumption control systems, the use of lightweight composite materials to reduce the weight of fuel tanks, and the possibility of using alternative fuels to reduce dependence on traditional sources.

Implementation of such measures will extend the AN-26 service life, reduce maintenance costs and ensure that the aircraft meets the modern requirements of military transport aviation in the conditions of the ongoing war.

RESEARCH ON WAYS TO IMPROVE THE FUEL EFFICIENCY (ECONOMY) OF THE SU-27 FIGHTER JET

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In wartime conditions and with the need to increase combat effectiveness, improving the fuel economy of fighter aircraft becomes a crucial task for the aviation industry.

This study analyzes technical and operational factors affecting the fuel consumption of the Su-27 and identifies ways to optimize them.

Key directions for improvement include:

Modernization of AL-31F engines to reduce specific fuel consumption;

Optimization of airframe aerodynamics;

Use of composite materials to reduce structural weight;

Implementation of modern flight control systems and fuel-efficient operating modes.

Expected outcomes:

Enhanced efficiency of combat sorties;

Reduction of operational costs;

Extension of aircraft service life.

Improving the Su-27's fuel efficiency is achievable through a comprehensive modernization approach, which will contribute to increasing the combat capability of the Air Force.

IMPROVEMENT OF TAKEOFF AND LANDING PERFORMANCE OF THE AN-26 MILITARY TRANSPORT AIRCRAFT CONSIDERING COMBAT OPERATION EXPERIENCE

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Given the experience of modern armed conflicts, enhancing the effectiveness of military transport aviation (MTA) has become increasingly relevant, particularly due to the need to improve its tactical and technical characteristics. The main directions of modernization include increasing aircraft survivability and protection, improving payload capacity, extending flight range, upgrading navigation and electronic systems, as well as integrating advanced active and passive defense technologies.

This report proposes an analysis of current trends in MTA development, examines the specific conditions of aircraft operation in combat zones, and identifies possible ways to optimize their design and systems. Special attention is given to the implementation of modular solutions that enable aircraft to be adapted for various mission types, the modernization of communication and coordination systems with other units, and the use of modern materials and technologies to reduce structural weight without compromising strength.

A proposed modernization of a prototype aircraft includes improvements to the flight control system and wing mechanization, aimed at enhancing maneuverability and improving handling characteristics.

Overall, the improvement of these features will contribute to increased combat capability of MTA, expansion of its functional range, and enhanced flexibility in performing both combat and humanitarian missions.

INVESTIGATION OF IMPROVEMENT METHODS FOR THE HYDRAULIC SYSTEM OF MILITARY TRANSPORT AIRCRAFT (CASE STUDY: AN-26 AIRCRAFT)

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The hydraulic system is one of the critical components of the An-26 military transport aircraft, ensuring the operation of landing gear, wing mechanization, flight control surfaces, and other essential units. Due to the aging and physical wear of the An-26 fleet, improving the reliability, maintainability, and energy efficiency of its hydraulic system has become a relevant issue. The purpose of this research is to analyze the current state of the An-26 hydraulic system, identify its major shortcomings, and develop modernization approaches based on contemporary technologies. Particular attention is given to the implementation of automated fault detection systems, upgrading of hydraulic pumps, improvement of fluid filtration units, and the use of advanced sealing materials. The expected outcomes of the study include enhanced system performance, reduced probability of in-flight malfunctions, and extended operational life of the aircraft without requiring significant capital investments. The results of this research may be applied by the Ukrainian defense industry for the modernization of the existing aircraft fleet.

RESEARCH ON THE POSSIBILITY OF EXPANDING THE COMBAT CAPABILITIES OF THE MIL MI-2 HELICOPTER FOR COUNTERING UAVS

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In the context of the Russo-Ukrainian war, where the enemy widely employs strike unmanned aerial vehicles (UAVs) to target civilian populations and infrastructure, as well as military and energy facilities, there is a growing need to involve existing aviation assets in countering these threats – particularly the aviation resources of the Army Aviation of the Ground Forces of the Armed Forces of Ukraine.

One of the methods of countering strike UAVs is engaging them with onboard small arms fire from helicopters. This study explores the feasibility of intercepting Shahed-136 strike UAVs by upgrading the Mi-2 helicopter to perform such air defense missions.

The study demonstrates that the Soviet-designed Mi-2 multipurpose helicopter, given its tactical and technical characteristics, is capable of intercepting and neutralizing a Shahed-136 UAV. A comparative analysis was carried out on automatic firearms suitable for installation inside the helicopter cabin – specifically machine guns of 5.56 mm, 7.62 mm, and 12.7 mm calibers of both Western and domestic production – with consideration of their dimensions, weight, rate of fire, and shooting accuracy.

The installation of the FN MAG 60.30 (Aviation) machine gun is considered the most suitable option due to its adaptation for aircraft mounting, relatively low weight – which is critical in helicopters – and high reliability.

A calculation of the takeoff weight after the installation of the weapon system was conducted, as well as an analysis of the structural loads imposed on the helicopter fuselage by the mounted machine gun.

ANALYSIS OF THE INFLUENCE OF OPERATING FACTORS AND BATTLE DAMAGE ON THE VIBRATION LEVEL AND RESOURCE EXPENDITURE RATE OF THE Mi-8 TYPE HELICOPTER

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The Mi-8 helicopter is one of the most mass-produced multi-purpose helicopters widely used during the Russian-Ukrainian war. Its operation in various conditions significantly affects the load level, technical condition, service life and overall flight safety.

The main operational factors affecting a helicopter include variable overloads, environmental effects, material fatigue, corrosion and mechanical wear of components. When artillery weapons are used to combat UAVs, the helicopter is subject to large variable recoil forces.

This is compounded by operational and combat damage, which can change the distribution of loads in the structure, causing an increase in the vibration background and even the appearance of dangerous self-oscillations.

Increased vibration adversely affects crew and equipment performance, and accelerates the consumption of fuselage, components, and assemblies.

The study of the impact of operational factors and combat damage on vibration levels and service life is key to ensuring long-term and reliable operation of Mi-8 helicopters under conditions of intensive use.

The data on variable stresses in the structure allow us to properly organize the operation of aircraft by condition and extend the service life of helicopters, which is of particular importance during combat operations.

DEVELOPMENT OF A MODEL OF A DEVICE FOR REDUCING INFRARED RADIATION OF SU-25 AIRCRAFT

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Based on the analysis of the experience of using attack aircraft in the course of hostilities during the full-scale armed aggression of the Russian Federation on the territory of Ukraine, the problem of vulnerability of aircraft to the use of infrared homing missiles was identified.

At present, the single-seat subsonic armoured Su-25 aircraft, which is capable of carrying guided and unguided air defence weapons, is used as an assault aircraft.

Based on the tasks of attack aircraft and the statistical data on the destruction of Su-25 aircraft during combat operations, the problem of protecting aircraft from missile damage by reducing the level of infrared radiation of the aircraft arises.

It is proposed to develop a model of a device for reducing the infrared radiation of the flow of hot gases flowing from the engine nozzles. The technology of injecting liquid into the gas stream to form a heat shield around it is used, which leads to a reduction in infrared radiation of the Su-25 aircraft. This system operates simultaneously with the system of firing fake thermal targets.

The implementation of the research results will reduce the vulnerability of the Su-25 aircraft and the safety of combat missions in the frontline combat zone.

AERODYNAMIC CONFIGURATION OF A SWARM STRIKE UAV

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The relevance of developing swarm-capable strike UAVs is driven by the need to increase operational effectiveness in complex combat environments, including frontline areas saturated with air defense (AD) systems and electronic warfare (EW) assets, while taking into account the capabilities of the domestic defense industry to produce such UAVs.

One of the key factors influencing the flight and technical characteristics of a swarm UAV is the choice of its aerodynamic configuration, which determines the optimal balance between size, maneuverability, and stability.

A comparative analysis was conducted on various aerodynamic balancing configurations: conventional, tailless, and canard layouts. As the primary option, a conventional configuration with an annular-arched wing was selected. This aerodynamic layout combines reduced induced drag of a high-aspect-ratio wing with the high efficiency of a propeller placed within the ring, an expanded range of acceptable center-of-gravity positions, and the ability to house the payload within the fairings between the arched and straight wing segments.

The modularity of this swarm strike UAV design enables easy adaptation of the payload to mission requirements – from explosive ordnance to electronic warfare systems.

RESEARCH ON WAYS TO IMPROVE THE HYDRAULIC SYSTEM OF THE MI-8MSB-V HELICOPTER

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The full-scale invasion of the Russian Federation into the territory of Ukraine has placed extraordinary pressure on the resources of the Armed Forces of Ukraine. Under conditions of limited funding and the lack of opportunities to procure new aviation equipment, the modernization of the existing helicopter fleet becomes particularly relevant, given their multi-purpose use in combat conditions. In particular, it is appropriate to improve the functional capabilities of onboard systems to enhance combat effectiveness and reduce risks to the crew.

Combat experience gained during active military operations indicates the need for a technical upgrade of the helicopter's hydraulic system, which in its current configuration does not provide for the control of the rear cargo cabin doors. Currently, these doors are opened manually, which increases mission execution time and the physical load on the crew.

The purpose of this study is to enhance the safety of personnel and the efficiency of combat task execution by implementing an automated system for opening and closing the cargo cabin doors. Solving this issue involves installing hydraulic cylinders inside the fuselage, which will control the doors based on a signal received from a control panel located in the crew cabin. At the same time, the existing hydraulic system does not require an increase in pressure or the installation of additional pump equipment, and the manual mechanism is not dismantled, preserving its function as an emergency backup.

The proposed modernization aligns with practices implemented on helicopters such as the CH-47 Chinook. It is technically and economically feasible and does not require significant structural changes to the helicopter.

RESEARCH OF WAYS OF IMPROVING THE POWER PLANT OF THE IL-76MD MEDIUM TRANSPORT AIRCRAFT

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Today, the military transport aviation of the Ukrainian Armed Forces is equipped with IL-76MD aircraft. This medium-sized military transport aircraft is powered by obsolete D-30KP-2 turbojet twin-circuit engines developed more than 45 years ago. These engines have low fuel efficiency, low reliability and create difficulties in their operation due to the shortage of original spare parts. All of this reduces the efficiency and combat readiness of the aircraft, which is why the modernisation of the IL-76MD powerplant is urgent.

One of the most promising options for improvement is to replace the D-30KP-2 engine with a more modern WS 18 turbojet engine based on the Chinese D-30KP-2 upgrade.

В The paper examines the technical and operational features of the WS-18, justifies its compatibility with the IL76MD airframe, and identifies potential benefits and risks of such a replacement in the context of long-term operation of the aircraft in military transport aviation.

The article analyses the advantages of using the WS-18 engine: reduced fuel consumption, increased flight range, and increased cargo capacity of the IL-76MD aircraft.

RESEARCH INTO MODERNIZATION PATHWAYS FOR THE AIRFRAME STRUCTURE OF THE L-39 AIRCRAFT

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Based on combat experience gained during the full-scale invasion by the Russian Federation, Ukraine's current military and political situation remains complex. Hostilities have continued for over three years across many regions and oblasts of the country, provoked by Russian occupiers.

Given the active use of L-39 trainer aircraft in wartime conditions in Ukraine and the increased combat loads, the issue of reduced service life and reliability of the airframe structure –manufactured from outdated materials – has become increasingly relevant.

To enhance combat effectiveness and extend the service life of these aircraft, it is advisable to modernize them by replacing the airframe skin with advanced composite materials, specifically carbon fiber polymers. Modern aircraft are already composed of up to 50% composite materials, and high-strength steel is being replaced with lightweight aluminum alloys.

Such a replacement would reduce the overall structural weight, improve resistance to dynamic loads and corrosion, and in turn, enhance maneuverability, increase aircraft lifespan, and lower operational costs in both training and combat conditions.

The study has shown that replacing the airframe skin material is a feasible and effective step toward increasing the combat capabilities of the L-39 aircraft and aligning it with modern aviation standards.

STUDY OF WAYS TO IMPROVE THE POWER ELEMENTS OF THE MI-8 HELICOPTER

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In connection with the full-scale invasion of the Russian Federation into the territory of the independent state of Ukraine, and based on combat experience, the use of the Mi-8 helicopter is key in military aviation. Ensuring its reliability and durability in combat conditions is an urgent task for aviation engineering.

Structural strength elements such as frames and attachment points for racks and assemblies are subjected to significant loads during flight and landing, especially in combat conditions, based on the combat experience of the Mi-8 helicopter.

The main problems that arise during operation include the risk of overloading the force elements of the chassis strut attachment units, loss of material strength, and uneven loading. Improvement of the force elements involves both the use of more durable materials and the introduction of design changes aimed at even load distribution.

Based on combat experience, it is worth paying attention to the impact of various operational factors, such as flight intensity, storage and operating conditions, on the long-term stability of the power spar. It is important to develop an optimal maintenance programme that includes periodic controlled loading, testing and inspection of the power spars.

The research and implementation of ways to modernise power elements will help to increase combat survivability, reduce maintenance frequency and increase the service life of the Mi-8 helicopters.

STUDY OF AREAS OF IMPROVEMENT OF THE FIGHTER AIRCRAFT ENGINE LAUNCH SYSTEM

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As experience in Ukraine shows, the specifics of combat operations by units of the Armed Forces require air support. A key element of this assistance is to ensure air dominance, eliminate ground targets and escort heavy aircraft. Timely air superiority and the elimination of ground targets guarantee the overall success of military operations.

At the same time, a fighter jet is a defensive weapon, and fighter aircraft have no specific role. However, today, based on the experience of military operations, with the increase in the thrust of these aircraft (and, accordingly, their load capacity), fighters have been able to effectively strike ground targets, and in combat conditions have become a universal weapon. In this context, the overall goal of the study is to investigate methods of improving the fighter engine start system with the prospect of achieving an immediate advantage in combat.

This report discusses the improvement of the fighter jet engine launch system. The main focus is on the improvement of the turbofan engine witch a free turbine power unit compressor, which aims to increase power. This is expected to lead to a reduction in launch time on the fighter.

CONVECTIVE FILM COOLING OF THE COMPRESSOR TURBINE NOZZLE BLADES: IMPLEMENTATION METHODS AND EFFICIENCY

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The modernisation of existing aircraft is a priority in the context of its further development and improvement to increase combat effectiveness.

To increase the temperature of the gases in front of the compressor turbine and increase engine power, it is proposed to switch from a convective cooling system to a combined one.

When the gas temperature upstream of the turbine rises to 1300 K, the air consumption required to cool the nozzle blades with combined cooling reaches 8% of the air consumption at the compressor inlet.

The design feature is that it is proposed to make cylindrical cavities in the body of the nozzle blade on the surface from the back, trough and edges along the entire length of the blade. The cavities should be closed with a hole plate on top.

This reduces the intensity of turbulent transport in the film boundary layer and laminarisation of the flow, and therefore the protective effect of the cooling air film will increase and remain at large distances from the blower.

In combination with convective and film cooling of the blade, this will make it possible to increase the gas parameters upstream of the turbine to a predetermined value, increase the service life and reduce the cooler consumption, and thus significantly increase the turbine efficiency.

Implementation of the proposed engineering solutions will increase engine power by 9% and reduce specific fuel consumption by 3%, which will contribute to increased combat effectiveness, improved high-speed performance and expanded helicopter capabilities.

SUBSTANTIATION OF RECOMMENDATIONS FOR IMPROVING THE QUALITY OF THE MI-24 HELICOPTER REPAIR SYSTEM BASED ON COMBAT EXPERIENCE

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Attack and transport helicopters are important in today's environment. Combat experience has become the basis for their modernization to better meet the requirements of the modern battlefield. The Mi-24 helicopter is a multi-purpose combat vehicle capable of simultaneously firing at the enemy and transporting troops. However, due to modern warfare, helicopters are heavily damaged, so it is necessary to improve the quality of the repair system.

The paper substantiates recommendations for improving the quality of the Mi-24 helicopter repair system based on combat experience. The author analyzed the flight and technical characteristics of the Mi-24 attack helicopter and the peculiarities of its combat use. The existing system of restoration of damaged aircraft at aircraft repair enterprises is studied, its effectiveness in the context of modern armed conflicts is analyzed.

Based on the data obtained, proposals have been developed to implement modern technical and organizational solutions aimed at improving the efficiency of repairing helicopters with combat damage in combat operations. Implementation of these recommendations will reduce the time required to restore the equipment, increase its combat readiness and overall reliability of the aircraft fleet.

STUDY OF WAYS TO IMPROVE THE TACTICAL AND TECHNICAL CHARACTERISTICS OF THE MI 24 HELICOPTER

V. Kapytsia
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Attack and transport helicopters are of great importance in modern general combat. Combat experience has led to the modernization of these vehicles to better adapt to the requirements of the modern battlefield. The Mi-24 is a multi-purpose attack helicopter that combines combat support and airborne transportation functions. At the same time, given the current requirements for aviation, its tactical and technical characteristics need to be significantly improved.

After analyzing the prototype control system to ensure reliability, simplification of repair and maintenance, it was proposed to replace the rigid wiring of the control of the skewer in the longitudinal-transverse channel with electric wiring.

Electric remote control eliminates the need for heavy and complex mechanical rods and levers, which reduces weight and increases reliability. The redundancy of electronic channels ensures high fault tolerance, and the ability to quickly diagnose faults greatly simplifies maintenance. In addition, electronic components require significantly less regular maintenance than traditional mechanical systems.

The introduction of remote wiring into the helicopter's control system for the automatic rollback is a feasible and technically sound solution. Such modernization can significantly improve flight reliability and safety, reduce the weight and volume of mechanical components, and simplify maintenance and repair.

IMPROVEMENT OF AI-24VT ENGINE PARAMETERS TO ENHANCE THE OPERATIONAL EFFICIENCY OF THE AN-26 AIRCRAFT

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In the current conditions of combat operations, the requirements for military transport aviation have significantly increased, particularly in terms of efficiency, reliability, and survivability. Despite its long service life, the An-26 aircraft continues to perform vital logistical tasks, but its technical potential is limited by the outdated characteristics of its powerplant.

The aim of this study is to substantiate the feasibility and directions for improving the main parameters of the AI-24VT engine in order to enhance the overall efficiency of the aircraft in combat areas. This is expected to be achieved by replacing the turbine blades with ones made from more advanced heat-resistant materials, which will increase both the efficiency and the lifespan of the engine components. Improvements to the turbine cooling system and the implementation of more precise fuel metering will reduce specific fuel consumption. Additionally, the use of improved sealing elements and bearing assemblies is proposed, which will decrease frictional energy losses and extend the engine's overhaul life.

The research on improving the main parameters of the AI-24VT engine focuses on increasing thrust, reducing specific fuel consumption, and extending engine life. This may include optimizing the compressor and turbine (new blade profiles, higher compression ratio), improving the combustion chamber (more efficient fuel-air mixing), implementing modern control and diagnostic systems, and using new heat-resistant materials. As a result, the power, fuel efficiency, and overall operational effectiveness of the An-26 aircraft will be increased without the need for complete replacement of the AI-24VT powerplant.

STUDY OF THE DIRECTIONS OF IMPROVEMENT OF FUEL SYSTEM ELEMENTS BY MEANS OF CONSTRUCTIVE CHANGES TAKING INTO ACCOUNT COMBAT EXPERIENCE

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The operation of the AN-26 aircraft in the conditions of intensive combat operations in the war against the Russian Federation, especially in the area of active use of enemy air defence, places increased demands on the reliability and survivability of its fuel system.

The combat experience of recent years shows that the aircraft fuel system is one of the most vulnerable weapons systems when performing missions in the combat zone. Damage to the fuel tanks can lead to leaks, fires, reduced combat effectiveness or complete loss of the aircraft. Taking into account the specifics of the AN-26 combat use – transportation of personnel, cargo, evacuation of the wounded and special missions – improving the reliability of the fuel system is an urgent task.

The analysis of the AN-26 combat experience and operational experience indicates the need to improve the fuel system structural elements to ensure their resistance to damage, minimise fire hazard, increase survivability and maintain functionality during flights in the area of active combat operations. The introduction of design changes, namely the improvement of the neutral gas system and filling of groups of caisson tanks with spongy synthetic material (polyurethane foam), installation of additional.

STUDY OF THE INFLUENCE OF OPERATIONAL FACTORS ON THE LOAD OF THE MAIN GEARBOX MOUNTING FRAME OF THE MI-24 HELICOPTER

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The Mi-24 helicopter is a multi-purpose combat aircraft that is extensively used under conditions of increased operational loads. Its structural components, particularly the main gearbox mounting assembly to the frame, are subject to constant dynamic forces arising during takeoff, landing, maneuvering, and combat operations. Under such conditions, it is crucial to consider a range of operational factors that may cause uneven load distribution, oscillations, vibrations, and the accumulation of fatigue damage.

Temperature fluctuations play a significant role, affecting the stiffness and mechanical properties of the structural materials. Corrosive environments, dust, moisture, and mechanical impacts resulting from combat damage further complicate operational conditions. These factors not only alter the dynamic behavior of the gearbox mounting assembly but may also lead to the premature failure of individual components, directly threatening flight safety.

Research on the loading of the gearbox frame mounting enables a deeper understanding of the mechanisms leading to critical structural states and allows for accurate prediction of the component's service life. The results of such studies form the basis for developing effective recommendations aimed at improving the reliability of the assembly units.

STUDY OF THE INFLUENCE OF OPERATIONAL FACTORS ON THE LOADING AND RESOURCE CONSUMPTION RATE OF THE AN-26 AIRCRAFT STRUCTURE DURING FLIGHT IN A TURBULENT ATMOSPHERE

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The An-26 is a multipurpose transport aircraft that is widely operated in both peacetime and wartime conditions. A distinctive feature of its operation is frequent flights at low and medium altitudes, which are often accompanied by exposure to turbulent atmospheric zones. Such conditions significantly affect the level of aerodynamic and inertial loads on structural elements, particularly the wings, fuselage, and engine mounting assemblies. Turbulence is one of the most unpredictable factors, capable of substantially amplifying variable loads and accelerating the process of fatigue failure in materials.

Under conditions of prolonged operation, it becomes necessary to account for the influence of atmospheric disturbances on the rate of structural resource consumption. This is especially relevant for aircraft performing flights in areas with increased turbulence. The study of loads during flight in a turbulent atmosphere makes it possible to model real operational scenarios.

The results of the conducted research allow the development of practical recommendations for extending the service life of the An-26 aircraft, optimizing operational regimes, and improving maintenance procedures.

STUDY OF IMPROVEMENT METHODS FOR TRANSMISSION ELEMENTS OF A LIGHT PRIMARY TRAINING HELICOPTER

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The full-scale armed aggression of Russia against Ukraine has imposed new demands on the military training system, particularly in the training of army aviation pilots. Under current conditions, the use of reliable and cost-effective training platforms – especially light primary training helicopters – has gained special importance. The efficiency of their operation largely depends on the reliability of the transmission system, which ensures the transfer of power from the engine to the rotors. Therefore, improving transmission components to enhance service life, reduce weight, noise, and vibrations, and increase maintainability is a relevant objective.

This study analyzes the main transmission components – gearboxes, shafts, couplings, and bearings. Modern technical solutions are considered, such as the use of lightweight and durable materials, advanced surface treatment methods, vibration isolation, and the integration of condition monitoring systems.

An engineering concept for the transmission of a light training helicopter is proposed, focused on weight minimization, improved efficiency, and simplified maintenance. The design includes an integrated gearbox, composite shafts, and damping elements. Requirements for compactness, manufacturability, and adaptability to different types of powerplants are also addressed.

The implementation of the proposed solutions will enhance flight safety, extend the service life of transmission components, and reduce maintenance costs.

RESEARCH ON IMPROVING THE HANDLING CHARACTERISTICS OF THE Mi-8MT HELICOPTER

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In the current context of full-scale armed aggression against Ukraine, army aviation plays a key role in ensuring mobility, fire support, casualty evacuation, and logistical support of troops. Special importance is attached to the operation of the multi-purpose Mi-8MT helicopter, which serves as one of the main platforms of the Army Aviation of the Armed Forces of Ukraine.

Particular attention is given to improving the lubrication system of the TV3-117VM engine used in the combat helicopter, with the goal of enhancing the cooling of the engine’s third bearing support – a critical aspect under active operation by the Armed Forces of Ukraine.

Improving the lubrication system can be achieved by increasing its efficiency. The paper proposes a method of increasing the pump’s performance by modifying its geometric characteristics, specifically by increasing the gear width of the pumps.

Considering the feasibility of engine modernization and the need for simple solutions that do not significantly alter the engine’s design, the proposed improvement – the use of higher-capacity oil pumps – appears to be a rational approach. As a result, it is expected to enhance reliability under combat conditions, extend engine service life, reduce maintenance costs, and improve overall engine performance.

RESEARCH ON WAYS TO IMPROVE THE COMBUSTION CHAMBER ELEMENTS OF THE MI-8MSB HELICOPTER POWERPLANT BASED ON COMBAT EXPERIENCE

R. Makei
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Taking into account the combat experience gained during the repulsion of Russian aggression on the territory of Ukraine, aviation equipment requires modifications that will extend its service life in order to gain an advantage over the enemy in the air.

The combustion chamber is one of the structural components of the engine. During intensive use in combat conditions, overheating factors of the combustion chamber were identified, leading to the burnout of its elements, which makes further engine operation impossible.

One approach to solving the problem of combustion chamber overheating is to improve fuel dispersion using injectors, which ensures a uniform flame front.

The paper proposes design changes to the flame tube front device, specifically the introduction of a fuel injector with additional air swirlers to stabilize the flame front and improve mixture formation. This will reduce the temperature of the flame tube components and the overheating of the combustion chamber casing walls. The advantages include the simplicity of the modification and a significant improvement in engine reliability.

Thus, the modernization of the flame tube front device of the combustion chamber will significantly increase the overall engine reliability, especially under combat conditions, where the engine operates under increased load. This demonstrates the feasibility of its research for implementation in aircraft design.

SUBSTANTIATION OF RECOMMENDATIONS FOR IMPROVING THE AN-26 AIRCRAFT RECOVERY SYSTEM BASED ON COMBAT EXPERIENCE

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The An-26 is one of the most widely used transport aircraft. Its use in combat operations during the Russian-Ukrainian war revealed a number of shortcomings in the existing maintenance and repair system.

The problem of restoration is especially relevant in the war zone, where there are limitations on resources, time and safety of repair activities.

Combat experience has shown that after even minor damage, the existing system often does not allow for quick diagnosis and rapid recovery. This requires more time and resources for repairs and reduces the fulfilment of logistical tasks.

In view of the above, the paper substantiates the need to modernise approaches to the maintenance of the Ан-26 aircraft. In particular, improvement of the system for tracking the technical condition using digital platforms, automation of accounting and control of technical resources. Particular attention is paid to the training of technical personnel and increasing their readiness to act in conditions of limited time and under fire.

The developed recommendations are intended to help preserve the flight and technical life of the aircraft and reduce maintenance costs.

RESEARCH ON THE IMPACT OF LOADS ON THE MAIN LANDING GEAR STRUTS OF THE MI-24 HELICOPTER DURING HARD LANDING

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The Mi-24 helicopter is renowned for its reliability and versatility in performing a wide range of missions. It is actively used during the full-scale invasion of the Russian Federation into Ukraine, carrying out combat, transport, and evacuation missions. One of the key components of its design is the main landing gear struts, which ensure stability during landing and takeoff, as well as shock absorption from the terrain's impact on the helicopter.

The main objective of this work is to study the structure of the Mi-24 helicopter landing gear struts to enhance operational efficiency and safety, taking into account combat experience gained during the full-scale invasion of Ukraine.

Improving the design of the Mi-24 landing gear struts may include the enhancement of strut assembly units to increase strength, as well as the optimization of geometry to improve the helicopter's stability and aerodynamic characteristics. New technologies may also be introduced to better adapt to various operating conditions and reduce maintenance costs.

Based on the obtained calculation results and load analysis, it is possible to determine the necessary measures to maintain and preserve the optimal condition of the load-bearing frame and landing gear attachment points.

It is advisable to establish regular inspection and monitoring of the load-bearing frame and landing gear attachment points to detect possible deformations, damage, or weak spots. Based on this data, recommendations can be developed for timely repair or replacement of components. Additionally, attention should be paid to the influence of various operational factors, such as flight intensity, storage, and operating conditions, on the long-term durability of the load-bearing frame and landing gear struts.

RESEARCH ON THE DIRECTIONS FOR IMPROVING THE CONTROL SYSTEM OF THE MIG-29 FIGHTER

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In modern air combat conditions, fighter aircraft must meet the growing demands for maneuverability, control accuracy, and survivability. The experience of combat operations during the full-scale Russian invasion of Ukraine has demonstrated the importance of operational responsiveness to changes in the tactical situation and the need to improve aviation systems, particularly control systems.

This paper explores the possibilities of improving the MiG-29's control system by integrating a fly-by-wire system, adapted from the Su-27 fighter. This replacement allows for optimizing the aircraft's response to pilot inputs, increasing the accuracy of combat maneuvers, and reducing the mass and complexity of mechanical components.

An analysis of various types of control systems for fighter-class aircraft was conducted, and ways to enhance the maneuvering characteristics of the MiG-29 were explored. The work proposes a project to replace the MiG-29's standard control system with a fly-by-wire system and addresses the technical maintenance of the upgraded system. The proposed measures aim to improve the aircraft's response to pilot commands, enhance stability in combat damage conditions, and generally increase the effectiveness of the MiG-29 in modern air combat.

By transitioning to the fly-by-wire control system for the MiG-29 fighter, improvements in control accuracy, response speed, and reliability in complex combat conditions have been achieved. The control system's weight was reduced by 8–21%, contributing to better maneuverability and reduced pilot workload. It is difficult to provide an exact quantitative assessment of its effectiveness in combat conditions due to the lack of experimental data.

RESEARCH OF WAYS TO IMPROVE THE EFFICIENCY OF THE FIRE CHAMBER OF THE MI-24 SERIAL STRIKE HELICOPTER

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The Armed Forces of Ukraine continue to operate the Mi-24 attack helicopter, whose main purpose is to provide fire support to ground forces. The helicopter's power plant includes two TV3-117VMA gas turbine engines, which operate in extremely difficult combat conditions.

The results of the analysis of the technical condition of the engine indicate an increased vulnerability of the combustion chamber under the influence of extreme thermal and mechanical loads. In order to improve the reliability and efficiency of its operation, a number of design improvements have been proposed. In particular, it is envisaged to install a conical nozzle with an optimized opening angle, as well as to integrate additional air holes into the flame tube body. These openings provide a directed air supply to the active combustion and mixing zones.

The implementation of these engineering solutions improves the process of fuel-air mixture formation and stabilization of the combustion process, as well as intensifies air cooling of internal surfaces by forming a protective air film along the walls of the flame tube, which in turn reduces the risk of overheating, increases the thermal resistance of structural elements and reduces the likelihood of burnout. In addition, the application of a heat-resistant coating to the inner surface of the flame tube helps to stabilize the heat load and extends the life of the combustion chamber.

STUDY OF THE INFLUENCE OF OPERATIONAL FACTORS ON THE LOADING OF THE LANDING GEAR AND AIRFRAME OF THE AN-26 AIRCRAFT DURING LANDING AND MOVEMENT ON AN UNEVEN AIRFIELD

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The AN-26 turboprop is a multi-purpose transport aircraft that performs a wide range of tasks. A special feature of its operation is a large number of take-offs and landings during training flights and other missions. This aircraft allows for the use of rough and uneven runways, including unpaved ones. As a result, the service life of the airframe and landing gear is significantly consumed. The most affected are the landing gear struts, spars, power struts and nerves. Airfield unevenness is the main factor that consumes the life of an aircraft.

Over the life of an aircraft, it becomes necessary to take into account the load from travelling on uneven airfields on the rate of airframe and landing gear service life. This is especially true for aircraft operating on unpaved runways. Analysing the impact of operational factors on the load on the landing gear and airframe using computer modelling makes it possible to assess the real factors when flying on an uneven airfield.

The results of the research make it possible to take measures to extend and preserve the service life of the AN-26 airframe and landing gear, and to increase the efficiency of technical operation.

AERODYNAMIC CONFIGURATION OF A SWARM FIGHTER UAV

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The development of a fighter UAV is a promising direction in military aviation. The use of autonomous swarms of fighter UAVs will enable the creation of an effective system to counter enemy UAVs, enhancing the operational effectiveness of UAV swarms.

The modification into a swarm fighter UAV is based on the fundamental aerodynamic configuration of a UAV, which features improved aerodynamic properties compared to its prototypes, resulting in enhanced flight performance characteristics. The fundamental aerodynamic configuration of the UAV is based on a tailless aerodynamic balancing scheme. The arch-ring wing of the fundamental UAV aerodynamic configuration includes a ring section that completes the load-bearing scheme of the arched wing section, increasing the efficiency of the propulsion system's propeller.

During the modification of the basic UAV configuration into a fighter UAV, an additional engine is incorporated into the propulsion system to increase thrust-to-weight ratio and maximize flight speed. Increasing the maximum flight speed of the fighter UAV is crucial, as among all parameters defining success in aerial combat against small UAVs, the most significant factor is the maximum the fighter.

A preliminary evaluation of the effectiveness of the swarm fighter UAV in intercepting and neutralizing enemy reconnaissance UAVs is presented.

BASIC AERODYNAMIC CONFIGURATION OF A MILITARY SWARM UAV

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The development of military swarm UAVs is a promising direction in military aviation, as autonomous UAV control enhances combat mission efficiency and eliminates personnel losses. The proposed basic aerodynamic configuration of a UAV features improved aerodynamic characteristics compared to its prototypes and serves as the foundation for swarm UAV modifications. The aerodynamic properties of the swarm UAV configuration determine its flight performance characteristics.

For the basic aerodynamic configuration, a tailless aerodynamic balancing scheme with an arch-ring wing has been selected. The arch-ring wing incorporates a ring section that completes the structural load-bearing scheme of the arch section while increasing the efficiency of the propulsion system's propeller. The shape of the arch-ring wing is particularly suitable for swarm UAV modifications.

When modified into a low-observable strike UAV, the entrance to the arch-ring wing section is covered with a grid to prevent electromagnetic radiation from enemy radar stations from penetrating inside.

When modified into a strike UAV, additional stabilizing surfaces are added on two booms to extend the range of longitudinal center-of-gravity positioning.

When modified into a fighter UAV, an additional engine is integrated into the propulsion system to increase thrust-to-weight ratio.

STUDY OF COMBAT DAMAGE TO THE AIRFRAME STRUCTURE OF THE MiG-29 AIRCRAFT

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The analysis of fighter aviation participation in modern armed conflicts, particularly in the context of the full-scale invasion of Ukraine by the Russian Federation, indicates the high-intensity use of MiG-29 aircraft. Practical combat experience has revealed both the strengths and vulnerabilities of this platform, especially regarding its survivability in environments saturated with air defense systems. This highlights the relevance of studying the nature and consequences of combat damage to the airframe structure.

This work presents a technical analysis of the MiG-29's combat deployment. Effective approaches to meeting tactical and technical requirements have been identified through the analysis of mass-inertial characteristics, particularly takeoff weight. The layout features of the airframe structure were examined with consideration of the operational center-of-gravity limits. The impact of various types of combat damage on critical structural components was studied. The stress-strain state of the main load-bearing elements under extreme conditions was calculated. Strength under critical operational scenarios was also assessed.

The proposed engineering methodology enables rapid evaluation of the aircraft's condition following combat damage and the implementation of justified operational restrictions – including combat load, speed, and flight range – to ensure continued safe operation and enhanced survivability in combat conditions.

DEVELOPMENT OF THE STRUCTURAL AND LAYOUT DESIGN OF A RECONNAISSANCE UNMANNED AERIAL VEHICLE (UAV)

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Analysis of the modern use of unmanned aerial vehicles (UAVs) in military conflicts, particularly in the context of the Russian-Ukrainian war, indicates a growing demand for their structural reliability, technological sophistication, and efficiency in performing reconnaissance missions.

The issue of developing a structural and layout design for a reconnaissance UAV is highly relevant, as it must ensure an optimal combination of flight performance characteristics, autonomy, and survivability.

The process of forming the aerodynamic configuration and structural-layout scheme involves modeling the mutual arrangement of the main structural elements, such as the fuselage, wings, empennage, propulsion system, control systems, and reconnaissance equipment. This enables a balanced compromise between mass and dimensional parameters, aerodynamics, payload placement, and maintenance convenience. Particular attention is paid to assessing the impact of layout decisions on UAV stability and controllability.

To enhance the operational effectiveness of the reconnaissance UAV, modern composite materials, a modular fuselage structure, and adaptive layout schemes are employed, taking into account the variable configuration of equipment depending on mission requirements.

The evaluation of technical solutions made during the design process allows for the identification of weak or limiting elements in the system and enables adjustments aimed at improving the overall efficiency and reliability of the UAV. Modeling and aerodynamic analysis provide recommendations for further improvement of the UAV's structural and layout design.

AERODYNAMIC LAYOUT OF A "SWEET" TRANSPORT UAV

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As the experience of the war in Ukraine shows, a feature of conducting combat operations by units and subdivisions of the Armed Forces is the need to ensure the actions of troops in any situation and their rapid response to any changes in the situation. An important part of this response is the ability to quickly ensure logistics between units, units and their supply points. Timely delivery of critically important cargo to areas of combat operations increases the survivability of troops.

Transport The tasks are currently being performed by military transport and army aircraft crews. However , in conditions of saturation of the battlefield with air defense means, this is accompanied by personnel losses. At the same time, transport vehicles may well become an alternative to manned vehicles. UAVs. However, existing UAVs have low payload capacity and range. In this regard, work on creating a transport-type UAV capable of carrying a wide range of payloads and operating covertly, autonomously, and as part of a swarm is relevant.

The modification into a swarm transport UAV was carried out on the basis of the basic aerodynamic layout of the UAV, which has improved aerodynamic properties and, accordingly, improved flight characteristics compared to the prototypes. The basic aerodynamic layout of the UAV is based on a tailless aerodynamic balancing scheme, therefore, when modifying into a transport UAV, a tail fin is added to the basic layout on two beams to increase the range of longitudinal centering.

RESEARCH IN THE AREAS OF IMPROVING THE FUEL EFFICIENCY (ECONOMY) OF THE Mi-8 TYPE HELICOPTER

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The Mi-8 helicopter, which is widely used in the Armed Forces of Ukraine, demonstrates high reliability and versatility. However, given the combat experience of recent years, including the full-scale invasion of Russia, the task of improving fuel efficiency is becoming more urgent.

Fuel efficiency is an important factor in the operation of helicopters, including the multi-purpose Mi-8.

Reducing fuel consumption allows to increase flight range, reduce operating costs and minimize environmental impact. The main areas of efficiency improvement include aerodynamic optimization, powerplant improvement, weight reduction, improved operating modes and the use of alternative fuels.

The helicopter's fuel efficiency depends on the following factors: fuel tank volume, takeoff weight and flight range. Since we do not change the fuel tank volume and weight, we decided to increase the flight range.

The flight range can be increased by: aerodynamics of the aircraft, reduction of takeoff weight (use of composite material) and modernization of the power plant.

The engine efficiency can be improved by increasing the combustion efficiency in the combustion chamber.

Operational measures include the introduction of flight control algorithms that reduce fuel consumption and the use of avionics to optimize routes.

A promising area is also the study of the possibilities of using biofuel or synthetic aviation fuel, as well as hybrid power plants. Implementation of these measures will help to increase the efficiency and effectiveness of the Mi-8 helicopter.

DEVELOPMENT OF MODELS OF SPECIAL DEVICES FOR THE PROTECTION OF THE MI-8 HELICOPTER IN THE EVENT OF A COLLISION WITH OBSTACLES SUCH AS POWER LINES

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During the full-scale invasion of the Russian Federation, Mi-8MT helicopters play a key role in supporting combat operations, effectively performing tasks in different types of groups of troops.

Due to their versatility, which includes the ability to carry out amphibious operations, evacuation of the wounded, transportation of goods, provision of fire support and reconnaissance, they demonstrate exceptional versatility in combat conditions.

Analyzing the experience of using Mi-8MT helicopters during the repulsion of the armed aggression of the Russian Federation, and flying at ultra-low altitudes, avoiding the influence of enemy air defense systems, precedents for helicopter losses due to their collision with power lines have become more frequent.

To solve this problem, there is a need to improve the Mi-8MT helicopter. To ensure safety and reduce the likelihood of destruction in the event of a collision with obstacles such as power lines, it is proposed to install special devices (cutters) on it. Studies have determined that a special device installed in the nose of the fuselage reduces the likelihood of an accident in a collision with power line wires by 88%. The proposed measures should help reduce the occurrence of emergencies when flying at night and at low altitudes, where there is a possibility of a helicopter colliding with a power line and the loss of combat-ready army aviation.

RESEARCH IN THE AREAS OF IMPROVING THE FUEL EFFICIENCY (ECONOMY) OF THE Mi-24 TYPE HELICOPTER

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Today, helicopter air transport has become very popular, performing various tasks related to a wide range of missions. The Mi-24 helicopter is one of the most widely used multi-purpose attack and combat helicopters. Landing and cargo delivery, infantry fire support, and evacuation of the wounded from the battlefield are just a small part of the wide range of capabilities of this aircraft. This type of helicopters uses turboshaft aircraft engine which in turn run on jet fuel.

Using a helicopter for its intended purpose and based on the experience of combat operations, the fuel efficiency of this type of equipment depends to a large extent on the powerplant. During takeoff and climb, namely when the engines operate at much higher power, fuel consumption increases due to the increased load on them. In steady-state flight, when the engines operate at rated power, fuel consumption decreases but remains at a fairly high level.

There are several ways to reduce the negative impact on fuel efficiency and increase the flight range of helicopters. One of them is to improve engine efficiency, which leads to a reduction in fuel consumption. Another important point is the efficient use of Mi-24 helicopters: maximum and rational filling of the cargo compartment, small arms and combat load, and proper optimization of routes.

Design bureaus headed by scientific and engineering personnel play a key role in improving fuel efficiency. Engineers and scientists are working on improved engine designs, aerodynamics and fuel systems. The new gas turbine engines of the 21st century are equipped with advanced combustion chambers, improved fuel injection systems, more efficient compression in compressors and modern ignition technologies, which ensures more complete combustion of fuel.

Thus, the remotorization of existing Mi-24 helicopters and improvement of their flight characteristics directly affect the reduction of fuel consumption and contribute to the helicopters' fuel efficiency.

RESEARCH ON IMPROVING THE SURVIVABILITY OF THE Mi-8MSB-V HELICOPTER

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In the current context of armed conflict, ensuring the survivability of aviation assets, particularly helicopters, which perform combat missions under direct enemy fire, has become increasingly critical. Based on combat experience gained during military operations, there is an evident need to modernize existing aviation systems in order to gain a tactical advantage over the adversary.

One of the key components affecting survivability is the fuel system, as damage to it poses a high risk of fuel ignition, potentially leading to the explosion of fuel-air vapor mixtures within the ullage space, which in turn results in catastrophic outcomes.

A promising direction for enhancing the survivability of the Mi-8MSB-V helicopter is the implementation of an inert gas system, designed to prevent fuel vapor explosions by displacing oxygen with an inert medium – carbon dioxide.

The system comprises a gas cylinder, pressure reducer, filter, heating unit, and an electro-pyrotechnic device for gas flow control. Its advantages include a simple design, remote control capability, and real-time monitoring via a display panel.

The deployment of this system significantly reduces the risk of explosion resulting from combat-related fuel tank damage, thereby increasing the chances of crew survival.

In conclusion, the installation of an inert gas system proves to be an effective method for improving the combat survivability of the Mi-8MSB-V helicopter. This confirms the feasibility and importance of further research into integrating such a system into the aircraft's design.

RESEARCH INTO WAYS TO IMPROVE THE SYSTEM FOR PROTECTING FIGHTER AIRCRAFT ENGINES FROM FOREIGN OBJECT IMPACT

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Modern combat operations are accompanied by the active use of aviation in conditions of limited infrastructure – on temporary or damaged runways, which increases the risks for aircraft power plants. One of the critical threats is the ingress of foreign objects into the air intakes of turbojet engines, which leads to compressor damage, reduced resource and increased probability of failure.

The paper analyzes the basic engine protection system of the MiG-29 fighter with automatic switching between the upper and axial air intakes. Despite its effectiveness in standard conditions, in combat operation it exhibits limited reliability due to the lack of control of the flap position, insufficient sensitivity of the drives and uncertain structural strength.

As part of the modernization, it is proposed to use an improved design of the protective panel and mesh, which significantly increases the effectiveness of preventing foreign objects from entering the air intake. This is especially relevant during combat operation of aircraft on temporary or damaged runways, where the level of air pollution and the risk of engine damage significantly increase. The updated design provides better aerodynamic consistency, minimal resistance to air flow and high structural reliability. Strength calculations confirm the compliance of the system elements with operational requirements, which contributes to reducing the probability of engine failure, increasing its resource and increasing the overall combat effectiveness of aviation equipment.

WAYS TO IMPROVE THE EFFICIENCY OF THE L-39 TRAINING AIRCRAFT

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The combat experience of recent years has become the basis for improving aviation equipment to enhance its compliance with the conditions of modern armed conflict. This applies not only to combat aircraft but also to training platforms. The L-39 Albatros is a jet-powered, single-engine, two-seat training aircraft that is actively used both for basic cadet training and for advanced pilot qualification. Its limited use as a fighter is due to its modest flight performance characteristics, including compact dimensions and limited armament. At the same time, the L-39 demonstrates effectiveness against small targets such as unmanned aerial vehicles and helicopters.

Currently, the L-39 aviation platform is available in sufficient numbers, with both its military and civilian modifications undergoing systematic upgrades. The modernization includes updates to control, communication, navigation, and weapon systems, which significantly expands the aircraft’s capabilities

During the research, an analysis was conducted on the prospects of using the L-39 in combat conditions, particularly while performing tasks within the framework of the Joint Forces Operation. Key tactical and technical requirements for the modernized version of the aircraft were identified, and the possibility of their implementation was confirmed. In particular, it is proposed to improve flight performance by installing the AI-25TLSh engine and a low-sweep wing, which will increase the maximum horizontal speed and permissible operational overload.

RESEARCH ON WAYS TO IMPROVE THE CHARACTERISTICS OF THE TVAD TURBINE OF THE MI-8MTV HELICOPTER TAKING INTO ACCOUNT COMBAT EXPERIENCE

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Research on the Improvement of the TVaD Turbine Characteristics of the Mi-8MTV Helicopter Based on Combat Experience.

The study of ways to improve the performance characteristics of the TVaD (turboshaft) engine turbine of the Mi-8MTV helicopter, taking into account combat experience, is a relevant task for enhancing the operational efficiency of this aircraft engine under intensive usage conditions. This work analyzes the issues encountered during the operation of the turboshaft engine in combat environments, including the effects of extreme temperatures and increased loads.

The main directions for improving the TVaD turbine characteristics include structural modifications to the cooling system of the compressor turbine (CT) to extend its service life. A critical stage in improving the cooling system is the optimization of heat exchange to reduce overheating of the nozzle guide vanes under high-load conditions. The study proposes replacing the current convective cooling of the nozzle vanes with a more intensive convective cooling method. Additionally, the use of advanced materials and protective coatings contributes to increased component durability.

Furthermore, the integration of modern diagnostic and failure-prediction methods using digital technologies and sensor systems will enable real-time engine health monitoring.

The research findings will support the implementation of structural improvements in the compressor turbine cooling system, thereby enhancing the operational reliability and combat effectiveness of the Mi-8MTV helicopters, which is critically important for their continued deployment in demanding operational environments.

IMPROVEMENT OF THE COOLING SYSTEM AND TURBINE BLADES OF A TWO-SPOOL TURBOFAN ENGINE

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The relevance of this work lies in the fact that, to increase engine power, the use of single-crystal casting of blades together with the given cooling system allows the gas temperature before the turbine to be raised to 1700 K. This is possible because the proposed cooling system meets the requirements necessary for cooling single-crystal turbine blades.

Since the selected alloy can withstand temperatures up to 2000 K, and in this study the gas temperature before the turbine reaches 1700 K, the proposed cooling system proves to be highly efficient. Therefore, in order to further increase engine thrust, it is proposed to reduce the air consumption for turbine cooling from 12% to

7.2%. This would decrease air consumption by 40%, which can be achieved by installing nozzles at the inlet of the heat exchangers.

Conclusion: With an increase in gas temperature before the turbine, the use of single-crystal blade casting becomes effective. The proposed cooling system is suitable for the chosen alloy and contributes to improved thrust characteristics of the engine by reducing the amount of air used for turbine cooling.

RESEARCH ON THE MODERNIZATION PATHS OF THE MI-8 MSB-V HELICOPTER CONDITIONING SYSTEM

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In the context of the ongoing war on the territory of Ukraine against the Russian Federation, prolonged combat operations are taking place. Due to the intensive use of aviation equipment, there is a growing need for continuous improvement and modernization of specific units and systems that ensure flight safety during combat missions.

Based on the combat experience gained during the execution of operational tasks, special attention has been paid to the analysis and justification of technical solutions for modernizing the air conditioning system on the Mi-8MSB-V helicopter.

As part of this modernization, the installation of an air conditioning system is planned, which will provide effective cooling of the crew cabin and the cargo-passenger compartment. This approach is aimed at improving crew comfort and performance during extended flights in demanding combat conditions, as well as reducing the load on the helicopter's standard systems.

INVESTIGATION OF THE LOADS ON AN AN-26 TYPE AIRCRAFT DURING TAXIING ON AN UNEVEN AIRFIELD

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During the full-scale invasion of independent Ukraine, the need for transport aviation increased significantly. Therefore, this study focuses on the An-26 transport aircraft and the loads experienced during taxiing on uneven airfields.

The landing gear of the An-26 aircraft is subjected to vibrations and oscillations during takeoff and landing operations. To counteract such vibrations, some modern aircraft are equipped with automatic oscillation damping systems. These systems function by generating forces and moments that oppose the elastic vibrations of the structure. Standard aircraft control surfaces or additional ones (e.g., those installed in the nose section of the fuselage) may be used for this purpose.

The oscillations that occur when the aircraft moves over rough ground differ from the previously mentioned forced vibrations in that their duration is relatively short (only during takeoff and landing). However, they contribute significantly to structural fatigue damage. Vibrations can cause rapid wear of equipment, make aircraft control during takeoff and landing more difficult, and lead to crew fatigue.

When assessing the operating conditions of equipment, it is important to determine the vibration levels and to identify the causes (sources) of the acting excitation forces.

Experimental calculations have made it possible to implement an automatic oscillation damping system.

STUDY OF WAYS TO IMPROVE THE L-39 AIRCRAFT FUEL SYSTEM

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In the current context of military and political tensions caused by the large-scale armed aggression against Ukraine, the modernization of aviation equipment, including combat training aircraft, is of particular importance. The Air Force of Ukraine actively uses the L-39 Albatros multi-role training aircraft as the main means of primary flight training. Its performance characteristics allow it to provide an adequate level of training for flight personnel to perform combat missions.

One of the promising areas of L-39 modernization based on combat experience is the improvement of the closed-loop fuel system. This includes the installation of an additional built-in fuel tank in the co-pilot's seat, which involves dismantling the ejection seat. This modification will increase the fuel reserve, reduce refueling time and improve the efficiency of the aircraft in combat conditions.

At the same time, this design change affects the weight and center of gravity characteristics of the aircraft, which requires repeated aerodynamic calculations, assessment of stability and controllability of the aircraft with the updated layout. It is important to take into account possible changes in the behaviour of the aircraft during various stages of flight, in particular during maneuvering and combat missions.

In general, such an upgrade requires a comprehensive feasibility study, including structural testing, operational reliability analysis, and risk assessment of the long-term use of the upgraded aircraft in modern conditions.

NECESSITY OF MODERNIZATION OF THE MI-8MT HELICOPTER AND MEASURES AIMED AT ENSURING A COMPLETE ENGINE TESTING CYCLE

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During the full-scale invasion of the Russian Federation, Mi-8MT helicopters have played a critically important role in combat operations, demonstrating high efficiency as versatile aerial platforms. Their multifunctionality includes airborne assault missions, medical evacuation, cargo transportation, fire support, and reconnaissance tasks.

Considering the specific features of the Mi-8MT powerplant, particularly the use of TV3-117VMA engines with increased power output up to 1637 kW, a significant challenge arises in conducting a complete cycle of engine tests – especially at maximum power settings, which typically result in the helicopter lifting off the ground.

This study explores methods to address the issue of full-cycle engine testing and proposes an improvement to the helicopter's main rotor system by installing special loading devices on the rotor blades during engine tests.

Power consumption calculations for the loading device during engine testing were carried out. It was determined that 88% of the engine power is absorbed by the device, enabling full testing of the engine in maximum power mode without the helicopter lifting off the ground.

STUDY OF DIRECTIONS OF IMPROVEMENT OF TRANSMISSION OF HELICOPTER TYPE MI-8 FOR INCREASING ITS SURVIVABILITY

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The experience of modern warfare against the Russian occupation forces has shown how important the role of the Army Aviation units of the Armed Forces of Ukraine, which are armed with Mi-8 helicopters of various modifications, is. They are tasked with destroying the enemy and its equipment on the ground, destroying Shahed-type air targets, landing troops and evacuating the wounded. The success of these tasks depends on the survivability of the helicopter, which is largely ensured by the reliability of its transmission.

This paper investigates the ways to improve the transmission of the Mi-8 helicopter to increase its survivability, namely:

– increasing the diameter of the transmission shaft, with a reduced shaft wall thickness;

– replacement of the metal transmission shaft with a composite one;

– replacement of the mechanical transmission of the rudder with an electric drive, which will allow the shaft to be excluded from the transmission scheme.

Based on the study of the above methods of transmission improvement, the paper concludes that the most rational way is to increase the shaft diameter with a reduced wall thickness. The possibility of implementing the chosen method is confirmed by the relevant calculations performed in the work.

DEVELOPMENT OF THE LAYOUT OF A TACTICAL STRIKE DRONE WITH AN ELECTRIC PROPULSION SYSTEM

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Based on the analysis of the development and use of unmanned aerial vehicles during the repulsion of the armed aggression of the Russian Federation on the territory of Ukraine, the requirements for a tactical-level strike UAV are formed. Among the variety of UAV layouts, the task is to select the optimal parameters to meet the specified tactical and technical requirements, such as a flight range of less than 50 km with a payload of 5 kg, and an electric power plant. For copter-type UAVs, it is not possible to meet the specified performance requirements with the current characteristics of batteries and electric motors. Therefore, a classical aircraft-type UAV layout with a high-mounted wing and an electric motor with a propeller was chosen.

The study compares the layout parameters of a tactical strike UAV, such as wing extension and specific wing load, to ensure maximum aerodynamic quality.

As a result of the study, a tactical strike UAV with an electric propulsion system was developed that meets the specified tactical and technical requirements and has significant advantages over enemy UAVs.

STUDY OF THE EFFECT OF COMBAT DAMAGE TO THE AIRFRAME ON THE STRENGTH OF THE STRUCTURAL ELEMENTS OF THE SU-25 AIRCRAFT

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Statistical data on the participation of attack aircraft in the full-scale invasion of the territory of independent Ukraine shows that aircraft were frequently involved in combat missions. This, in turn, leads to significant losses of aircraft as a result of enemy actions and the use of modern air defence systems. In this regard, the problem of assessing airframe damage in the event of combat damage is becoming more urgent.

This paper presents engineering calculations and analysis of the performance of combat missions by the Su-25 aircraft. The possibility of meeting the specified tactical and technical requirements by determining the normal take-off weight of this aircraft is substantiated. The structural and layout scheme was studied by calculating the operational range of centre of gravity. The influence of combat damage on the structure of the aircraft is also analysed.

The design calculations of the Su-25 airframe's power elements under loads were carried out, as well as a check for compliance with the maximum permissible loads. A verification calculation with the maximum permissible load was performed. The proposed methodology makes it possible to quickly perform engineering calculations and set operational limits necessary to ensure the survivability of the aircraft. In particular, these include restrictions on payload, speed, and flight range.

RESEARCH OF WAYS TO IMPROVE THE TURBINE CHARACTERISTICS FOR MILITARY TRANSPORT AIRCRAFT

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In connection with the full-scale military aggression against Ukraine, the issue of strengthening the state's defense capabilities has become critical.relevance. The use of military transport aviation plays an important rolein the war, performing strategically important logistics and evacuation tasks.and evacuation. The frequent use of military transport aircraft in difficult weather conditions and at high weather conditions and under heavy loads places high demands on engines. They must be not only reliable, but also economical in terms of fuel consumption. There fore, it is important to implement new technical solutions that improve the performance of a gas turbine engine without significantly complicating its production or maintenance.

In this context, the following is of particular relevance research into design solutions that reduce energy losses in the turbine sector is of particular relevance. One of such solutions is the use of a banding shelf on the blade, which reduces the axial flow of gas through the radial gap. This increases overall turbine efficiency and improves the fuel efficiency of the engine.

The paper will analyze the efficiency of the banding, the optimal parameters of its design will be determined, and practical recommendations for implementation to improve turbine performance for a military transport aircraft.

ANALYSIS AND SUBSTITUTION OF THE FLIGHT-TECHNICAL CHARACTERISTICS OF AN ATTACK UAV

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The experience of the Russian-Ukrainian war necessitates the creation of stealthy strike UAVs as part of swarms, which will increase the effectiveness of strike operations. Swarm-based stealth strike UAVs are designed for pinpoint attacks and air defense suppression.

The aerodynamic layout of the strike low-observable UAV has a payload in the bays, based on the basic layout of an arched-ring wing with a propeller in the central nacelle. The aerodynamic arrangement of an arched-ring wing with a propeller is a development of the arched wing with a propeller, in which the reduction of the overall dimensions of the UAV is achieved by the high properties of the upper surface of the wing in interaction with the propeller. In such an arrangement, the propeller is located near the trailing edge and serves to reduce the pressure gradient on the rear half-slope of the lower arched part of the wing, thus preventing the development of tear-off phenomena in it with an increase in the angle of attack, and increasing the load-bearing properties.

Such a layout with an inlet anti-radar grille and lattice rudders can significantly reduce the overall dimensions of the UAV, its radar, infrared and visual visibility, and protect the rotor from damage during takeoff, which is important for the combat use of a stealthy attack UAV as part of a swarm.

RESEARCH ON THE IMPROVEMENT OF LANDING GEAR SYSTEMS FOR THE BAYRAKTAR TB2 UAV

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The Bayraktar TB2 UAV is a foreign-made weapon system used by the Armed Forces of Ukraine, demonstrating high reliability and versatility.However, considering the combat experience of recent years, particularly the full-scale invasion by the Russian Federation, the task of improving the strength and reliability of the landing gear struts has become increasingly relevant. Bayraktar TB2 is one of the most advanced UAVs in its class, which is confirmed by its high reliability, versatility, and combat effectiveness. Nevertheless, due to the experience gained during the full-scale invasion and the deterioration of runway surfaces caused by constant shelling of airfields, there is a growing need to improve the landing gear of such UAVs as the TB2.

The landing gear strut dissipates the impact energy during UAV landings. Given the specific landing characteristics of the Bayraktar TB2 – unlike conventional aircraft – it touches down immediately on all three landing gear struts after the flare phase, which causes additional stress on the nose gear. Strengthening the landing gear reduces the risk of damage during takeoff and landing, as well as during taxiing over uneven surfaces, thereby decreasing the likelihood of UAV loss during an incident. This work presents an improvement to the nose gear by increasing the wall thickness of its structure.

Operational measures can enhance the reliability and service life of the struts. For example, lubrication of the strut improves damping performance and reduces vibration.

A promising direction for future development is the study of possibilities for integrating shock absorbers into the main landing gear struts of the Bayraktar TB2 UAV.

TACTICAL AND STRATEGIC CAPABILITIES OF STRIKE DRONES. MEANS OF IMPROVING THEIR CHARACTERISTICS.

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In the conditions of modern warfare, UAVs have become one of the key factors in the confrontation, allowing to significantly reduce risks to personnel and increase the accuracy of strikes. The efforts of the domestic defense industry have ensured the emergence of over 1 million ordered UAVs and about 500 manufacturing companies. According to Prime Minister Denys Shmyhal, the share of domestic strike drones on the front already exceeds 96%. At the same time, the development of artificial intelligence technologies opens up new possibilities for autonomous target detection and control of UAVs.

Tactically, strike UAVs have dramatically expanded the range of combat capabilities of units. Small FPV "kamikazes" have become available to assault groups and artillerymen and have demonstrated high efficiency in destroying enemy equipment and manpower at the tactical front.

In the future, we should expect deeper integration of Ukrainian drones into network-centric systems: the creation of unified control centers, network cloud communication nodes, and integration with space surveillance systems. Further improvement involves the use of unmanned "convoys" and coordination of actions of several drones in groups (swarm technology). In addition, vertical take-off and landing UAVs are promising for mobile strike operations, as well as supersonic drones to overcome advanced air defense systems. The high demand for autonomous systems on the battlefield means that scientific research and production will receive significant investments: contracted production volumes are already measured in millions of copies.

TECHNICAL SOLUTION FOR THE OPERATION OF THE UAV IN LOW TEMPERATURE CONDITIONS

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The investigates the urgent problem of improving the performance of the Bayraktar TB2 strike UAV in conditions of possible icing during flight. An analysis of the functional limitations of the standard anti-icing system showed its insufficient adaptability to environmental changes, which makes it difficult to use UAVs in regions with harsh climates. In this regard, a technical improvement was proposed by introducing an adaptive multi-mode heating system.

The essence of the proposed solution is to create a flexible modular system that automatically switches between operating modes depending on the actual weather conditions and the level of icing threat. This system operates on the basis of data that is constantly received from temperature, humidity and atmospheric pressure sensors placed on critical parts of the vehicle.

In normal conditions, when the risk of icing is minimal, the system operates in standby mode, maintaining the base temperature of the surfaces with minimal power consumption. If supercooled droplets or high humidity combined with low temperature are detected, the system automatically switches to active mode – electric heating elements are switched on to ensure a rapid increase in temperature in vulnerable areas. If the level of icing exceeds the safe threshold, the emergency mode with maximum heat output is activated to remove the ice immediately.

The multi-mode heating system increases efficiency and saves energy, which is important for UAVs. Together with hydrophobic coatings and heated composites, this increases the reliability of the Bayraktar TB2 in low temperature conditions.

MODERN METHODS OF MODERNIZATION OF TRANSPORT AIRCRAFT DE-ICING SYSTEMS

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Ensuring the reliable and safe operation of transport aircraft in adverse meteorological conditions requires the introduction of highly efficient de-icing systems. Current technologies in this area are often characterized by insufficient energy efficiency, limited reliability, and high operational losses. In this regard, it is important to scientifically substantiate and develop approaches to modernizing existing de-icing systems in order to increase their efficiency and reduce maintenance costs.

In order to improve the efficiency of the de-icing system, an innovative approach combining electrothermal and nanocoating protection is proposed. The proposed system uses flexible graphene heating elements that ensure uniform distribution of thermal energy over critical areas of the aircraft structure. Additionaly, a superhydrophobic nanocoating is used to reduce the adhesion of ice to the surface. The combination of active and passive protection methods can significantly reduce energy consumption compared to traditional de-icing technologies.

Studies have shown that the modernized de-icing system increases protection efficiency, reduces energy consumption and improves aircraft reliability. It also helps to reduce operating costs and increases the efficiency of operation in difficult conditions.

DESIGN AND DEVELOPMENT OF A CLASS I FIXED-WING STRIKE UAV

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In the context of the full-scale war in Ukraine, drones have become a key tool for modern combat operations. They enable reconnaissance, fire adjustment, and precision strikes on enemy targets, significantly enhancing the effectiveness of military actions. Strike UAVs, in particular, play a crucial role by destroying critical targets deep behind enemy lines, even under conditions of active electronic warfare.

This study analyzes the successful deployment of both Ukrainian and foreign drones, which have demonstrated their effectiveness in a variety of operational roles. Based on this analysis, key requirements for next-generation UAVs have been outlined, focusing on their long flight range, payload capacity, autonomy in case of signal loss, and resistance to advanced electronic warfare systems. Additionally, the study emphasizes the necessity of developing UAVs that can operate in complex environments while maintaining high operational efficiency.

The proposed design concept combines ease of manufacturing, simplicity in maintenance, and the potential for mass production. Additionally, the use of advanced materials plays a crucial role in ensuring the UAV's performance and durability in field conditions. This approach allows for rapid responses to battlefield needs and ensures continuous renewal of the UAV fleet.

The development and mass production of this type of UAV represent a critical step in strengthening Ukraine’s defense capabilities, reducing reliance on foreign weaponry, and fostering the growth of the national defense industry. By focusing on these strategic goals, Ukraine can ensure a more resilient and self-sufficient defense sector, capable of meeting the challenges of modern warfare.

DEVELOPMENT OF PROPOSALS FOR IMPROVING THE FUEL MEASURING PART OF THE FIGHTER AIRCRAFT FUEL CONSUMPTION SYSTEM TO IMPROVE THE ACCURACY OF MEASUREMENT AND CALCULATION OF THE FLIGHT RANGE

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The use of tactical aircraft is an integral part of combat operations, in particular to defeat enemy ground forces and counter enemy aircraft. In the course of performing missions, the accuracy of the fuel balance measurement by the MiG-29 fuel and flow measurement system plays an important role in determining the estimated flight range and the actual value of the fuel level, which is a rather important component of flight safety.

The MiG-29's fuel and flow metering system includes DT-36A fuel sensors, which are outdated and inaccurate enough to lead to high errors in calculating the remaining fuel on board the aircraft, and can reach 5 to 15% deviations from actual measurements.

Taking into account the shortcomings of such sensors, to improve the accuracy of fuel level measurements, it is proposed to reduce the error by integrating ultrasonic fuel gauge sensors.

To achieve this goal, it is proposed to replace the existing capacitive sensor DT-36A in the fuel measuring part of the STR6-2A system with a multi-fuel sensor of the DRP type, which does not depend on the type of fuel. This will significantly reduce the fuel level measurement error to 1-2%.

This modernization will improve the accuracy of onboard fuel level measurement and calculate the estimated flight range more accurately, thereby potentially increasing the combat radius and enhancing the combat capabilities of the aircraft in the performance of combat missions.

STUDY OF THE PROCESSES OF VOLTAGE REGULATION OF AIRCRAFT GENERATORS USING ADAPTIVE CONTROLLERS

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To ensure the stable operation of aircraft equipment, the voltage of aircraft generators, regardless of the size, nature of the electrical load and operating mode, must vary within specified limits. For this purpose, voltage regulators operate together with the generators, which in turn ensure stabilisation of the generators' voltage by changing the magnetic flux of the electrical machine. Currently, in the Air Force aviation, aircrafts use voltage regulators of different operating principles, which are proportional-integral-differential regulators (PID-regulators). However, the dynamic properties of the generator as a control object significantly depend on the operating mode, so these regulators cannot always provide consumers with electricity of the required quality.

The paper analyses modern methods of voltage stabilisation by introducing adaptive regulators into power supply systems.

The characteristics of electricity quality under the influence of various disturbances were studied using virtual models of a generator with a classical PID-regulator, an adaptive PID-regulator using parameter tables, an adaptive controller with a reference model, and an adaptive fuzzy controller developed in MATLAB.

The results of the study show that the use of adaptive voltage regulators allows maintaining the voltage at the generator output with a significant change in the rotational speed and load, and also improves the characteristics of transient processes.

ANALYSIS OF THE POSSIBILITIES OF APPLICATION OF DIGITAL SAC AND CONTROL OF THE OPERATION OF AN AVIATION ENGINE

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In modern aviation, where accuracy, reliability, and functionality are crucial, digital systems for automatic control and monitoring of aircraft engines (DSACAEC) are an integral part of the successful operation of an aircraft. This is especially true for such high-tech machines as the MiG-29, where flight efficiency and safety depend on flawless engine operation.

Modern aircraft manufactured by many aircraft manufacturers have FADEC systems that help increase engine efficiency and operational efficiency.

The RD-33 turbojet engine, which is equipped with the MiG-29 aircraft, can be equipped with a modern digital control system with FADEC functions instead of the BARK-88 (Automatic Regulation and Control Unit).

The introduction of a digital system based on FADEC on RD-33 engines will provide a significant improvement in all aircraft systems due to:

– more precise engine thrust control, which leads to better acceleration, maneuverability and fuel efficiency.

– increased engine life, which contributes to an increase in service life.

– improved reliability: the digital system is more reliable compared to analog hydromechanical control systems.

– reduction in weight and volume of electronic components
– improved diagnostics, which provides expanded capabilities for diagnosing engine condition.

OPPORTUNITIES FOR ENHANCING THE AUTONOMY OF UAV NAVIGATION AND FLIGHT CONTROL SYSTEMS

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The navigation system of unmanned aerial vehicles (UAVs) is a key component for accurately determining their spatial position and serves as the informational foundation for the flight control system of the aircraft. Autonomous navigation systems enable flight operations even in areas where satellite communication is disrupted by electronic warfare measures. The level of autonomy of these systems directly determines the effectiveness and combat resilience of UAVs in the context of modern conflict with an aggressor.

Operating in autonomous mode ensures flight stability under challenging conditions, allowing UAVs to carry out missions even in the absence of external navigation signals. This is especially critical for reconnaissance and strike missions, where reliability and precision are essential.

To enhance the efficiency of autonomous navigation, the use of modern correction methods is proposed, particularly through the integration of electro-optical systems and digital terrain maps. This will significantly expand the capabilities of UAVs, making them impervious to electronic jamming.

The development of advanced autonomous navigation systems is a prerequisite for the effective deployment of UAVs in today's evolving warfare landscape.

DEVELOPMENT OF CONTROL AND TEST EQUIPMENT FOR RADIO COMMUNICATION EQUIPMENT IN THE ULTRA-SHORT-WAVE FREQUENCY RANGE

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Ukraine is actively countering the armed aggression of the Russian Federation, which requires high efficiency and reliability of technical means, in particular radio communication systems, which are critical for coordinating the actions of units in real time.

The aviation of the Armed Forces of Ukraine widely uses ultra-short-wave communications, including during combat missions, but the effectiveness of its use largely depends on the technical condition of the equipment and the possibility of its operational testing without stationary equipment.

Existing diagnostic tools are outdated, cumbersome, or unsuitable for use in the field, which creates additional risks and complications for the engineering and technical staff. In such conditions, the creation of modern test equipment that would provide prompt diagnostics of the serviceability, accuracy of adjustment and signal quality of radio communication equipment without reference to the location and power sources becomes especially relevant. Thus, the new test equipment will be autonomously powered by a 12 V power bank, which will ensure independence from stationary power sources.

Such an approach in the conditions of combat operations will increase the reliability of communication, reduce the time for engineering and technical personnel to prepare equipment for operation, and ensure prompt detection and elimination of radio communication equipment malfunctions without the need to involve stationary control equipment.

RESEARCH OF WAYS OF IMPROVING THE SYSTEM OF TEMPERATURE LIMITATION AND ROTATION CORRECTION OF THE AN-26 TRANSPORTATION AIRCRAFT

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The AN-26's PRT-24 temperature limit and speed correction system performs a critical function of monitoring and maintaining optimal temperature conditions and correcting engine speeds. However, like any technical system, it has certain drawbacks that affect its performance and reliability. The problem with this system is the imperfect design of the URT-24 unit itself and its cooling, which leads to unstable operation and failures at high temperatures, reducing its efficiency.

Almost all failures of the URT-24 unit occur due to overheating and failure of the unit's element base (capacitors).

To improve the system performance, it is proposed to use modern temperature sensors with higher resolution to reduce the system error.

To improve the design of the URT-24 unit, it is proposed to replace electrolytic capacitors with solid-state ones, which will significantly increase the service life and reduce the risk of unit failure due to drying of the liquid electrolyte of the capacitors.

Replacing conventional operational amplifiers with high-speed ones with lower error and using MOSFET or IGBT transistors instead of mechanical relays for faster system control and adding a switching voltage regulator will reduce the unit's heating and power consumption.

These changes will help to improve the performance of the PRT-24 system and the URT-24 unit, making it more accurate, reliable and efficient to use.

PROPOSALS FOR THE APPLICATION OF DIAGNOSTIC METHODS FOR THE DC POWER SUPPLY SYSTEM OF A LIGHT TRANSPORT AIRCRAFT

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Light transport aircraft, as part of military transport aviation, perform a wide range of combat missions. During combat operations, these missions become more complex and extensive, which leads to increased requirements for the operability of onboard equipment. The performance of this equipment, in turn, depends on the reliability of the aircraft's power supply systems.

Carbon regulators RN-180 series 2 are used to control STG-18TMO direct current generators. They feature a simple design, high reliability, and ease of maintenance.

The monitoring tools for power supply system parameters provided by the operational documentation do not fully meet modern requirements in terms of depth, reliability, labor intensity, and standardization of control.

The most common malfunctions of carbon regulators are caused by wear or sintering of carbon washers, mechanical wear, and deterioration of electrical contacts.

The technical condition of the DC power supply system can be assessed by:

– using automated test benches with microprocessor control to determine voltage recovery time, regulator thermal stability, and to diagnose uneven wear of carbon elements;

– applying spectral analysis of the output voltage, which is based on changes in the waveform and harmonic composition due to faults in the regulation elements;

– analyzing the results of objective monitoring after engine testing.

UNIVERSAL OPTICAL-ELECTRONIC RECONNAISSANCE CONTAINER CONSIDERING THE PRINCIPLES OF CONSTRUCTION AND FUNCTIONING OF OPTICAL-ELECTRONIC SYSTEMS OF RECONNAISSANCE AIRCRAFT OF LEADING COUNTRIES OF THE WORLD

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Leading countries worldwide are actively employing electro-optical systems for reconnaissance, surveillance, and target designation, integrating them into universal containers for multi-purpose use across various air platforms. russia's armed aggression against Ukraine has emphasized the need for such technologies within the Ukrainian Air Force. A promising direction is the integration of these systems into containers capable of operating in conditions of intensive electronic warfare.

The proposed container features a modular architecture, multispectral observation, high resolution, real-time data processing, and information protection. The system includes an optical module (hyperspectral sensors, high-sensitivity cameras, laser rangefinders), an infrared subsystem (thermal imagers in the medium and long-wavelength ranges), a computing module with artificial intelligence, secure storage, encrypted communication channels, and a gyro-stabilized platform with distortion compensation algorithms.

Analysis of global systems demonstrates the effectiveness of such technologies in combat scenarios. Implementing a similar system in Ukraine could significantly enhance air reconnaissance capabilities and contribute to an informational advantage on the battlefield.

DEVELOPMENT OF A PROPOSAL FOR IMPROVING THE SYSTEM OF RESTRICTIVE SIGNALS OF A FIGHTER AIRCRAFT

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The experience of warfare shows that the reliability of aircraft and its rapid repair are critical to achieving the tasks set.

It is flights at extremely low altitudes and modes with extended restrictions on aerodynamic parameters that have become the main modes of aviation flight in the context of combat operations.

The Su-27's SOS-2 system of restrictive signals, which helps pilots perform such flights, has significant drawbacks. Its analog components are difficult to diagnose and repair, requiring scarce spare parts and special equipment. It is vulnerable to combat loads and only warns the pilot without interfering with control, which can lead to the loss of the aircraft.

Effective operation of combat aircraft requires modern digital systems that ensure high reliability and minimize repair time.

It is proposed to take as an example the digital Flight Control Limiter (FCL) system used on Western fighters, which is much more efficient both in operation and in repair. It has a digital architecture that allows for rapid software updates without complex mechanical intervention. Unlike SOS-2, FCL not only signals an unsafe condition but also automatically corrects the control, preventing loss of control over the aircraft. This system has a modular design, which simplifies its repair - faulty units can be replaced with new ones without the need for complex diagnostic procedures. Self-diagnosis and the ability to quickly adapt to combat conditions.

STUDY OF THE POSSIBILITY OF IMPLEMENTING DIGITAL TECHNOLOGY TO IMPROVE THE PROCESS OF DETERMINING AEROMETRIC PARAMETERS OF A MILITARY TRANSPORT HELICOPTER

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In the context of the ongoing modernization of Ukraine’s defense and aviation sectors, the digitalization of processes for monitoring and analyzing the flight performance of military aircraft – particularly military transport helicopters – has become increasingly critical. One of the key elements in ensuring operational safety and reliability is the accurate determination of aerometric parameters (altitude, airspeed, pressure, air temperature, etc.), which directly affect flight control, navigation accuracy, and maintenance scheduling.

Traditional methods for acquiring and processing aerometric data, which rely primarily on analog instruments and mechanical sensors, present several limitations, such as low measurement accuracy, slow response time, and poor integration with modern avionics systems. These shortcomings reduce the operational efficiency of helicopters, especially under high-stress conditions typical of military missions.

Therefore, the aim of this research is to explore the feasibility and benefits of implementing modern digital technologies – including digital sensors, microprocessor-based data acquisition systems, and automatic calibration algorithms – to enhance the process of aerometric parameter determination. The integration of digital technologies enables more precise, real-time measurements, increases the reliability of onboard systems, and allows for seamless interaction with other digital flight control components.

RESEARCH INTO THE ACCURACY AND PERFORMANCE CHARACTERISTICS OF PRIMARY INFORMATION SENSORS FOR SELECTING A RATIONAL AUTONOMOUS CONFIGURATION UAV

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The performance and reliability of autonomous unmanned aerial vehicles (UAVs) of the aircraft type largely depend on the accuracy of data coming from primary information sensors, such as inertial measurement units (IMUs), global navigation satellite systems (GNSS), barometric altimeters and airspeed sensors. Different autonomous UAV configurations, differing in hardware, control algorithms and purpose, require different levels of accuracy of these sensors to achieve optimal operational characteristics.

The report will examine the relationship between the accuracy of individual primary information sensors and key operational characteristics of aircraft-type UAVs, such as:

– mission accuracy. High positioning and navigation accuracy, provided by high-quality GNSS and IMUs, is critical for performing tasks requiring high spatial accuracy (e.g. mapping, inspection of communication lines);

– stability and controllability. Accurate data on angular rates and acceleration from the IMU are necessary for the effective operation of stabilization systems and autopilot, especially in wind loads or when performing complex maneuvers;

Based on the analysis, recommendations will be formulated for selecting the optimal autonomous configuration of an aircraft-type UAV, taking into account the required level of accuracy of primary information sensors to achieve the desired operational characteristics and economic feasibility. The results of the study will contribute to a more informed selection of components and architecture of autonomous UAV systems.

FEATURES OF THE FUNCTIONING OF THE FLIGHT CRITICAL COMPUTER (FCC) OF THE BAYRAKTAR TB2 UAV SYSTEM

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The Flight Critical Computer (FCC) is a key component of the Bayraktar TB2, ensuring autonomous control, sensor data processing (IMU, GNSS, barometers), and trajectory stabilization under challenging conditions.

The FCC architecture is based on redundancy: the Main Unit Computer (MUC) performs primary navigation and stabilization computations, while the Safety Unit Computer (SUC) monitors its performance and initiates emergency protocols in accordance with high-reliability standards.

In complex environments, the FCC faces GNSS jamming, spoofing, C2 interference, and communication channel overloads. These conditions force the system to switch to inertial navigation, where cumulative IMU drift significantly reduces positional accuracy, potentially resulting in loss of controlled airspace compliance.

Internal malfunctions (e.g., CRC errors in UART or Bus-Off events in CAN) also affect controllability. Redundant RS422 channels provide partial compensation, but the lack of feedback pathways limits control responsiveness.

The study revealed that the FCC of the Bayraktar TB2 becomes highly vulnerable when three conditions occur simultaneously: loss of GNSS signals (e.g., GPS), drift or errors in the IMU (which determines orientation), and data transmission failures. In such scenarios, the FCC is unable to accurately determine the UAV’s position and orientation, threatening flight stability.

Future development of the FCC should be grounded in multi-layer redundancy and machine learning-based algorithms for real-time diagnostics and adaptive response mechanisms.

COMPARATIVE ANALYSIS OF METHODS OF TECHNICAL DIAGNOSTICS OF VOLTAGE REGULATORS IN MILITARY AVIATION OPERATION CONDITIONS

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Ensuring the reliability of power supply systems for combat aircraft is a critically important condition for its safe operation, which makes the study of voltage regulator diagnostic methods relevant.

Reliable operation of voltage regulators guarantees stable operation of key onboard systems, including navigation, automatic control and communication systems. In wartime, when aircraft preparation must be as fast and error-free as possible, effective diagnostics become a critical element of safety.

Traditional diagnostic methods based on stationary measurements and visual assessment are not effective enough in conditions of limited time and increased requirements for service efficiency.

Classical diagnostic methods are mostly based on manual measurements and visual inspection. They require significant labor costs, take a lot of time and depend on the experience of technical personnel. In addition, such methods often do not allow diagnostics to be carried out without dismantling the equipment. This reduces the effectiveness of their use in conditions of limited time.

It allows you to reduce the influence of the human factor and ensure the stability of results regardless of the type of aircraft.

New generation microprocessor systems provide a comprehensive approach to diagnosing voltage regulators.

They can generate test signals, record the system's response and automatically analyze the results. Such tools significantly reduce the likelihood of errors and allow diagnostics to be carried out directly on board the aircraft. This increases the mobility and efficiency of maintenance.

PROSPECTS FOR THE INTRODUCTION OF MODERN AUTOMATIC CONTROL SYSTEMS ON AIRCRAFT OF THE AIR FORCE OF UKRAINE

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Automatic control systems (ACS) play a key role in ensuring the safety and efficiency of flights, especially in combat conditions.

Current trends require the transition from outdated analog autopilot systems such as AP-155 or APS-84 to digital ACS with enhanced functionality. One example of modernization is the Kearfott INS/GPS system, which has already been integrated on certain platforms in cooperation with US partners. It ensures high navigation accuracy even in case of satellite signal loss.

Another important example is the introduction of the SUV-39 fly-by-wire control system on modernized versions of the Su-27, which provides electronic stabilization of the aircraft and the ability to programmatically redistribute control signals in case of damage.

Also relevant is the development of a domestic digital ACS of the Cascade-1 type, which is being tested on medium-class unmanned aerial vehicles. It is built on a modular principle and has an open architecture that allows it to be adapted to different types of aircraft.

The main problems are the low level of compatibility of old Soviet aviation systems with new digital solutions, the lack of software products, and dependence on imported components. The prospects are to create a domestic universal digital ACS with the integration of inertial-satellite navigation, automatic failure detection (BITE), and adaptive control based on artificial intelligence. The use of such systems allows.

PROPOSALS FOR MODERNIZATION OF ADVANCED CONTROL AND VERIFICATION EQUIPMENT OF AEROMETRIC INSTRUMENTS FOR MULTIPURPOSE AIRCRAFT

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During the technical operation of aerometric instruments and air pressure transmitter systems, aviation crews use air pressure transmitter checking equipment (APC). Its design and principle of application ensure that air pressure transmitter systems are tightly sealed, that aerometric instruments are operable, and that their readings are accurate.

Currently, the equipment is morally and materially outdated and needs to be replaced or modernized. The proposed modernization uses modern electronic pressure regulators and intelligent pressure sensors in its structure. The control is carried out by a microcontroller and wireless communication based on ZigBee technology in the 2.4 GHz band, designed to transmit small amounts of information from many sources, including battery-powered ones. This allows to improve the technical characteristics of the test equipment, the flexibility of reprogramming tests, as well as to eliminate the disadvantages inherent in the existing test equipment of air pressure transmitters, namely

– lack of remote control;

– lack of registration of actions of the engineering and technical staff and commenting on the test results;

– the impact of the level of training of the engineering and technical staff on the quality of the inspection.

DEVELOPMENT OF WAYS TO IMPROVE THE DA-200 AIRBORNE HORIZON DUPLICATOR TO INCREASE THE ACCURACY OF AERODYNAMIC PARAMETER MEASUREMENTS

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Modern aircraft, which perform a wide range of tasks in a wide range of flight characteristics, require equipment with accurate aerometric parameters. The requirements for piloting accuracy, navigation and efficiency in solving combat missions are constantly increasing.

In order to improve flight safety, redundancy of the main flight parameters is envisaged (for example, the use of a DA-200 airborne horizon duplicator). This device combines a variometer, an electric turn indicator, and a glide indicator.

The disadvantages of the DA-200 are the relatively low accuracy of the vertical speed measurement and the correct indication of the roll angle only at a fixed flight speed of 500 km/h. In order to improve the quality and efficiency of the DA-200, it is necessary to investigate ways to improve it in the areas of increasing the accuracy of determining the vertical speed and ensuring the ability to determine the roll angle in the full range of aircraft speeds.

Increasing the accuracy of the DA-200 airborne horizon duplicator in determining the vertical speed can be achieved by optimal processing of the vertical acceleration signals and the derivative of the absolute flight altitude.

The report shows the Simulink model of the third-order filter and the values of the gains found to optimize the parameter estimation. To develop a model of the universal turn indicator, the functional dependence of the roll angle on two arguments of the linear flight speed V and the angles.

DEVELOPMENT OF PROPOSALS FOR THE IMPROVEMENT OF THE CONVERSION UNIT BPM 1-5 OF THE FUEL CONSUMPTION MEASURING SYSTEM STR 6-2A OF THE FIGHTER AIRCRAFT

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Modernization of the fighter jet fuel and consumption system is becoming increasingly important due to the outdated element base and the high percentage of errors produced by the system during operation. The BPM 1-5 conversion unit is the brain of the STR 6-2A and is a technically outdated product. Its component base is based on electronic elements that have long been discontinued, making it impossible to replace them as part of a standard repair.

To improve reliability, reduce weight and dimensions, and improve maintainability, it is proposed to upgrade the BPS 1-5 unit by replacing all outdated electronic components with modern integrated circuits and microprocessor solutions. This modernization will significantly reduce the weight and dimensions of the device through the use of modern elements with a high degree of integration, increase system performance through the introduction of digital signal processing, which reduces response time and improves accuracy.

In turn, this improvement will improve maintainability and unification by standardizing the element base, using a modular construction principle and simplifying diagnostics. All of this leads to an increase in system reliability by eliminating obsolete elements and components that are sensitive to mechanical stress and temperature.

PECULIARITIES OF OPERATION OF AIR PRESSURE TRANSDUCERS AND ANEROID MEMBRANE DEVICES FOR MEASURING THE FLIGHT ALTITUDE OF BAYRAKTAR TB2

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Altitude measurement is critical to ensure stable operation of unmanned aerial vehicles (UAVs) at altitudes up to 11.3 km and during long missions of up to 27 hours. Pitot tubes, piezoelectric pressure sensors, and aneroid membrane devices play a key role in determining altitude data, but their effectiveness depends on adapting to challenging environments such as extreme temperatures, turbulence, and the risk of icing.

Piezoelectric pressure sensors, which generate a signal in proportion to the applied pressure, have a fast response time, making them ideal for dynamic measurements in turbulent environments. However, their unsuitability for static measurements and sensitivity to temperature make them difficult to use.

To increase the reliability of piezoelectric sensors in Bayraktar TB2 UAVs, it is advisable to use advanced low-noise amplifiers to reduce electromagnetic interference, use materials with increased thermal stability (e.g., modified quartz) to reduce temperature errors, and implement digital signal processing to compensate for the zero drift. Additionally, integration with microcontrollers is possible for real-time signal correction, which in turn will increase accuracy in dynamic conditions, which is especially important for highly maneuverable operations at different altitudes.

DEVELOPMENT OF PROPOSALS FOR IMPROVEMENT OF THE OF THE INERTIAL NAVIGATION SYSTEM OF THE UAV BAYRAKTAR TB2

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The inertial navigation system (INS) plays a key role in the functioning of the Bayraktar TB2 UAV, providing autonomous orientation and navigation without the need for external signals such as the Global Positioning System (GPS). The INS provides a safe determination of the position, speed and orientation of the vehicle in space.

The Bayraktar TB2 uses a micro-electromechanical systems – inertial measurement unit (MEMS-IMU) integrated with the Global Navigation Satellite System (GNSS) to improve accuracy. The IMU consists of an inertial measurement unit (IMU), a computer, and signal processing algorithms.

The IMU is combined with the GNSS to compensate for errors by correcting the IMU using a Kalman filter.

In case of loss of GNSS (for example, in the jamming zone or electronic interference), the system switches to inertial autonomous navigation, which leads to a gradual increase in errors.

To improve the accuracy and reliability of the INS, it is advisable to modernize the system.

It is proposed to use fiber-optic gyroscopes (FOG) instead of MEMS. They have significantly less drift, higher accuracy, and better stability over a wide temperature range.

RESEARCH OF MODERN PLATFORM-FREE INERTIAL NAVIGATION SYSTEMS FOR THEIR ADAPTATION TO AIRCRAFT TO IMPROVE THE ACCURACY AND RELIABILITY OF POSITIONING

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Improving the accuracy and reliability of combat aircraft navigation is an important task in today's warfare environment, especially given the constant threat of GPS signal loss due to enemy electronic countermeasures. One of the promising solutions is the introduction of platform-free inertial navigation systems (PFIS) that operate autonomously and do not depend on external sources of navigation information. Such systems are capable of continuously determining the position, speed, and orientation of an aircraft, even in the event of a complete loss of communication with satellites.

Several important aspects must be taken into account for the effective adaptation of BINS on aircraft of the Air Force of Ukraine. Firstly, the selection of modern models of INS based on MEMS sensors or fiber optic gyroscopes, which have sufficient accuracy and compact size to allow their integration without significant changes to the aircraft design. Secondly, the development of software to integrate the BINS with existing systems and external sources of information (GPS, radar data, digital maps). Third, the creation of an error correction system that will ensure stable navigation accuracy on long routes.

Implementation of such solutions will allow combat aircraft to increase autonomy and flight accuracy, reduce dependence on satellite navigation, and operate effectively in conditions of active electronic warfare. This will significantly enhance the combat capability of aviation units of the Armed Forces of Ukraine.

PROSPECTS FOR THE INRODUCTION OF INNOVATIVE POWER SUPPLY SYSTEM FOR COMBAT AIRCRAFT IN AIRSPACE DEFENSE

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Based on the experience of combat operations in the airspace against the armed forces of the Russian Federation, improving the power supply systems of combat aircraft remains an extremely urgent task. A stable power supply is critical for the effective performance of combat missions in the challenging conditions of modern warfare.

One of the main approaches is the introduction of high-voltage DC systems on board aircraft. This reduces the current required to power consumers, allowing the use of smaller cables and, consequently, reducing the overall weight of the aircraft. Such solutions are used in many modern Western combat aircraft, including the F-22 Raptor.

As a modern solution for supplying consumers with a constant current, isolated DCM converters from Vicor Corporation can be used to create an isolated output using an unregulated input with a wide range. The converter supports 28V input and up to 270V output with power from 60W to 1300W. The use of such converters in aviation systems where reliable conversion of low DC voltage to high voltage is required improves the efficiency of the onboard power supply system.

The integration of such solutions contributes to the creation of modern, flexible aircraft platforms capable of meeting the requirements of the modern combat space.

COMPARATIVE ANALYSIS OF THE COMBAT EFFECTIVENESS OF THE S-8 AND HYDRA MISSILES IN MODERN COMBAT CONDITIONS

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In modern combat conditions, the importance of highly effective aviation weapons, particularly unguided aerial rockets (UARs), is increasing. These rockets provide rapid and mass fire damage to targets on the battlefield. Among such weapons, special attention is given to the Soviet S-8 missile and the American Hydra 70 missile, both of which are widely used by the armed forces of various countries.

The aim of this study is to conduct a comparative analysis of the two mentioned missile types – the S-8 and Hydra – considering their tactical and technical characteristics, combat capabilities, and operational conditions in combat situations.

The S-8 missile, developed in the USSR, is intended for use with helicopters and attack aircraft. It has an 80 mm caliber and various types of warheads. The Hydra 70, on the other hand, is an American missile with a 70 mm caliber, designed for targeting with helicopters and aircraft. It offers a wide range of warhead types, including those with precision navigation.

The comparison reveals that both missiles have similar combat tasks but differ in their design solutions. The S-8 is more focused on mass application in conventional warfare, while the Hydra is more adaptable to modern conditions due to its capability to use guided warhead modules.

Thus, the comparative analysis shows that both systems are effective, but the Hydra has better prospects for further modernization and adaptation to the high-tech battlefield.

RESEARCH ON THE POSSIBILITIES OF UPDATING TEST AND CONTROL EQUIPMENT FOR AVIATION LAUNCH DEVICES ON OPERATIONAL AIRFIELDS

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In modern conditions of mobile combat operations, the technical condition of aviation launch devices plays a decisive role in the effectiveness of air operations. A critical element of ensuring their operational readiness is the reliable functioning of Test and Control Equipment (TCE), which is used for verifying the status of these devices on operational airfields. Given the limitations of infrastructure and potential damage to facilities, ensuring the availability and functionality of TCE is essential for the efficient and rapid deployment of launch systems.

Main Problems and Solutions:

1. Outdated TCE Systems

Existing equipment is often outdated and does not meet modern requirements for accuracy and speed of checks. Conventional systems, such as the RS (Radio Station) with large dimensions and complex setup requirements, have limited mobility and efficiency in the field.

2. Low Mobility and Difficulty in Deployment

The large size and complex setup of traditional systems make them difficult to deploy in the field, especially on airfields with damaged infrastructure.

3. Dependence on the Operator and Human Factor

Traditional systems require skilled personnel to operate them, with results often dependent on the experience of the operators, which can lead to errors and inconsistencies.

4. Insufficient Resistance to External Conditions

Temperature fluctuations, moisture, and radio-electronic interference often disrupt the operation of equipment, leading to inaccurate results.

ANALYSIS OF MODERN MEANS OF DEFEATING TACTICAL-LEVEL UAVS AND PROSPECTS FOR THEIR IMPROVEMENT

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In modern combat conditions, tactical-level unmanned aerial vehicles (UAVs) have gained widespread use due to their mobility, low cost, and effectiveness in reconnaissance, fire correction, and strike missions. Their mass deployment presents new challenges for air defense forces.

The main means of countering such UAVs include small arms, short-range air defense missile systems, electronic warfare (EW) tools, mobile interception systems ("drone catchers"), as well as experimental laser weapons. Each method has its advantages and limitations. For instance, EW systems are effective against GPS-guided UAVs but lose effectiveness against autonomous models. Small arms require high precision, and air defense systems are not always cost-effective against inexpensive targets.

Prospective directions for improvement include enhancing targeting accuracy, miniaturizing systems, automating target detection and destruction processes, and integrating strike systems with military command networks. A key focus is the development of low-cost, reusable solutions capable of countering drone swarms.

Thus, effective counteraction against tactical-level UAVs requires a comprehensive approach that combines modern technologies, adaptive weapon systems, and innovative combat strategies.

SYNTHESIS OF ALGORITHMS FOR DETERMINING THE CHARACTERISTICS OF ADVANCED AIR-TO-SURFACE GUIDED MISSILES FOR ENGAGING ENEMY RADAR SYSTEMS OF THE AGM-88 HARM TYPE

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In the current context of the development of air defense systems (ADS) and electronic warfare (EW) technologies, the relevance of creating high-tech air-to-surface guided missiles targeting enemy radar systems (air-to-radar missiles) is steadily increasing. One of the most well-known representatives of this type of weapon is the American AGM-88 HARM missile, which is used to suppress enemy radar stations by homing in on their electromagnetic emissions.

The goal of this research is to develop and synthesize algorithms that enable the determination of optimal design and combat characteristics of advanced domestic air-launched missiles capable of effectively engaging current and future enemy radar systems, taking into account new challenges –such as the mobility of radar stations, variable emission patterns, use of low-observability operating modes, and deployment of decoys.

The research includes the following components:

– Classification of typical radar targets and analysis of their characteristics;

– Development of mathematical models for missile trajectory and homing processes;

– Synthesis of algorithms for optimizing missile parameters (range, speed, warhead, stealth characteristics, and electronic countermeasure capabilities);

– Computer simulation of radar engagement scenarios under various combat conditions (e.g., in the presence of electronic countermeasures or active target maneuvering).

The application of the developed algorithms enables a comprehensive assessment of the effectiveness of future missile designs at the early stages of development, reducing time and costs associated with research and development.

RESEARCH ON THE APPLICATION OF 1 KG CALIBER AIRCRAFT FRAGMENTATION BOMBS FROM CLASS 1 UAVS

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In the ongoing Russian-Ukrainian conflict, Class 1 unmanned aerial vehicles (UAVs) have proven essential for precision strike missions. The integration of 1 kg aircraft fragmentation bombs allows effective targeting of enemy personnel and lightly armored assets. Key Issues and Solutions:Limited explosive yield: Improved by using high-energy explosives and optimizing bomb shape and material to maximize fragmentation and blast radius.Accuracy challenges: Resolved through GPS/GLONASS and inertial navigation systems, with optional optical or laser guidance for moving targets.Weather sensitivity: Countered by stabilized bombs with trajectory correction and UAV-mounted thermal cameras for low-visibility operations.UAV vulnerability: Minimized with evasion algorithms, electronic warfare systems, and coordinated drone swarm tactics.

The enhancement of munition design, navigation systems, and deployment strategies significantly boosts the efficiency of 1 kg fragmentation bombs launched from Class 1 UAVs.

FEATURES OF FORMING THE OUTLINE OF A MODERN SAMPLE OF ANTI-TANK AIRCRAFT GUIDED MISSILE

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Modern armored targets use active protection, mobility and electronic warfare, which reduces the effectiveness of existing anti-tank missiles. Existing missiles are often inferior in range, accuracy and are unable to penetrate modern dynamic protection.

At present, there is an urgent need for a well-founded formation of the outline of these missiles that would correspond to the characteristics of modern models of anti-tank weapons. For this, it is necessary to substantiate at least the main characteristics of their modern model.

To solve this issue, it is possible to use theoretical methods that are an important tool at the initial stages of developing technical systems. They allow you to predict the main characteristics, optimize the design and reduce the cost of full-scale testing, that is, the practical component of research.

The study used statistical methods, they are one of the key theoretical approaches to determining the characteristics of various objects.

The proposed research method allowed us to identify patterns and obtain quantitative estimates of the main characteristics, which makes it possible to form an approximate outline of a modern aviation anti-tank missile.

RESEARCH ON METHODS FOR REDUCING THE MISS DISTANCE OF GUIDED AERIAL WEAPONS AGAINST AIR TARGETS

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In modern combat conditions, the air component plays a crucial role in achieving operational and strategic superiority. Given the high maneuverability, speed, and active counteraction capabilities of air targets, effective engagement requires the use of precision-guided munitions – guided aerial weapons (GAW). However, despite the high technological level of such systems, the issue of engagement accuracy remains relevant: misses may result from both external factors – such as active maneuvering of the target, use of electronic countermeasures, and adverse weather conditions – and internal limitations of the weapons themselves, including navigation inaccuracies, outdated guidance algorithms, and limited adaptability to changing combat environments.

The purpose of this scientific research is to conduct a comprehensive analysis of the factors affecting the accuracy of guided aerial weapons against air targets, as well as to study and substantiate the most effective technical and algorithmic solutions aimed at reducing the probability of a miss in modern combat scenarios.

The study focuses on the following key areas:

– improvement of tracking and guidance algorithms;

– implementation of artificial intelligence and machine learning in flight control systems;

– integration of inertial, satellite, and optoelectronic navigation systems to enhance accuracy under electronic interference;

– a-daptive trajectory planning considering target behavior changes;

– modeling and simulation of air combat to test the effectiveness of updated solutions.

RESEARCH ON INCREASING THE FLIGHT RANGE OF PLANE-BASED BOMBS

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1. Optimization of aerodynamics.

Folding wings of increased span: allows to increase lifting force without compromising dimensions during suspension.

Low frontal resistance: due to the streamlined shape of the body and smooth surface.

Aerodynamic fins or stabilizers: for stabilization and greater stability on the trajectory.

2. Increase the height and speed of the drop.

Dropping from a higher altitude (for example, over 12 km) significantly increases the planning range.

A high-speed carrier (high-speed aircraft or launch vehicle) allows for the initial delivery of more energy.

3. Using an auxiliary drive

Solid rocket booster: Provides a short-term increase in speed after launch.

Pulse jet engine (PRD) or turbojet microengine: Provides sustained speed over a long distance.

4. Improvement of the control system.

Intelligent navigation (GPS/GLONASS + inertial system): provides an optimal trajectory with minimal energy loss.

Adaptive surface control algorithms: allow you to save energy during flight.

5. Weight reduction or weight distribution optimization

Lightweight hull materials (composites): allow weight reduction without loss of strength.

Centering: Correct center of mass placement increases stability and handling.

JUSTIFICATION OF PARAMETERS FOR A PERSPECTIVE AVIATION STRIKE SYSTEM TO IMPROVE THE EFFECTIVENESS OF DESTROYING LIGHTLY ARMORED GROUND TARGETS IN MODERN COMBAT CONDITIONS

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In modern combat conditions, there is a growing need for effective and reliable aviation strike systems capable of destroying lightly armored ground targets, such as infantry fighting vehicles, armored personnel carriers, command and staff vehicles, and logistics equipment.

The aim of the study is to justify the requirements and examine the key parameters of a prospective aviation strike system (ASS) that will effectively destroy lightly armored ground targets in complex combat conditions. The prospective strike system refers to an aviation missile or unguided munition with modern characteristics that ensure accuracy, reliability, and adaptability to various combat scenarios.

The study examines parameters of the ASS, such as the type of warhead, guidance or stabilization system, caliber, speed, weight, range, armor-piercing capability, and the likelihood of hitting the target at various angles of approach. Special attention is given to the physical and technical characteristics of the warhead, which should be capable of effectively destroying vehicles with low and medium-level armor protection.

The results of the study can be used to improve or create new types of aviation strike systems.

RESEARCH ON THE CHARACTERISTICS OF IMPACT MECHANISMS OF AIRCRAFT FUZES

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The full-scale war launched by Russia against Ukraine has led to a new level in the use of unmanned aerial vehicles (UAVs). From the early stages of the invasion, the deployment of UAVs demonstrated high effectiveness, and they remain a highly effective tool to this day. The use of aerial munitions from UAVs requires the reconfiguration of fuzes. This is due to the fact that the design of such aerial bombs was originally intended for deployment at higher speeds and altitudes.

One of the key components of fuzes is the impact mechanism. This report examines the influence of impact mechanism characteristics on the effectiveness and safety of employing aerial munitions. The main characteristics of impact mechanisms include: activation time, sensitivity, and reliability.

Therefore, in order to enhance the combat effectiveness of aerial munitions, the main directions for adjusting the parameters of aircraft fuzes have been identified. These modifications will allow for the deployment of munitions from lower altitudes, thereby increasing the capabilities of Ukraine's defense forces.

MODERNIZATION OF MODERN TYPES OF AIR-LAUNCHED GUIDED WEAPONS

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During Russia's full-scale invasion of Ukraine, the modernization of air-launched guided weapons (ALGW) became a key area for enhancing the combat capabilities of the Ukrainian Air Force. This process includes both the adaptation of existing Soviet-era aircraft to modern standards and the integration of advanced Western technologies.

The modernization of air-launched guided weapons is carried out to ensure high strike precision, reduce personnel losses, adapt to the conditions of modern warfare, and counter emerging threats, including enemy electronic warfare (EW) and air defense systems. It enables the effective use of both Soviet and Western platforms, the integration of advanced targeting technologies, and the achievement of strategic superiority on the battlefield.

In the context of war with Russia, modernization is critically important for ensuring the effectiveness and safety of combat operations. The integration of Western weaponry, the upgrading of aviation platforms, and the development of unmanned systems enable Ukraine to adapt to modern challenges and enhance its defense capabilities.

STUDY OF THE PENETRATION CAPABILITY OF SMALL-CALIBER AERIAL SHAPED-CHARGE MUNITIONS

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The main issue faced by existing small-caliber shaped-charge munitions is the limited ability of the shaped-charge jet to penetrate modern armored materials. Under such conditions, the jet generated by current munitions does not always achieve the optimal level of energy concentration required to penetrate protected targets, especially considering the complexity and diversity of the materials used. Therefore, current munition designs do not fully account for the specific interaction of the jet with new-generation armor, which necessitates further research.

This study is based on analysis and calculations regarding the implementation of substantiated solutions aimed at improving the effectiveness of small-caliber shaped-charge munitions. This includes modifying the parameters of the shaped-charge liner and using new materials to enhance the jet formation. The goal is to achieve an increase in penetration capability compared to existing designs.

The conducted calculations confirmed the feasibility of the proposed solutions, as they demonstrated improved performance of the shaped-charge jet. This ensures sufficient penetration when encountering obstacles while maintaining compact weight and dimensional characteristics without reducing the destructive potential of the munition.

The proposed solutions make it possible to improve the destructive characteristics of the shaped-charge jet in small-caliber aerial munitions, while preserving their compactness and suitability for use in modern combat environments.

RESEARCH ON A PROSPECTIVE AIRCRAFT BORE-SIGHTING SYSTEM IN COMBAT CONDITIONS AT OPERATIONAL AIRFIELDS

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In modern conditions of high-intensity combat operations, aviation plays a key role in achieving operational superiority. One of the critical stages of combat employment is the precise bore-sighting of aircraft weapons. Operational airfields have limited resources and a constant threat of destruction, therefore they require fast and accurate technical solutions.

Development of a technical concept of a prospective bore-sighting system that will provide accurate, automated, and safe alignment of aircraft weapons in field conditions.

To analyze modern bore-sighting systems and identify their shortcomings in combat conditions.

To define the requirements for the new system taking into account mobility, accuracy, speed, and safety.

To propose a technical architecture of the system using intelligent systems, sensor technologies, and remote control.

To evaluate the effectiveness of the proposed solution by the criteria of speed, reliability, and adaptability.

A concept of a mobile bore-sighting system is proposed, based on automated platforms with sensor modules and a self-diagnostic system. The system is capable of operating in conditions of limited access, dynamic movement, and shelling threats. It ensures significant reduction in alignment time, reduction of human factor, and enhancement of the operational effectiveness of the air force component.

MODERNIZATION OF TRANSPORTATION MEANS FOR AIM-9 AIR-TO-AIR MISSILES FOR MIG-29 AND SU-27 AIRCRAFT

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The adaptation of MiG-29 and Su-27 aircraft to NATO standards includes not only avionics and weapon integration but also the modernization of ground support systems, particularly those used for transporting and handling air-to-air missiles such as the AIM-9 Sidewinder. Unlike Soviet-designed missiles (e.g., R-60, R-73), the AIM-9 has different physical and interface characteristics, requiring significant upgrades to transport carts, support cradles, and loading mechanisms.

This thesis addresses the design and implementation of improved transportation systems compatible with both NATO and legacy missile formats. Modifications include updated securing mechanisms, universal mounting systems, and protective features to ensure safety during movement and handling. The modernized equipment supports faster pre-flight preparation, minimizes damage risks, and ensures proper alignment with the pylons of MiG-29 and Su-27 aircraft.

The study emphasizes interoperability, reliability, and compliance with NATO logistical standards. Practical testing confirmed the effectiveness of the proposed upgrades, reducing maintenance time and enhancing overall combat readiness. These innovations play a vital role in aligning post-Soviet air platforms with current Western operational requirements.

ANALYSIS OF FLIGHT-BALLISTIC CHARACTERISTICS OF MODERN GLIDEABLE AVIATION MUNITIONS WITH A 250 KG CALIBER

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In modern combat conditions, tactical-level unmanned aerial vehicles (UAVs) have become widely used due to their mobility, low cost, and effectiveness in reconnaissance, fire adjustment, and strike missions. Their widespread use presents new challenges for air defense forces.

Among the main means of UAV destruction are: small arms, short-range surface-to-air missile systems, electronic warfare (EW) tools, mobile interception systems ("drone catchers"), and experimental laser weapon prototypes. Each type has its advantages and limitations. For example, EW systems are effective against UAVs with GPS navigation but lose effectiveness against autonomous models. Small arms require high accuracy, and air defense is not always economically viable against low-cost targets.

Prospective areas for improvement include enhancing targeting accuracy, miniaturization of systems, automation of target detection and destruction processes, as well as integration of weapon systems with military command networks. An important aspect is the development of inexpensive, reusable solutions for countering drone swarms.

Therefore, effective counteraction against tactical-level UAVs requires a comprehensive approach that combines modern technologies, adaptive weapon systems, and innovative methods of conducting combat operations.

MEANS OF EQUIPPING THE AIRCRAFT OF THE ARMED FORCES OF UKRAINE WITH PROTECTION SYSTEMS

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The main threat to aircraft (AC) today comes from surface-to-air missile (SAM) systems and anti-aircraft artillery (AAA) systems, which may include radar systems (RS), electro-optical targeting systems with thermal imaging and television channels, and laser rangefinders. Additional threats include man-portable air-defense systems (MANPADS), anti-aircraft guns, anti-tank guided missiles (ATGMs), grenade launchers, unguided rockets, and anti-helicopter mines.

The main drawback of current protective measures is the absence of missile launch warning systems (except for the Su-24M aircraft), which prevents timely automatic activation of countermeasure systems to release decoys.

Currently, domestic Ukrainian enterprises are developing and installing new protection systems for the aircraft of the Armed Forces of Ukraine:

– "Adros" KT-01AV Electro-Optical Jamming Station (EOJS) – for helicopters (adopted by the Armed Forces of Ukraine);

– "Adros" KT-03U EOJS – for helicopters and transport (special-purpose) aircraft;

– "Adros" KUV 26-50 combined countermeasure dispensing system – for helicopters and aircraft (adopted by the Armed Forces of Ukraine);

– ASH-01V exhaust screen device – for helicopters;

– "Omut" individual electronic protection station – for aircraft.

In turn, the analysis of aircraft protection systems indicates that a prospective protection system should include the following components:

– A warning system for aircraft illumination (radar and laser-based) – for all types of aircraft;

– A missile launch warning system (operating in infrared and ultraviolet ranges) – for all types of aircraft;

– An electro-optical countermeasure station (including laser-based systems) – for helicopters and military transport aircraft;

– An active electronic jamming station – for fixed-wing aircraft;

– Decoy dispensing systems – for all types of aircraft.

RESEARCH ON THE DEVELOPMENT DIRECTIONS OF A UNIVERSAL SUSPENSION SYSTEM FOR VARIOUS TYPES OF AERIAL WEAPONS

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In modern combat conditions, there is an increasing need to enhance the effectiveness of combat aviation, particularly through the unification of technical suspension systems for aerial weapons (AWS). This approach helps reduce the time required to prepare an aircraft for a combat mission, lower logistical costs, and ensure greater flexibility in the use of weaponry.

The key requirements for a universal suspension system include the ability to operate with AWS of various types and calibers, reliability under harsh operational conditions, compatibility with different platforms (aircraft, UAVs), and support for rapid reconfiguration. An analysis of existing solutions shows that most current systems are either limited in versatility or overly complex.

Promising development directions include the creation of modular designs with standardized interfaces, integration of self-diagnostic and remote-control features, and the use of lightweight high-strength materials. Of particular relevance is the use of adaptive mounts that allow for quick changes in suspension configurations.

At the same time, it is important to consider not only technical but also tactical-operational aspects of such systems. Development should take into account real-world combat scenarios, the ability to interface with automated command and control systems, and compatibility with international standards. Configuration flexibility for specific missions and conditions also plays a critical role. Additionally, the implementation of universal suspension systems reduces dependency on individual manufacturers and enhances strategic autonomy. Thus, a comprehensive approach to the development of a universal suspension system holds strategic importance for the advancement of modern aviation.

Therefore, the development of a universal AWS suspension system is a vital component in increasing the combat readiness of air forces, requiring a combination of engineering innovation, combat experience, and modern manufacturing technologies.

EXPERIENCE OF USING THE F-16 IN THE AIR FORCES OF THE AFU DURING THE RUSSIAN-UKRAINIAN WARS

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Since 2024, the Air Force of the Armed Forces of Ukraine has begun to receive multi-role F-16 fighters transferred by partner countries. Their commissioning has become an important step in the modernization of the aviation fleet and increasing combat capability in the face of large-scale armed aggression by the Russian Federation. Ukrainian F-16s are involved in both defensive and offensive missions. In particular, they participate in countering enemy air objects - cruise missiles, unmanned aerial vehicles and enemy aircraft. In addition, these machines are used to deliver high-precision strikes on ground targets, including air defense elements, ammunition depots and enemy equipment. The aircraft are equipped with modern weapons, including: AIM-9X guided missiles (short-range), AIM-120 AMRAAM (medium-range), AGM-88 HARM anti-radar missiles, as well as air bombs with a guidance system, such as the GBU-39. The standard equipment also includes a six-barrel M61 Vulcan cannon, designed for close combat. In the future, it is envisaged to use more advanced weapons, in particular long-range JASSM missiles, which will significantly increase the strike potential. Practical experience of operating the F-16 has proven their effectiveness in the difficult conditions of the modern theater of operations. Despite the need to install additional systems (fuel tanks, electronic warfare equipment), which partially reduces the combat load, these aircraft have become a reliable means of air cover and deterrence of the enemy. Their appearance changed the dynamics of the air campaign, forcing the Russian aviation to act more cautiously and avoid direct collisions. Thus, the F-16 became not only a tool of armed struggle, but also a symbol of the transition to new standards of warfare, demonstrating the effectiveness of Western technologies in the fight for Ukrainian sovereignty.

RESEARCH ON METHODS OF DEPLOYING INFRARED FLARES TO ENHANCE AIRCRAFT SURVIVABILITY

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In light of the active use of infrared-guided missiles (IR seekers) by the enemy, particularly the latest-generation systems equipped with imaging infrared (IIR) matrix sensors, there is a critical need to enhance the effectiveness of aircraft protection systems. One of the promising directions is the optimization of flare deployment methods, specifically through salvos that can mimic the thermal signature of a real aircraft with minimal deviations in spatial, energetic, trajectory, and temporal parameters.

Taking into account the selection algorithms in modern IR seekers, effective flare salvos should include a combination of high-temperature and low-temperature decoys with varying spectral characteristics, as well as implement delays in the deployment of individual flares. This creates a false emission structure within the IR seeker's field of view, similar to that generated by the fuselage, nozzles, and engine exhausts of an aircraft in different flight modes. Particularly promising are adaptive flare deployment methods controlled by software integrated with missile approach warning systems (MAWS), which can account for threat direction, missile energy profile, and parameters of the targeted aircraft.

Experience from the full-scale war launched by Russia against Ukraine has demonstrated the effectiveness of complex multi-component flare salvos, combining elements with different thermal regimes and utilizing spatially dispersed flare deployment in three orthogonal directions.

Thus, research on flare deployment methods should focus on developing intelligent schemes for forming a false thermal image that considers the aircraft's physical characteristics, type of threat, and specifics of combat application.

RESEARCH ON INFRARED HOMING HEADS FOR AIR-TO-AIR MISSILES

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The development of air-to-air missile guidance systems is crucial for modern aerial combat. This study explores infrared homing heads (IRHH) with multispectral sensors, which enhance targeting precision and resistance to optical and thermal countermeasures.

Key parameters such as spectral sensitivity, spatial resolution, and response time were analyzed, alongside a comparison of infrared, ultraviolet, and combined sensors. The study also evaluated how signal processing algorithms affect guidance accuracy.

Multispectral sensors proved effective in distinguishing targets from interference and enabling automatic tracking. Recommendations include applying adaptive filtering and machine learning to improve recognition and missile efficiency.

Findings support improved design and modernization of air-to-air missiles for enhanced performance in complex scenarios.

STUDY OF PENETRATION CAPABILITY OF TANDEM SHAPED MUNITIONS CONSIDERING THE EXPERIENCE OF LOCAL WARS

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Under modern combat conditions, the role of precision-guided munitions capable of effectively engaging enemy armored vehicles – particularly those equipped with reactive armor – has significantly increased. One of the key solutions in countering such vehicles has been the development of tandem shaped-charge munitions, which can overcome complex layers of both active and passive protection.

Combat experience from local wars – in Afghanistan, Syria, Ukraine, and the Middle East – has confirmed the effectiveness of using tandem warheads in handheld anti-tank weapons, anti-tank guided missile systems, and aerial munitions. The principle of operation of such warheads lies in the sequential activation of two shaped-charge elements: the first triggers the reactive armor, while the second penetrates the main armor.

The effectiveness of the penetration depends on numerous factors: warhead design, timing between detonations, distance to the target, armor type, and operational conditions. In particular, urban combat has revealed the need to improve tandem systems for defeating vehicles with reinforced frontal protection.

Prospects for the development of tandem munitions include improving the geometry of shaped-charge liners, using new materials for liner construction, and implementing digital guidance systems. An important area of focus is the creation.

STUDY OF WAYS TO IMPROVE THE STATIONARY GASIFICATION UNIT SGU-7KM TO IMPROVE TACTICAL AND TECHNICAL CHARACTERISTICS

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In today's environment, the completeness, timeliness and quality of logistics support have a very important impact on the combat capabilities of the Air Force of the Armed Forces of Ukraine (AFU). Combat experience in the war between Russia and Ukraine shows that limitations in logistics capabilities make it difficult for aviation units to conduct active combat operations. First of all, this concerns the manning and serviceability of military equipment, tactical, technical and operational characteristics of military equipment, readiness of the airfield network, provision of airfield technical support facilities, etc.

To prevent disruption of combat missions due to enemy attacks, it is advisable to use mobile gasification units that do not require connection to the power grid and can be moved to appropriate unheated sites in a short time. All this will contribute to the ease of use and preservation of the cryogenic product from enemy attacks aimed at destroying the main and operational airfields.

An example is the latest foreign-made gasification units used in NATO countries to supply air bases and industry. These samples are mobile, easy to use, reliable in operation and able to perform tasks without fail in the conditions of hostilities. Therefore, conducting research on the use of modern gasification units with appropriate tactical, technical and operational characteristics and meeting the requirements for military equipment is an urgent task.

DEVELOPMENT OF PROPOSALS FOR THE MODERNIZATION OF SPECIAL EQUIPMENT OF THE APA-5D MOBILE AVIATION POWER UNIT TO IMPROVE OPERATIONAL CHARACTERISTICS

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The stages of modern rapid technological development and the implementation of advanced aviation systems such as the F-16 AM/BM MLU impose stringent requirements on the most widely used mobile aviation power units – the APA-5D.

The urgency of addressing this issue lies in improving the reliability of aircraft engine starting systems and power supply systems for aircraft, as well as in ensuring comprehensive logistical support for units through the modernization and enhancement of outdated equipment, and equipping these units with modern airfield equipment based on next-generation chassis platforms.

The issue of stabilizing both AC and DC currents with capacities up to 40 kW and stabilizing their frequency must be addressed by introducing modern circuit design solutions and integrated component bases using PWM (Pulse Width Modulation) technologies, such as the ADF4159 Fractional Synthesizer, to construct reference inverter generators that produce ideal waveform and frequency AC power for the current stabilization system.

Additionally, in high-load scenarios, the use of automated control systems for technical parameters based on binary sensors like Fibaro and inductive sensors such as the Schneider XS8D1A1PAM12 is necessary.

Thus, the modern development of the ground-based power supply infrastructure for aircraft must correspond to the advancements in aviation technology, incorporating modern technologies and innovative solutions.

DEVELOPMENT OF PROPOSALS FOR IMPROVING THE RELIABILITY OF THE CONTROL AND PROTECTION SYSTEM OF THE UKZ-2M UNIT ON THE AERODROME MOBILE ELECTRIC AGENCY REGATTA APA-80

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In the current conditions of a full-scale invasion, the issue of ensuring the reliable functioning of airfield infrastructure, in particular ground-based power supply for aircraft, is particularly acute. The APA-80 airfield mobile power unit, equipped with the UKZ-2M protection control and command system, performs an important function in providing aircraft with electrical energy to start aircraft engines and power on-board equipment in ground conditions, which directly affects the overall readiness of aviation equipment to perform combat missions.

The performance of tasks in the conditions of a full-scale invasion is accompanied by an increased level of threats to the technical integrity of systems – including the risks of electromagnetic pulse (EMI) damage, shelling, communication outages, and the lack of stable power supply. In such situations, the reliability of the control and switching system of the UKZ-2M unit determines the ability of the APA-80 to effectively perform its functions at critical points – during the start of aircraft engines, charging on-board batteries and providing ground maintenance of aircraft.

During intensive operation of the APA-80 airfield mobile power unit, especially in a combat situation, the UKZ-2M unit demonstrates a number of technical shortcomings.

To ensure the reliable functioning of the APA-80 airfield mobile power unit, especially in combat conditions, it is advisable to introduce an emergency reserve switching unit (ERSU). This device automatically switches power to a backup source in the event of a failure of the main one and provides protection against short circuits and overvoltage, which is critically important for uninterrupted power supply of aviation equipment.

RESEARCH ON THE POSSIBILITY OF IMPLEMENTING MODERN OXYGEN EXTRACTION TECHNOLOGIES BASED ON THE ABSORPTION METHOD OF AIR SEPARATION

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The implementation of modern oxygen extraction technologies based on the adsorption method of air separation represents a promising direction in the development of energy-efficient and environmentally safe gas production. This approach allows for the optimization of oxygen generation for industrial and medical needs by reducing energy consumption and increasing process selectivity.

The relevance of this research is driven by the need to enhance the energy efficiency of technical gas production processes, particularly in the context of the transition to sustainable development. The aim of this study is to analyze the possibilities and prospects of applying modern adsorption technologies for oxygen extraction from atmospheric air, to assess their advantages, disadvantages, and potential for industrial deployment. Special attention is given to recent developments in the field of adsorbents, the optimization of technological schemes, and the environmental aspects of this method.

Thus, the study is aimed at substantiating the feasibility of introducing innovative adsorption technologies into the practice of oxygen extraction as an alternative to traditional air separation methods.

One of the most promising approaches is the adsorption (or absorbent-based) technology, which is based on the principle of selective capture of gas mixture components by special materials – adsorbents or molecular sieves. This method enables efficient and economically viable production of both oxygen and nitrogen without the significant energy expenditures typical of conventional cryogenic air separation.

RESEARCH OF METHODS OF OPERATIONAL IMPROVEMENT. CHARACTERISTICS OF THE COOLING SYSTEM OF THE COMPRESSOR EQUIPMENT OF THE AUTOMOBILE OXYGEN EXTRACTION STATION

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Under the current conditions of full-scale invasion in Ukraine, where the logistics of the Air Forces face numerous challenges, reliable aerodrome-technical support has become especially crucial. One of the key elements of this process is the mobile oxygen-nitrogen production station AKDS-70M, which extracts and supplies liquid and gaseous oxygen and nitrogen to aviation units in accordance with national standards (DSTU). These resources are critically important for maintaining aviation combat capability, conducting operational tasks, and ensuring personnel safety.

In conditions of intensive use, where the equipment operates in extreme and dispersed environments, the risk of technical malfunctions increases. One of the most common issues is a drop in pressure within the compressor cooling water system due to clogging of the standard filter located before the 2KM-6S pump.

Therefore, the implementation of technical solutions aimed at improving the reliability and uninterrupted operation of the compressor equipment has become highly relevant. One such solution is replacing the standard filter with a modular filter block, which allows cleaning to be performed without stopping the process. This innovation ensures stable operation of the cooling system, reduces the workload on personnel, and minimizes risks associated with equipment downtime under combat conditions.

Thus, the modernization of the AKDS-70M cooling system through the introduction of a modular filter block is a strategically important step toward strengthening the technical capabilities of the Air Forces, ensuring operational readiness, and preserving the lives of service membe.

DEVELOPMENT OF A DISTRIBUTION BOX FOR SPECIAL EQUIPMENT APA-5D

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This work investigates the possibility of improving the aviation mobile power unit APA-5D by replacing the standard AC generator GT40PCH6 with a capacity of 40 kW with a generator GT60PCH8ATV with a capacity of 60 kW. Such modernization is aimed at improving the technical and operational characteristics of the electric power unit.

The drive of the generators in the APA-5D stock is provided by a diesel engine installed on the basic Ural-4320 automobile chassis. The torque from the KAMAZ-740 engine is transmitted to the PR600x2 DC generator and the AC generator GT40PCH6 with the provision of additional speeds.

Since the GT60PCH8ATV generator operates at higher shaft speeds, its installation requires the development of a new transfer case with a different gear ratio. As part of the work, an analysis of the suitability of the APA-5D power unit for effective operation with a generator of increased power was carried out. A power balance calculation, kinematic analysis, and calculation of the parameters of shafts, joints, rolling bearings, and gears of the new transfer case were performed.

PROPOSALS FOR USING A GAS CYLINDER UNIT IN A SET WITH A BOOSTER-TYPE COMPRESSOR AS A GAS CHARGING STATION

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The report examines the operational experience of vehicle-mounted gas charging stations used for airfield technical support of Air Force aviation. An analysis of the possibilities for optimizing the process of charging aircraft onboard systems and expanding the operational capabilities of airfield technical support units through the implementation of cylinder units complete with booster compressors has been conducted.

The existing means for charging the onboard oxygen and nitrogen systems of the Air Force aviation are based on Soviet-made automobile chassis and are equipped with compressors driven by chassis engines through a cardan shaft, which is excessively powerful for this purpose. The main disadvantages of this design include the dependence of the station's special equipment functionality on the technical condition of the chassis, the inefficient use of engine resources and fuel for compressor operation, as well as significant time spent on equipment preparation.

Furthermore, the piston compressors used have a limited service life before overhaul, and in case of seal failures, they degrade the quality of the output gases. There is also the problem of a significant amount of work required for the maintenance of the compressor and the dehumidification system under time constraints.

It is proposed to use certified BB-12.40-350 cylinder units in combination with OV-30 type booster compressors as backup equipment for charging onboard gas systems. The use of pneumatically driven compressors will allow for a more efficient utilization of gas reserves in cylinders at operational airfields, reduce maintenance costs for specialized ground equipment, and involve a wider range of non-specialized transport for delivering gases to aircraft technical positions.

APPLICATION OF THE LATEST METHODS AND MEANS OF CERTIFICATION OF PRESSURE VESSELS IN MILITARY UNITS OF THE AIR FORCE OF THE ARMED FORCES OF UKRAINE

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In aviation aerodrome technical support, pressure vessels are widely used, particularly cylinders for transporting and storing gases in compressed, liquefied, or dissolved states at ambient temperatures. To ensure their safe operation, it is necessary to regularly verify that their technical characteristics comply with safety requirements.

During operation, it is mandatory to conduct technical inspection of these cylinders at specialized testing points at specified intervals. Cylinders in operation in military units, including those installed on aerodrome technical support equipment, are also subject to periodic inspection.

To simplify this process, the method of ultrasonic flaw detection is considered, which allows for the inspection of cylinders without dismantling them, directly at their workstations or on aerodrome technical support equipment, significantly facilitating the assessment of their continued use.

RESEARCH ON MODERN METHODS AND MEASURES FOR QUALITY CONTROL OF COMPRESSED AND LIQUEFIED GASES

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In the context of ongoing hostilities, the completeness, timeliness, and quality of the analysis of compressed and liquefied gases have a very significant impact on the combat capabilities of the Air Force of the Armed Forces of Ukraine (AFU). Combat experience in the war waged by the Russian Federation against Ukraine shows that the time spent on controlling compressed and liquefied gases leads to an increase in the readiness time of aircraft for combat duty. First and foremost, this concerns the quality control means for liquefied and compressed gases currently in service with the Air Force of the Armed Forces of Ukraine.

In aviation units of the AFU, devices PAKiA, 8-Sh31, and G-2 are used for controlling compressed and liquefied gases. One of the peculiarities during the full-scale armed aggression of Russia against Ukraine has been the dispersal of aviation units at main and operational airfields, as well as the dispersal of equipment by units at the airfield. This complicates the process of controlling compressed and liquefied gases.

The main disadvantage of the listed devices for quality control of liquefied and compressed gases is their limited transportability, a large requirement for the material being tested, and spare parts for repairing the devices due to the cessation of their production.

To ensure control and uninterrupted preparation of aircraft for combat missions, a lot of time is spent collecting material for conducting analyses. And the analyses themselves must be carried out in a laboratory, which creates a threat to personnel.

An example is the latest models of foreign-made control and quality assurance equipment used in NATO countries to support air bases and industry. These models are mobile, easy to use, reliable in operation, and capable of performing tasks flawlessly in combat conditions.

PROPOSALS FOR IMPROVING THE OPERATIONAL PERFORMANCE OF POWER PLANTS OF AIRFIELD TECHNICAL SUPPORT FACILITIES

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Airfield technical support vehicles in the Armed Forces of Ukraine are usually based on ZIL-131, Ural-4320, ZIL-130, and GAZ-66 vehicles. All of them are equipped with V-shaped 8-cylinder engines that have exhausted their modernization potential. The large displacement of these engines is required only at maximum speeds, while most of the time the equipment operates in light load modes.

To reduce fuel consumption and increase motor life, it is advisable to use engines with variable displacement.One of the most promising methods is to shut down the cylinders.This can be realized by stopping the fuel supply or stopping the valve mechanism through an electromagnetic or hydraulic drive.

Modular cylinder shutdown is the most efficient option.In this system, the engine is divided into independent modules that are connected or disconnected according to the load.This eliminates friction losses and gas exchange in the disconnected cylinders, which significantly increases fuel efficiency.

This approach can be applied to both gasoline and diesel internal combustion engines with mechanical or electromechanical injection.The introduction of variable displacement engines on railroad vehicles will ensure more efficient fuel use, reduce operating costs and increase the service life of the equipment.

STUDY OF WAYS TO IMPROVE THE ELEMENTS OF GAS COMMUNICATION OF SPECIAL EQUIPMENT UGZS.M-131 TO IMPROVE THE TECHNICAL CHARACTERISTICS OF THE STATION

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In this work the improvement of elements of gas communication of special equipment of UGZS.M-131 is considered.

Aerodrome – technical support of flights is a set of measures and technological processes. One of these processes is the timely supply of conditioned, compressed gases to the aircraft and charging them with its on-board systems. Charging with compressed nitrogen gas in the aviation parts of the ZSU is performed by regular gas charging stations UGZS.M-131.

The unified gas charging station based on ZIL-131 is designed to charge oxygen, nitrogen and pneumatic systems of aircraft with conditioned compressed gases.

In order to improve the technical characteristics, as well as to improve the gas communication system of the station, it is proposed to replace the outdated membrane compressor MK-120-120/350 with a modern compressor with a pneumatic drive.

This improves the reliability and manufacturability of the station. The kinematic scheme of special UGZS.M-131 equipment is simplified, and at the same time maintenance is facilitated.

And also to monitor the pressure decrease in the group below 10 kgf/cm2, it was decided to install a pressure sensor on each group. Its task is that when the pressure in the group approaches 10 kgf/cm2, inform the station operator about this in the form of an alarm signal and an emergency light on the control panel.

RESEARCH ON WAYS TO ENHANCE THE JAMMING RESISTANCE OF COMMAND RADIO CONTROL LINKS

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The primary task of a command radio control link is to ensure reliable communication between a fighter aircraft and the control center, even under enemy electronic warfare conditions. In the context of full-scale warfare, the enemy actively employs electronic warfare systems that can significantly disrupt this communication. Therefore, the study of methods to enhance the jamming resistance of command radio links, particularly the E502-20 system, is extremely relevant.

This study analyzes key technical solutions aimed at improving resistance to jamming. One of the most effective is the implementation of Frequency Hopping Spread Spectrum, where the signal continuously changes its frequency to prevent the enemy from intercepting or jamming it. Another efficient method is the use of modern digital modulation such as Orthogonal Frequency Division Multiplexing, which splits the signal into multiple narrowband sub-signals and transmits them simultaneously, enhancing resistance to interference. Also important are the use of noise-like signals, which are difficult to detect and jam, and the modernization of the hardware components of the radio link to improve sensitivity and performance.

Evaluation of these methods demonstrates that combining digital technologies with advanced hardware significantly enhances communication reliability. This ensures stable aircraft control even under complex combat conditions, directly influencing the success of mission execution.

USE OF FREQUENCY-TUNED SPATIALLY DISTRIBUTED TRANSMITTERS FOR GENERATING FLUTTER JAMMING IN GROUP PROTECTION OF AIRCRAFT

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Electronic warfare plays a crucial role in modern high-tech warfare, which is why leading military nations pay special attention to the development and improvement of electronic countermeasure systems. In combat operations, adversaries increasingly employ strike aircraft groups equipped with radar-guided missiles. Therefore, to protect and cover friendly aircraft, effective jamming measures must be employed.

Flutter jamming (FJ), regardless of its implementation method, is considered universal because, under certain conditions, it can affect any radar direction-finding system. The effect of FJ can be created using spatially distributed jamming transmitters (JTs) with continuous frequency tuning. As a result, the antenna system of the jammed radar will switch from tracking one target to another, experiencing destabilization according to the operational program of the JTs.

The advantage of frequency-swept jamming (FSJ) lies in its ability to impact a large number of radars whose operating frequencies fall within the tuning frequency range of JTs.

When generating FSJ, different numbers of JTs can be used, with the tuning laws of each transmitter being controlled manually or automatically via an electronic computing machine. When four JTs are used, the following operating modes:

each JT is set to a specific fixed frequency;

the frequency of each JT is adjusted within a designated portion of the bandwidth to ensure full frequency coverage;

each noise JT sweeps its frequency across the entire bandwidth according to a sawtooth waveform.

Using four JTs for FSJ increases power by 6 dB compared to a single JT operating in a limited-band jamming mode with frequency retuning.

DEVELOPMENT OF A SITUATIONAL NAVIGATION FIELD FOR GROUP UNMANNED AERIAL VEHICLE MISSIONS

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Ensuring flight safety of unmanned aerial vehicle (UAV) operations, particularly in group formations, is a key objective of air traffic management systems. The high density of flight paths in launch and landing zones necessitates precise control over the relative positioning of UAVs. To coordinate and synchronize group flights, an optical inter-aircraft navigation system is proposed. This system enables accurate determination of relative positions, generation of navigation commands, and maintains low observability in contrast to less precise radio-based systems.

The situational navigation field is generated as a set of digital images in the visible or infrared spectrum. Each fragment of the situational navigation field represents a portion of the overall scene, where gradient-based methods are employed to detect object contours and their angular coordinates. The situational navigation field is treated as a matrix composed of all segment elements, with its dimensionality determined by the number and size of the individual fragments. The positions of navigation reference points, defined in the UAV's coordinate system, are converted into azimuth and elevation angles to support coordinated movement.

The central point of the UAV's coordinate system is defined through the optical sensor's field of view (FOV), which is divided into segments corresponding to elements of situational navigation field. The FOV for each element is calculated separately in terms of azimuth and elevation, accounting for the non-uniformity of FOVs across the hemispheres. Navigation points detected through machine vision are identified by their position within the situational navigation field and their angular deviation from the central point, thereby enabling precise group navigation.

DEVELOPMENT OF PROPOSALS FOR MODIFICATION OF AIRPORT ELECTRICITY UNIT APA-5D BY REPLACEMENT OF DC GENERATOR PR-600x2 WITH AC GENERATOR GT-40PCH-6

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To determine the technical condition of onboard equipment, individual units and systems and to prevent the release of faulty aircraft into flight, ground maintenance and preparation of aircraft for flight are carried out. At the same time, the equipment, units and systems under inspection are supplied with electrical energy from ground power sources in order to save the engine life of aircraft engines, save fuel and lubricants, ensure safety and reduce the time for maintenance and inspection.

Aviation mobile power units (APUs) are fully autonomous and are widely used at all airfields.

It is proposed to replace the regular DC generator PR-600x2 with an alternator GT40-PCH6, which has a number of advantages.

In the course of the research, the following was carried out: analysis of the existing DC system of the APA-5D electrical unit, experience of its application, and evaluation of the efficiency of operation. A structural and circuit diagram of rectification of three-phase alternating current 115 V 400 Hz to direct current of 24 V (28.5 V) and 48 V (57 V) for aircraft launching was developed.

In the course of development and calculation of the scheme of rectification of 3-phase alternating current 208 V 400 Hz to direct current of aircraft launching 24 V (28.5 V) and 48 V (57 V) with replacement of the regular DC generator PR-600x2 with alternator GT40-PCH6 , It was possible to significantly minimize the size and weight of the entire APA-5D electrical unit, unify the overall electrical circuit, get rid of the outdated collector-type DC generator PR-600x2, and minimize the time for maintenance of the APA-5D.

STUDY OF WAYS TO IMPROVE THE SECONDARY RADAR SYSTEM OF AIR TRAFFIC MANAGEMENT

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Taking into account modern requirements for ensuring flight safety and increasing the operational efficiency of aviation, the development of air traffic management systems (ATMSs) is extremely relevant. The outdated component base of existing devices limits their functionality and reliability, increasing risks during missions.

A method for improving secondary radar systems of ATMS through the implementation of addressable aviation transponders and collision avoidance systems has been proposed. This involves upgrading the SO-69 and SO-72 aviation transponders to ensure compatibility with RBS and S mode operations.

The development is aimed at improving the reliability of ATMs by duplicating altitude data, thereby minimizing the number of conflict situations during flights. It also provides real-time automatic warnings to the crew of dangerous situations.

Thus, the proposed development makes it possible to integrate modern technologies into existing radar systems of the ATMSs, increase their efficiency, reduce the risks of collisions and optimize the use of airspace.

PROSPECTS FOR THE EVOLUTION OF NAVIGATION IN UKRAINIAN AVIATION

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In modern combat aviation, radionavigation systems form the core of the operational effectiveness of 4th-generation aircraft. A comparison between the Soviet MiG-29 and Su-27 and the Western F-16 Fighting Falcon and Mirage 2000 reveals fundamentally different technical approaches to navigation support.

The MiG-29 and Su-27 rely on robust inertial navigation systems combined with Doppler radar systems and A037-type radio altimeters, enabling autonomous navigation without satellite signals. Meanwhile, the F-16 is equipped with the LN-260 inertial-satellite system, tactical aids (TACAN, ILS), and digital communication systems (UHF/VHF, IFF). The Mirage 2000 has a similar configuration, with additional digital processors and the high-precision ULISS 52P INS.

Despite the high degree of autonomy in Soviet aircraft, Western designs offer an advantage in digital integration, self-protection systems, and accuracy in joint-force operations.

Thus, the technical evolution of navigation in aviation reflects deeper strategic philosophies: the Soviet emphasis on independence versus the Western focus on network compatibility and precision.

RESEARCH ON THE MODERNIZATION OF THE ONBOARD INTEGRATED NAVIGATION AND LANDING EQUIPMENT OF THE KURS-93M

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Among the aircraft landing systems, the KURS-93M equipment occupies an important place, ensuring accurate operation even in difficult weather conditions. The complex complies with the regulations governing flights by instrumentation in cases where visibility is limited.

With advances in avionics, the requirements for accuracy, stability and interaction between elements are increasing. The main objective of the upgrade is to increase functionality while maintaining the basic design and interconnections with other onboard systems.

One of the priorities of modernization is the transition from analog to digital equipment. This involves replacing outdated analog components, such as amplifiers, filters, and signal converters, with modern digital components that can perform their functions with higher accuracy, reliability, and speed. Digital processing will allow work to be performed using algorithms that are represented in the form of code and run on a microprocessor or digital signal processor (DSP). This direction will make it possible to accurately distinguish useful signals from noise, easily change processing algorithms for specific flight conditions, and reduce sensitivity to unstable temperature and component wear.

Thus, the modernization of KURS-93M equipment is a promising solution that will ensure greater reliability of aircraft navigation and landing, especially in low visibility conditions. The transition to digital converters and the introduction of microprocessor-based signal processing will improve the system's performance, stability and adaptation to various flight conditions.

ANALYSIS OF MODERN PERSONAL PROTECTIVE EQUIPMENT FOR MILITARY HELICOPTERS AGAINST GUIDED MISSILES

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The analysis of combat losses of Mi-8 transport-combat helicopters in the course of countering the armed aggression of the Russian Federation shows that the vast majority of cases of aircraft damage are associated with the use of portable anti-aircraft missile systems (MANPADS) by the enemy, whose missiles are equipped with infrared homing heads.

The use of modern guided missiles with IRH is one of the key threats to Mi-8 transport and combat helicopters, given their high speed, maneuverability, targeting accuracy, and difficult detection. In this regard, the issue of ensuring effective protection of helicopters of this type from destruction by guided missiles is extremely relevant.

In order to increase survivability and reduce combat losses, Mi-8 helicopters were equipped with electronic countermeasures, namely: the Adros optoelectronic jamming station KT-01AV and the Adros KUV 26-50 combined device for firing false heat targets. Taking into account the positive results of the use of these means in combat use, there is a need to expand the functionality of the complex, in particular, to ensure timely detection of a missile attack.

In this regard, it is proposed to integrate an additional missile attack warning station into the "Adros" defense system, which will increase the combat effectiveness of the operation of Mi-8 transport and combat helicopters in the conditions of enemy weapons.

DIRECTIONS FOR IMPROVING THE ODC "KARPATY" IN THE INTERESTS OF THE ENGINEERING AND AVIATION SERVICE

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The experience gained from countering armed aggression has demonstrated the urgent need to upgrade aviation protection systems to enhance resistance against high-precision enemy weaponry. The further development of the complex is driven not only by rapid technological growth in the field of electronic warfare and weapons, but also by practical combat experience, which requires flexible, reliable and adaptive defense systems.

Improvement of the onboard defense complex "Karpaty" (ODC) installed on Su-24 aircraft of the Air Force of the Armed Forces of Ukraine, is an important component in optimizing the design and use of the latest materials, which will make it possible to increase the reliability of the system and its resistance to long-term combat use.

Modern trends in the development of onboard defense complex (ODC) focus on reducing the size and weight of its components, while the application of a modular design will ensure flexible adaptation of the system to various types of threats.

One of the critical elements of the complex is the MAU-UL (L-082) unified heat-seeking radar designed to detect missile launches by infrared radiation. Its effectiveness directly affects the reaction time of the ODC and the possibility of timely application of countermeasures.

Thus, one of the promising directions for improving the L-082 is proposed to be: expanding the detection spectrum through new types of photodetector arrays and enhancing the range and accuracy of missile launch detection by improving signal processing algorithms.

DEVELOPMENT OF A METHOD TO IMPROVE THE RELIABILITY OF THE OPERATION OF THE RSBN-6S SHORT-RANGE NAVIGATION RADIO SYSTEM OF THE SU-24M AIRCRAFT

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In the current context of military confrontation, where Ukraine is forced to defend its independence and territorial integrity, the effective use of combat aviation has become increasingly critical. One of the key assets of the Ukrainian Air Force is the Su-24M frontline bomber, which is tasked with striking both strategic and tactical enemy targets.

A vital component of the aircraft's navigation suite is the short-range radio navigation system (RSBN-6S). Given that the activation of ground-based RSBN stations generates electromagnetic emissions that are easily detectable by the enemy, there is a growing need for the aircraft to operate its navigation systems autonomously – without relying on ground-based beacons. However, such autonomous operation significantly reduces the accuracy of navigation data, which in turn affects the effectiveness of combat missions.

One of the potential solutions to enhance navigation accuracy is the integration of the RSBN-6S with modern Inertial Navigation Systems (INS) based on laser or fiber-optic gyroscopes, as well as the implementation of satellite navigation (GNSS).

The implementation of these measures will contribute to the increased combat effectiveness of the Su-24M and ensure more reliable mission performance under the conditions of modern warfare.

DIGITAL ADAPTIVE FILTERING IN ON-BOARD RADARS

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Digital adaptive filtering is an effective way to increase the noise immunity of radar systems, including product N019, in dynamic conditions. The use of the Kalman algorithm for filtering and target position correction significantly reduces the impact of random signal and noise variations and increases the accuracy of real-time target position estimation. The Kalman algorithm estimates and corrects the target trajectory based on the statistical properties of the signal and noise, adapting to changes in noise and interference, which is very important when working in unstable conditions.

Wiener filters provide optimum filtering by minimizing the RMS error between the input and output signals, which can significantly reduce the noise level at the system output. This is especially effective when processing signals that are weak to constant interference, which is typical for detecting small targets in RF noise. The Wiener filter optimizes the signal-to-noise ratio and improves the accuracy of target detection and localization, especially in conditions where the signal is much weaker than the interference. The use of both methods in the N019 radar guarantees high reliability of the system and maintains accuracy and efficiency in a wide range of interference, which is important for modern military equipment.

Improvements in digital adaptive filtering in airborne radars, in particular through the use of the Kalman and Wiener filtering algorithms, significantly increase the resistance to interference. This leads to more accurate target position correction and more effective noise suppression, which is especially important for detecting small targets in high noise environments. The integrated use of these techniques contributes to the reliability and efficiency of the radar system in difficult operating conditions.

STUDY OF WAYS TO IMPROVE THE ACCURACY OF MEASURING THE COURSE ANGLE OF THE AUTOMATIC RADIO COMPASS RADIO OF A FIGHTER AIRCRAFT

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Landing is the most critical phase of flight, placing high demands on the performance of landing systems and requiring accurate, reliable, and continuous determination of the aircraft's position relative to the runway. The challenge becomes even greater at non-categorized aerodromes equipped with simplified landing systems.

This work proposes an enhancement to the simplified landing system by introducing an additional Non-Directional Beacon (NDB), positioned at a fixed distance and aligned with the runway threshold, along with a method for automatic detection of aircraft deviations. The technique is based on calculating the difference in bearing angles between the outer and inner NDBs using an Automatic Direction Finder. The additional NDB allows for precise determination of the aircraft's distance to the runway threshold.

The proposed improvement to the simplified landing system enables more efficient approach guidance and more accurate determination of critical landing parameters.

A STUDY OF WAYS TO MODERNIZE THE TARGET LOCATION RADAR COMPLEX RLPK-29 OF THE MIG-29 AIRCRAFT

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In times of armed conflict, it is extremely important to have combat-ready equipment that is constantly ready to perform combat missions. To effectively conduct combat operations during war, military equipment must be able to respond quickly to threats and act accurately and reliably.

Onboard radar systems are an integral part of modern combat aviation, since they determine how effectively an aircraft can detect, track and engage targets.

The radar targeting system is a key element of aviation weapons, responsible for the creation and transmission of powerful pulse signals in the centimeter wave range, reception of reflected signals from air targets, their processing, determination of coordinates and characteristics of object movement. It also provides the transmission of this information to the aircraft's onboard systems and generates signals for weapon guidance and aircraft control.

Therefore, the airborne radar system requires further research and modernization, which will contribute to increasing its efficiency and improving the overall operation of the aviation complex.

Thereby airborne radar plays a key role in modern fighter aircraft, providing detection, tracking of air targets and precise guidance of weapons. Thanks to the development of computing technologies, modern pulse-Doppler radars are able to simultaneously perform several important functions, which significantly increases the combat capabilities of aircraft.

ANALYSIS OF WAYS TO INCREASE THE SECRECY OF THE UAV RADIO COMMUNICATION CHANNEL

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During the full-scale Russian invasion of Ukraine, the issue of countering enemy electronic warfare systems has become particularly actual, especially when controlling unmanned aerial vehicles (UAVs).

One way to improve the jamming resistance of the UAV control signal is to use radio modules with a complex information protection algorithm. It is clear that when enemy EW systems affect the drone's navigation radio signals, the aircraft loses its orientation in space, its normal operation is disrupted, and communication with the operator is lost.

The report examines the characteristics of the mini GPS module from Walksnail, which uses an integrated receiver with built-in protection against interference and signal simulation. The use of a built-in magnetic mini-compass and a modern chip is expected to improve the reliability and accuracy of coordinate measurement.

Thus, suggested improvements to the mini GPS module can be used in mini UAVs. Additional filtering algorithms will help reduce the impact of radio frequency interference, ensuring its stable operation and significantly increasing the jamming resistance of the received signal, especially from satellite systems.

WAYS TO IMPROVE THE ACCURACY OF ALTITUDE MEASUREMENT BY A LOW-ALTITUDE RADAR ALTIMETER OF THE SU-27 AIRCRAFT

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In combat conditions, low-altitude flight is an important element of the Su-27 fighter’s tactical deployment. Reliable altitude measurement is critically necessary for its safe and accurate execution. Radar altimeters, which are part of the aircraft’s onboard systems, are capable of providing high accuracy, but their performance is significantly affected by external factors – primarily the characteristics of the underlying surface. Over water, the device operates quite stably because the signal reflects well, but over forests or built-up areas, significant interference can occur, leading to measurement errors.

To reduce the impact of external factors on altitude measurement accuracy, several technical solutions are used. In particular, the antenna's directional pattern is improved, which helps reduce the number of unwanted reflections. Additionally, frequency-modulated signals with a wide spectrum are applied – this increases resistance to interference. Another important element is the self-monitoring system, which makes it possible to detect instrument malfunctions even during flight.

These improvements make the radar altimeter on the Su-27 more stable and accurate, which is especially important for low-altitude flights in complex environments – such as over forests, mountainous terrain, or urban areas. It becomes easier for the pilot to navigate, the risk of navigation errors decreases, and the overall flight becomes safer. This directly affects the effectiveness of combat mission execution.

ANALYSIS OF PROPOSALS TO IMPROVE THE L-203B "GARDENIA" ACTIVE JAMMING SYSTEM

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The experience of combat operations has shown that it is impossible to imagine any air operation without the use of electronic warfare. This largely depends on the reliable functioning of onboard electronic warfare equipment.

Modern approaches to the further development of airborne electronic warfare equipment clearly define the existence of trends in the advanced development of these means and systems, taking into account forecasts of the development of air defense means and systems.

Therefore, increasing the capabilities of airborne electronic warfare systems of the Armed Forces of Ukraine by reducing the effectiveness of enemy air defense systems and means is a rather relevant scientific and practical issue today.

Based on the analysis of the current state and prospects for the development and modernization of the L-203B "Gardenia" active jamming system, it can be concluded that in order to increase the efficiency of use, it is necessary to modernize the relay channel of the L203B station.

Thus, this modernization will expand the range of interference generated by the L-203B Gardenia AS and make electronic suppression more effective.

RESEARCH ON METHODS TO ENHANCE THE DETECTION OF GPS SPOOFING ATTACKS ON UAVS

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During the armed conflict against the Russian Federation, the urgency of the problem of GPS spoofing was revealed, which is a serious threat to unmanned aerial vehicles (UAVs). Since this allows the enemy to change the coordinates of the device, disrupting navigation and successful execution of missions of the Armed Forces of Ukraine.

Unmanned aerial vehicles spoofing is a targeted impact on the navigation or telemetry systems of an unmanned aerial vehicle in order to disorient or intercept its control. Such an effect can be realized by simulating authentic signals (in particular, GPS or control commands), as a result of which the device receives false coordinates or commands, which it interprets as reliable.

There are synchronous and asynchronous spoofing. Synchronous is an exact substitution of GPS signals with full synchronization, which allows you to quietly take control of the UAV navigation.

Asynchronous is a crude way with uncoordinated signals that can cause failure or loss of communication, but is easier to detect.

Methods for detecting spoofing GNSS signals are aimed at detecting fake signals to warn users about incorrect location and time data, which can lead to dangerous situations. The main methods include monitoring the signal-to-noise ratio, analyzing pseudo-conditions and signal correlation, using hardware simulators and the antenna array method. The combination of these approaches provides reliable protection against spoofing attacks.

RESEARCH OF METHODS FOR CREATING A DIGITAL AUTOMATED MODEL FOR DECODING INFRARED AERIAL IMAGES

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In modern combat conditions, rapid and accurate interpretation of infrared aerial imagery is critically important for military intelligence. The volume of such data is growing rapidly, so traditional image analysis methods cannot keep pace with the incoming data. This necessitates the automation of image interpretation based on artificial intelligence and deep learning.

To address this problem, a new approach is proposed that integrates state-of-the-art computer vision and language models. The developed system uses the YOLOv8 neural network for highly accurate detection of military objects in IR images, as well as the multimodal visual-language model BakLLaVA (a GPT-like network) to generate an analytical description of the scene. All components run locally and are combined into a graphical user interface (GUI), which allows uploading images, adjusting the detection threshold, and obtaining textual explanations from a chatbot. The key advantages of this solution are autonomy (offline operation without internet), high speed (real-time image processing), and adaptability to field conditions. Test results on a specialized infrared image dataset confirmed the system’s effectiveness. It achieved high target detection accuracy and generated correct scene descriptions, indicating promise for practical implementation.

WAYS TO IMPROVE THE ACCURACY AND RELIABILITY OF THE AUTOMATIC RADIO COMPASS WITH A FLEXIBLE SYSTEM OF DRIVEN RADIO STATIONS ON THE MIG-29 AIRCRAFT

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The MiG-29 automatic radio compass (ARC) determines the heading angle and flight to the nearest control radio station, which is important when performing combat missions. An ARC is a device that uses radio signals from ground-based radio beacons to determine the aircraft's course. The device automatically adjusts only to receive signals and determines the direction to the radio beacon.

The accuracy of determining the heading angle of a radio station depends on the conditions of radio wave propagation, flight mode, and the characteristics of the system itself.

Under normal conditions, the radio compass receives a vertically polarized radio wave. However, due to the presence of horizontally arranged frame elements, it is affected by a field with horizontal polarization under abnormal radio wave propagation conditions. Under these conditions, distortion of the directional pattern and direction finding errors may occur.

To improve the accuracy of direction finding in the medium wave range, it is proposed to use the Adcock cross loop, which consists of two or four vertical dipoles arranged in pairs. Each pair forms the electrical equivalent of a loop antenna, but reduces the sensitivity to horizontal polarization. Additionally, the use of phase correctors as part of the antenna system makes it possible to compensate for phase distortions, which allows to increase the accuracy of determining the direction to the radio station, especially under the influence of the structural elements of the aircraft.

The application of the above proposals allows to increase the accuracy and reliability of the automatic radio compass, which will allow to more effectively perform combat missions.

ENHANCING ANTI-SPOOFING RESILIENCE OF GLONASS AND GPS USER EQUIPMENT SN-3307-02

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In the current environment, where the risk of intentional electronic interference with satellite navigation systems is increasing, ensuring the spoofing resistance of navigation equipment has become critically important. Spoofing signals pose a serious threat to navigation accuracy by imitating legitimate satellite signals and deceiving user equipment. To improve the spoofing resistance of GLONASS and GPS user equipment, such as the SN-3307-02 system, several approaches are applied.

One of the primary strategies involves upgrading antenna systems. The use of directional antennas or phased arrays enables determination of the signal source direction and suppression of signals arriving from atypical angles. Additionally, adaptive signal filtering algorithms are employed, comparing the timing, phase, and frequency characteristics of incoming signals against known standards. Spoofed signals often exhibit specific anomalies, allowing their identification.

Integration with inertial navigation systems also enhances spoofing resistance. In suspected spoofing scenarios, position and heading can be temporarily determined using inertial sensors. Furthermore, logic can be embedded into the system's software to govern its behavior during signal attacks – such as switching to alert mode or disabling navigation functions while logging data for post-event analysis.

Therefore, improving spoofing resistance is a comprehensive task that requires simultaneous advancements in hardware, software, and tactical deployment strategies. For military aircraft such as the Su-27SM, this is a critical factor for mission success.

STUDY ON METHODS FOR IMPROVE THE RELIABILITY OF THE N019-01 BLOCK IN THE RLPK-29 RADAR LOCATION TARGETING COMPLEX OF THE MIG-29 AIRCRAFT

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Daily intense attacks by "Shahed" type unmanned aerial vehicles and missile strikes pose a serious threat to Ukraine. The inadequacy of ground-based air defense necessitates the active use by the Air Force of aircraft equipped with modern radars, which detect, identify, and simultaneously track up to ten aerial targets, classifying them by threat level.

Modern radar systems can accurately determine target coordinates, calculate parameters for launching various types of missiles, including determining the engagement zone and providing target illumination for precise guidance. They cooperate with other aircraft systems, which allows for rapid data exchange and real-time coordination of actions. However, with the development of enemy technologies, particularly the emergence of more sophisticated drones and missiles, there is a growing need for continuous modernization of radar systems.

To enhance the effectiveness of air defense, key technical improvements are proposed, such as upgrading the antenna-waveguide system, which will accelerate airspace scanning and improve target detection accuracy. Also important is the expansion of the operating frequencies of radars, transitioning to higher frequencies, which will reduce the impact of electronic jamming and improve the stability of the system in electronic warfare conditions. Such improvements will allow for more effective counteraction against modern threats, such as drone swarm attacks or maneuverable cruise missiles, ensuring Ukraine's strategic advantage in air defense.

TECHNICAL OPERATION OF THE AIRCRAFT OF THE ARMED FORCES OF UKRAINE UNDER THE ARMED AGGRESSION OF THE RUSSIAN FEDERATION

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The full-scale invasion of Ukraine by the russian federation in 2022 has significantly transformed the approach to the technical operation of aircraft within the Armed Forces of Ukraine. Under the conditions of intense combat, constant threats of missile strikes on military infrastructure, and limited resources, technical maintenance has acquired not only a functional but also a strategic role. The primary task of technical personnel has become ensuring maximum combat readiness of aircraft with minimal opportunities for scheduled maintenance.

In wartime, key directions include the mobility of repair units, the use of field maintenance bases, and the adaptation of servicing processes to non-standard conditions. Special attention is given to the use of improvised solutions for restoring damaged aircraft, including the use of available civilian technologies and tools such as 3D printing or substitution of parts with non-aviation components.

Another crucial aspect of effective technical operation is the digitalization of processes – keeping electronic records of aircraft condition, remote diagnostics, and coordination through secure digital platforms. In the face of a shortage of spare parts and resources, close cooperation between aviation units and the defense-industrial sector becomes increasingly important, along with the need to improve the technical training of personnel.

Thus, the experience of operating aircraft of the Armed Forces of Ukraine under wartime conditions demonstrates the necessity of constant adaptation, flexibility, and innovation to preserve the country's air capability.

WAYS TO IMPROVE THE EFFICIENCY OF THE SU-27 RADIO TECHNICAL SHORT-RANGE NAVIGATION SYSTEM

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The course of Russia's war against Ukraine has demonstrated the importance of performing combat missions by the Su-27 aircraft, which is equipped with the PNK-10 flight and navigation complex, which is designed to solve navigation and piloting tasks at all stages of flight in simple and complex weather conditions, at any time of the year and day, over land and over sea in any geographical conditions and consists of two subsystems: the PK-10 flight complex and the NK-10 navigation complex.

The navigation complex NK-10 includes the A-317 radiotechnical short-range navigation system (RTSRNS) with the A-313 digital computing device, which performs the following tasks: return to a programmed airfield equipped with radio landing aids in manual and flight on a given route, automatic and director piloting modes, pre-landing maneuver with access to the range of radio beacons, landing to an altitude of 50 m in automatic mode and re-landing.

The quality of the tasks performed by RTSRNS A-317 depends not only on the methods of measuring and processing signals received from ground-based beacons, but also on some parameters of these signals.

To improve the efficiency of the A-317 RTSRNS of the Su-27 aircraft, in order to optimize the parameters of the applied signals and reduce the weight of the overall characteristics, it is proposed to replace the A-312-001 receiving unit and the A-317-002 transmitting unit with the SDR-technology HackRF One transceiver, which uses special programs when applied.

APPLICATION OF HARDWARE AND SOFTWARE COMPLEX TO IMPROVE THE MAINTENANCE SYSTEM

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Currently, it is important to ensure the speed and accuracy of avionics maintenance work on aircraft during armed confrontation with the aggressor country.

The creation of a specialized software and hardware complex for avionics maintenance on aircraft is a necessary step to ensure the technical superiority of the engineering and technical staff.

Avionics maintenance software will increase the efficiency of aircraft avionics maintenance, reduce costs and increase the reliability of the aircraft maintenance system.

With the help of the software, it becomes possible to digitize documentation and instructions, implement their electronic versions with interactive diagrams, and integrate the application with aircraft onboard systems to automatically collect data on the avionics status and identify and predict potential malfunctions.

One of the aspects of implementing a modern hardware and software complex is optimizing scheduling, namely simplifying the maintenance system and distributing tasks among technical personnel. The creation of a software and hardware complex requires a comprehensive approach, including: analyzing the needs of technicians, developing a user-friendly and intuitive interface, integrating with aircraft onboard systems, and providing authorized access to protect data.

DEVELOPMENT OF A MODEL FOR RECOGNITION AND CLASSIFICATION OF ENEMY GROUND FORCES OBJECTS BASED ON ARTIFICIAL INTELLIGENCE

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In the current conditions of armed aggression against Ukraine, the issue of increasing the efficiency of processing aerial reconnaissance data is of particular relevance. The experience of combat operations shows the need to introduce artificial intelligence technologies to automate the processes of recognition and classification of enemy ground forces due to unclear visual observation, which is characterized by a high load on the operator. The use of modern computer vision methods can significantly increase the speed and accuracy of intelligence analysis, which, in turn, contributes to making informed decisions in real time.

A key aspect of model development is the formation of a high-quality data set that should take into account the peculiarities of the combat environment: the diversity of terrain and the appearance of objects with methods of camouflage. The efficiency of deep learning models directly depends on the completeness of the input data and their adaptation to reality. A particular difficulty is the need to ensure high accuracy with limited input data, the variability of the combat environment, and the lack of typical features of enemy objects.

The proposed conceptual solution involves the creation of a model based on modern deep learning methods focused on accurate recognition of enemy ground forces. The results of the implementation of such a model can be used as part of automated situational awareness systems to improve the quality of intelligence analysis and reduce the burden on the operator while increasing combat capabilities.

PROPOSALS FOR INCREASING THE EFFECTIVENESS OF USING STRIKE UAVS AGAINST AIR TARGETS

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Modern warfare demonstrates the growing role of strike unmanned aerial systems (UAS) in countering aerial targets such as aircraft, helicopters, and enemy UAVs. Combat experience highlights the need to improve technology, tactics, and training to increase the effectiveness of such systems.

Combat experience is the basis for developing proposals. The study of operations shows that the successful destruction of air targets depends on the speed of response, the accuracy of sensors and resistance to electronic warfare (EW) means. For example, low-altitude targets require highly sensitive sensors, while high-speed objects require maneuverable UAVs with powerful weapons. Analyzing enemy tactics, such as the use of electronic warfare or counter-UAVs, is also key to developing effective countermeasures.

The integration of multi-spectral sensors (infrared, radar, optical) will ensure reliable target detection in difficult weather conditions. The use of high-precision missiles with adaptive guidance systems will increase the probability of hitting. Resistance to electronic warfare is ensured by protected communication channels and autonomous control systems. Coordination of UAVs with air defense systems to create a multi-layered defense will ensure rapid target detection and make it impossible to track them. UAVs can simultaneously detect, track, and attack targets, increasing effectiveness.

Thus, increasing the effectiveness of strike UAVs in combating air targets requires a comprehensive approach: from the analysis of combat experience to the implementation of advanced technologies and tactics. The integration of AI, new rackets and, as well as high-quality training of operators will provide an advantage in modern combat conditions.

DEVELOPMENT OF A METHOD FOR IMPROVING THE NAVIGATION SYSTEM OF UNMANNED AERIAL VEHICLES UNDER ENEMY ELECTRONIC WARFARE CONDITIONS

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The extensive use of unmanned aerial vehicles (UAVs) in modern combat conditions necessitates the evolution and enhancement of navigation system resilience. Since UAV positioning primarily relies on global navigation satellite systems (GNSS), which remain vulnerable and can be partially or completely blocked by enemy electronic warfare measures, a new approach is proposed for building a UAV navigation system. This approach is based on a hybrid integration of RTK technology, an inertial navigation system (INS), and SLAM visual odometry algorithms.

The system design involves a physical and mathematical model of subsystems for autonomous data fusion from a stereo camera, an inertial measurement unit, and a satellite receiver. It also includes an adaptive navigation mode switching algorithm depending on external environmental conditions. In the event of RTK signal loss, the system automatically switches to the INS+SLAM mode, maintaining navigation accuracy in areas with disrupted communication.

Studies of this system’s performance in various electronic warfare scenarios confirm its reliability and justify the feasibility of implementing the proposed system in serial UAVs of the Air Force of the Armed Forces of Ukraine.

DEVELOPMENT OF PROPOSALS TO INCREASE THE OPERATIONAL OF DESTROYING GROUND TARGETS BASED ON AIR RECONNAISSANCE DATA

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Modern warfare demands rapid and precise destruction of ground targets, which is increasingly reliant on accurate and timely air reconnaissance data. The integration of unmanned aerial systems (UAS), real-time data transmission, and advanced targeting algorithms allows for significantly improved decision-making and combat effectiveness.

Air reconnaissance provides essential intelligence about enemy positions, movements, and infrastructure. The collected data, when processed and integrated with targeting systems, enhances the precision of air strikes and artillery fire.

To further increase the efficiency of destroying ground targets, proposals include the development of multi-layered reconnaissance networks, the use of swarm UAVs for persistent surveillance, and enhanced data fusion technologies. These developments will lead to faster response times, reduced collateral damage, and greater mission success rates in complex combat environments.

Moreover, it is essential to enhance interoperability between different platforms and units by implementing standardized communication protocols and unified data formats. This allows air reconnaissance data to be rapidly and seamlessly utilized by various branches of the armed forces, ensuring synchronized and coordinated strikes on high-value targets.

Thus, the effective use of air reconnaissance data is a key factor in the success of modern operations, and its further integration with strike systems is essential for maintaining battlefield superiority.

ANALYSIS OF EXISTING APPROACHES TO THE PROCESSING AND DECODING OF LARGE VOLUMES OF AEROSPACE INTELLIGENCE DATA IN COMBAT CONDITIONS

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Modern aerospace intelligence has evolved beyond being merely a source of visual data collection and has become one of the key tools in achieving tactical and operational superiority in high-intensity conflicts. The Russian-Ukrainian war, particularly since 2022, has demonstrated the effectiveness of large-scale use of satellite imagery, unmanned aerial vehicles (UAVs), infrared and radio-technical sensors, all integrated with cloud technologies and artificial intelligence.

To process the massive volume of data received from satellites (such as Maxar, ICEYE), UAVs ("Leleka-100", Bayraktar TB2), and situational platforms like DELTA, the Ukrainian Armed Forces employ automated analytics tools, neural networks for object recognition, and geospatial information systems (GIS). Crowdsourcing and open-source intelligence (OSINT) technologies also play a vital role by enabling civilian analysts to assist in decryption and geolocation.

Artificial intelligence and big data have become crucial for rapid response: using algorithms for automatic decoding of videos, images, signal interceptions, and radio communications, the Ukrainian military has been able to act faster than the adversary. Cloud services (such as Azure and AWS) enable real-time data storage and processing, regardless of the geographical location of military units.

Thus, the experience of the Armed Forces of Ukraine has proven that modern intelligence operations require not only high-quality data collection but also a flexible, scalable, and integrated processing system. The application of digital technologies, automation, and decentralized data processing in wartime has transformed the traditional concept of military intelligence, creating a new model of warfare – fast, precise, and network-centric.

DEVELOPMENT OF PROPOSALS FOR THE CREATION OF A MODEL FOR DETECTING ENEMY AIR TARGETS USING COMPUTER VISION TECHNOLOGIES

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With the development of technology, unmanned aerial vehicles are increasingly being used for surveillance, reconnaissance and airspace control. One of the most pressing challenges for such platforms is the effective detection of airborne targets, which is critical to ensuring safety and operational response. Traditional methods, such as radar systems, have a number of limitations: significant energy consumption, dependence on weather conditions and difficulties in detecting small or low-visibility objects.

At the same time, the effectiveness of computer vision systems largely depends on dynamic flight conditions. The airflow caused by both the UAV's movement and external factors can cause vibrations, camera shake, changes in the viewing angle, and other optical distortions. This creates challenges for recognition algorithms, which must be adaptive to such disturbances. In particular, it is necessary to take into account the aerodynamic characteristics of the flight and implement methods to compensate for the effects of airflow to stabilise the image and reduce noise.

This study examines modern approaches to automated detection of airborne objects using computer vision. The main focus is on the impact of airflow on image quality and target recognition accuracy, as well as on ways to eliminate the negative impact of flight dynamics on detection results. The implementation of such solutions will significantly improve the efficiency of unmanned systems in airspace control and object identification in difficult operating conditions.

DEVELOPMENT OF A MODEL FOR DETECTION AND TRACKING OF MOVING GROUND TARGETS USING COMPUTER VISION TECHNOLOGIES

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The experience of combat operations on the territory of Ukraine demonstrates the active use of unmanned aerial systems (UAS) by both the enemy and the defense forces. A wide variety of unmanned aerial vehicles (UAVs) are used for aerial reconnaissance, produced by both domestic and foreign manufacturers. The difference lies in the payload – types of onboard aerial reconnaissance systems (television, infrared, laser) and their functional capabilities.

It should be noted that among the domestically produced UAVs actively used since the beginning of the large-scale invasion are models such as Furia, Leleka, PD-2, ACS-3, and others. On the other hand, one of the most widespread foreign-made UAVs, used despite being designed for civilian purposes, are DJI copter-type UAVs. The main representatives of this product line include the Mavic 3 series drones, which offer a balance between cost and quality (technical characteristics of the television reconnaissance system).

These aerial reconnaissance tools enable the collection of high-resolution data: up to 5K for digital video images and FHD for streaming video. However, a current challenge of aerial reconnaissance systems is the significant time delays that occur during the decoding of video data. Therefore, the goal of this research is to find approaches to improve the responsiveness of aerial reconnaissance data decoding.

This approach will create conditions for improving the responsiveness of aerial reconnaissance data decoding by automating the detection of objects of interest.

DEVELOPMENT OF RECOMMENDATIONS FOR IMPROVING THE EFFICIENCY OF AERIAL RECONNAISSANCE DATA PROCESSING BASED ON THE EXPERIENCE OF COUNTERING LARGE-SCALE AGGRESSION

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In the current context of large-scale aggression by the Russian Federation against Ukraine, the rapid processing of aerial reconnaissance data is critically important for effective combat planning and operations. To achieve this goal, it is necessary to improve the information processing system, particularly through the implementation of automated algorithms and the use of artificial intelligence.

The enhancement of data processing can be achieved through the use of AI-based platforms and computer vision technologies. These systems enable the automatic creation of object catalogs by processing information received from aerial reconnaissance tools in real time. This significantly reduces the time needed for data analysis and transmission. The use of artificial intelligence makes it possible to automatically identify the type, class, and category of targets with high accuracy, enabling swift and reliable decision-making.

In conclusion, it is essential to integrate modern artificial intelligence and computer vision technologies into reconnaissance data processing software. This will make it possible to process large volumes of information in real time, reduce data transmission times, and ensure timely information delivery to the relevant structures

СЕКЦІЯ 3

ТАКТИКА ТА БОЙОВЕ ЗАСТОСУВАННЯ ПІДРОЗДІЛІВ ЗЕНІТНИХ РАКЕТНИХ ВІЙСЬК

Керівники секції: майор Дмитро МОЛЧАНОВ
Секретар секції: сержант Олексій КЛАССЕН

DEVELOPMENT OF PROPOSALS FOR THE RATIONAL COMPOSITION AND COMBAT ORDER OF THE AIRBORNE MISSILE DEFENSE FORCE, ARMED WITH OPEN ARCHITECTURE FOR THE PROTECTION OF CRITICAL INFRASTRUCTURE

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The study considers the urgent issue of increasing the effectiveness of anti-aircraft missile coverage of critical infrastructure facilities in Ukraine in the case of constant attacks by air attack aircraft of the russian federation. An urgent issue is the development of proposals for the rational composition and combat order of an anti-aircraft missile division armed with an open-architecture anti-aircraft missile system.

The analysis of modern air attack means, their tactical and technical characteristics, experience of use and typical scenarios of attacks on critical infrastructure facilities requires radical changes in the tactics of using anti-aircraft missile systems.

The main indicators and criteria for the effectiveness of anti-aircraft missile cover are substantiated. Comparison of different variants of the combat order will allow to determine the appropriate parameters of the combat order, taking into account the speed of response, the area of destruction, the multiplicity of cover and interaction with neighboring units.

The developed proposals for the optimal composition and rational variant of the combat order of an anti-aircraft missile division can be used in planning anti-aircraft missile coverage of critical infrastructure facilities. As a result, the effectiveness of combat operations in difficult air conditions will increase.

DEVELOPMENT OF PROPOSALS TO INCREASE THE SURVIVABILITY OF THE ARMAMENT OF AN ANTI-AIRCRAFT MISSILE UNIT ARMED WITH A SHORT-RANGE ANTI-AIRCRAFT MISSILE SYSTEM

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Modern armed conflicts indicate the growing role of anti-aircraft missile units in the air defense system. In connection with the widespread use of enemy air attack means, especially high-precision weapons, there is a need to improve methods for increasing the survivability of weapons of such units. The survivability of weapons is becoming a critical factor in ensuring the performance of combat missions.

The proposals proposed in the paper to increase the survivability of anti-aircraft missile weapons take into account the dynamics of modern combat, various options for striking by the enemy and the impact of possible measures to increase survivability on its level, which makes it possible to conduct a comparative analysis of proposals to ensure the required level of survivability of anti-aircraft missile weapons in headquarters (military command bodies) in the course of planning and conducting hostilities. In the course of the study, modern approaches to increasing survivability are considered, in particular: the use of natural and artificial means of camouflage and the introduction of reserve firing positions.

The use of the proposed solutions can significantly increase the effectiveness of the combat use of air defense systems, reduce the level of weapon damage and ensure the preservation of the unit's combat capability for a long time, even in conditions of intense enemy influence. Thus, the developed proposals are an important contribution to improving the overall effectiveness of the air defense system of the Armed Forces of Ukraine.

DEVELOPMENT OF PROPOSALS FOR IMPROVING THE PROCEDURE FOR ASSESSING THE FIRE CAPABILITIES OF THE S-300P AIR DEFENSE MISSILE BATTALION USING THE GEOGRAPHIC INFORMATION SYSTEM (GIS) "ARGUMENT-2023"

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The experience of employing air defense missile troops (ADMT) units in modern combat conditions shows that they operate in a highly dynamic environment with limited time for battle preparation, necessitating the use of advanced information technologies.

The purpose of this work is to improve the procedure for assessing the fire capabilities of the S-300P air defense missile battalion using the geographic information system (GIS) "Argument-2023".

The paper provides an analysis of combat employment experience of ADMT units during military operations; the operational planning process of S-300P battalion command elements is defined for evaluating the unit’s fire capabilities; the assessment procedure is substantiated using various methodologies and GIS tools, including: selection of the optimal battle formation, calculation of detection zones and engagement envelopes, and firepower estimation both through general methodologies and modern information technologies.

Based on the results of the study, proposals were developed to improve the procedure for assessing the fire capabilities of the S-300P battalion using GIS "Argument-2023", which contribute to enhancing the speed and accuracy of tactical calculations, thereby enabling well-grounded decision-making regarding mission execution by the S-300P battalion.

RESEARCH INTO WAYS TO IMPROVE TACTICAL METHODS OF ANTI-AIRCRAFT MISSILE UNIT COMBAT WHEN ENGAGING CRUISE MISSILES

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Modern armed conflicts have demonstrated the growing role of cruise missiles as one of the main means of attack. In this regard, improving the effectiveness of air defense, particularly anti-aircraft missile units capable of engaging such targets, becomes critically important. Enhancing the tactical methods of conducting air defense combat when engaging cruise missiles is a necessary condition for increasing the combat capabilities of air defense units.

The purpose of this work is to investigate current directions for improving the tactics of anti-aircraft missile unit operations to ensure maximum effectiveness in engaging cruise missiles in modern combat conditions.

In the course of this work, the following were conducted:

an analysis of the use of cruise missiles in local wars and armed conflicts over recent decades;

an analysis of the methods and tactical techniques of combat application of anti-aircraft missile units when engaging cruise missiles, based on the experience of modern wars and armed conflicts;

a study of ways to improve the tactical methods of air defense combat by anti-aircraft missile units when engaging cruise missiles.

As a result of this work, modern approaches will be proposed for improving the tactical methods of anti-aircraft missile unit operations against cruise missiles, which will increase the effectiveness of their combat use in modern warfare conditions.

DEVELOPMENT OF PROPOSALS REGARDING THE PROCEDURE FOR FORMULATING METHODS FOR EXECUTING A COMBAT MISSION BY AN S-300P SURFACE-TO-AIR MISSILE BATTALION USING THE GEOGRAPHIC INFORMATION SYSTEM (GIS) "ARGUMENT-2023"

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The planning of combat operations by the S-300P SAM battalion is an integral part of combat preparation, which is carried out during both the preparatory phase and the actual conduct of combat operations, as evidenced by the experience of the use of Air Defense Missile Troops units in modern warfare.

The purpose of this work is to develop proposals concerning the procedure for formulating methods for executing a combat mission by an S-300P surface-to-air missile battalion using the Geographic Information System (GIS) "Argument-2023".

The paper presents the sequence of actions by the battalion commander during combat planning, which begins with receiving a combat order and follows the algorithm: comprehending the combat mission; determining immediate actions required to prepare the unit for mission execution; conducting (approving) a time calculation; assessing the situation; developing a concept of operations; formulating a decision; assigning combat tasks to subordinate units; organizing coordination, support, and control; reporting the methods of mission execution to the senior commander; organizing the battalion's preparation for the combat mission.

To substantiate the methods of executing the combat mission by the S-300P SAM battalion, taking into account the experience of combat employment of Air Defense units, the study involved: conducting tactical calculations using the GIS "Argument-2023"; developing a sample commander's briefing report on the methods of mission execution.

Based on the qualification work results, proposals have been provided regarding the procedure for formulating methods of executing a combat mission by an S-300P SAM battalion using the GIS "Argument-2023".

DEVELOPMENT OF PROPOSALS ON WAYS TO IMPROVE THE METHODS OF CONDUCTING ANTI-AIRCRAFT COMBAT BY A TACTICAL AND FIRE UNIT ARMED WITH HAWK AIR DEFENSE SYSTEMS, TAKING INTO ACCOUNT THE EXPERIENCE OF COMBAT OPERATIONS

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Modern armed struggle is accompanied by the active use of air attack means (CAP) by the enemy, among which high-precision means, unmanned aerial vehicles, cruise missiles and other elements of complex air strike systems play an increasingly important role. Successful counteraction to such threats requires constant improvement of the tactics of air defense units.

HAWK-type anti-aircraft missile systems, being in service with tactical and fire units, remain effective means of air defense. However, their effectiveness largely depends on the methods of combat use, adapted to new forms and means of conducting an air attack.

An analysis of trends in the development of air defense and combat experience shows that the existing approaches to the organization of air defense need to be updated. The ways of improving the methods of conducting anti-air combat proposed in the study make it possible to analyze the existing methods of conducting anti-air combat by a tactical and fire unit, to determine and sort the shortcomings according to each classification feature, to make a decision on improving the methods of anti-aircraft combat.

The results of the work are aimed at increasing the effectiveness of the combat use of the HAWK air defense system and can be used in the practical activities of the air defense units of the Air Force of the Armed Forces of Ukraine.

INVESTIGATION OF THE DIRECTIONS OF IMPROVEMENT OF THE METHODOLOGY FOR CALCULATING THE BOUNDARY OF THE AIR ENEMY'S TASKS WHEN USING AIRCRAFT BOMBS WITH A UNIVERSAL MODULE OF PLANNING AND FLIGHT CORRECTION

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The paper examines the trends in the combat use of aviation weapons, in particular in local conflicts of the late XX – early XXI century. Emphasis is placed on the growing use of adjusted aircraft bombs and means with a planning function.

The tactical techniques of the Russian Federation during the war against Ukraine are analyzed separately, in particular the use of UMDs to increase the range of destruction. throwing from a safe distance outside the air defense zone, bypassing difficult terrain and using weather conditions.

The traditional methodology for calculating the boundary of airborne munitions drop is analyzed. Limitations are identified, including the failure to take into account the aerodynamic properties of the UAS, limited accuracy in variable weather conditions, and inadequate adaptation to dynamic combat and changes in the flight route.

The following areas of improvement are proposed modeling trajectories taking into account the airframe characteristics of bombs, integration of geographic information systems and real terrain, analysis of combat experience to refine calculation parameters.

The proposed model will make it possible to more accurately determine the boundaries of air enemy missions, which will increase the efficiency of air defense forces.

IMPROVING THE METHODOLOGY FOR ASSESSING THE IMPORTANCE OF COVER OBJECTS DURING COMBAT OPERATIONS USING SPECIALIZED SOFTWARE

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An analysis of the experience of combat operations during the Russian-Ukrainian war has shown the need to improve the methodology for assessing the importance of cover objects used by anti-aircraft missile units in planning air defense. Existing methods based on expert assessments are often cumbersome, inefficient, and do not allow for rapidly changing battlefield conditions.

The proposed improvement is based on the use of specialized software, in particular the Argument-2023 GIS and the Virage Tablet system, which automates the process of collecting, analyzing and interpreting information on the air situation and the importance of cover objects.

The developed methodology makes it possible to more accurately and quickly determine the priority of covering elements of an operational group of troops, taking into account their role in combat operations, the degree of threat from the enemy and the predicted actions of air attack assets. It is based on an improved method of hierarchy analysis using qualitative assessments and a matrix of pairwise comparisons with consistency checks.

Thus, the implementation of this methodology will help to improve the efficiency of decision-making in the field of air cover, allow for a rapid response to changing situations and a more rational distribution of air defense forces and means in modern combat.

ANALYSIS OF EXISTING METHODS FOR DETERMINING THE LOCATION OF AIR DEFENSE MISSILE UNIT FIRE ELEMENTS IN THE COMBAT ZONE USING GLOBAL POSITIONING SYSTEMS AND GEOGRAPHIC INFORMATION SYSTEMS

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The development of satellite positioning technologies and geographic information systems has significantly increased the level of automation and accuracy of air defense unit management. The successful execution of combat missions by these systems largely depends on the precision and effectiveness of managing their fire units.

This work analyzes the current state and prospects for the development of GPS monitoring systems for mobile objects in SAM units. The implementation of GPS monitoring in air defense missile units contributes to increasing their combat effectiveness by providing accurate positioning, coordination, and integration into the overall command and control system of the Air Force.

The use of GPS monitoring systems significantly improves situational awareness, enables prompt decision-making, and optimizes the movement of fire units.

Characteristics of existing weapons and satellite navigation systems analyzed.

DEVELOPMENT OF PROPOSALS FOR DETECTING AND COUNTERING SMALL-SIZED QUADCOPTER-TYPE ENEMY UNMANNED AERIAL VEHICLES

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In modern combat conditions, the enemy actively uses small-sized unmanned aerial vehicles of the quadcopter type for reconnaissance, fire control, and strikes. Their availability, difficulty in detection, and wide functionality necessitate the development of effective means of detection and countermeasures.

Reasoned recommendations for detecting and countering small unmanned aerial vehicles, taking into account modern technical capabilities and combat conditions, are an integral part of today.

Analysis of literary sources, comparison of tactical and technical characteristics, modeling of typical situations of use of drones, elements of electronic warfare systems and optoelectronic surveillance requires balanced technical and tactical solutions.

The research is relevant, technically sound, and has practical significance for increasing the effectiveness of combating small enemy unmanned aerial vehicles. The implementation of the above-mentioned decisions on the implementation of detection and countermeasure systems at the level of Defense Forces units will contribute to increasing the efficiency of performing assigned combat missions and reducing losses among personnel and equipment, as well as increasing the level of security of critical infrastructure facilities.

DEVELOPMENT OF TECHNICAL PROPOSALS FOR IMPROVING THE DEVICE FOR PROVIDING FIRING AT LOW-ALTITUDE TARGETS OF THE S-125M1 SAM SYSTEM

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The features of the combat operation of the S-125M1 SAM against targets at low altitudes are considered, taking into account the experience of combat operations in the Russian-Ukrainian war, the technical means of increasing the efficiency of firing at low-altitude targets are analyzed, the construction and functioning of the device for supporting firing at low altitudes SNR-125M1 is considered.

When tracking targets flying at low altitudes, a signal reflected from the ground, called a "mirror" signal, may appear at the input of the receiver.

The antenna is scanned in inclined planes. To reduce tracking errors by shifting the center of weight of the resulting signal, the SNR uses the blanking of "mirror" signals in each scanning plane.

To reduce the target tracking errors and to exclude the possibility of switching the angular tracking systems to tracking the "mirror" signal in the LA (low altitude) mode, an additional discriminator of the error watchdog signal was added to the main discriminators of the angular block tracking systems.

Proposals are made to improve the low-altitude detection device by balancing the watchdog discriminators by noise and eliminating the possibility of disrupting the device's operation by providing an additional delay in the range selector pulses that coincide with the second watchdog strobe.

The use of error watchdog discriminators in missile channels is impractical, since in missile channels the greatest interfering effect of "mirror" signals occurs at the point of missile-target contact and sufficiently close alignment of the "mirror" signal with the main signal is possible only at the lowest target flight altitudes.

DEVELOPMENT OF A PHASED ARRAY RADAR ANTENNA MODEL AND STUDY OF ITS CHARACTERISTICS TO IDENTIFY PROSPECTIVE IMPROVEMENT DIRECTIONS

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Phased array antennas (PAA) play a crucial role in modern radar systems by enabling fast and accurate spatial scanning. Their implementation enhances the performance of radars in military, civil, and research applications. The aim of this study was to develop a mathematical model of a PAA to analyze key parameters and improve accuracy, performance, and energy efficiency.

PAA consists of multiple elements, each with independent control of the signal phase shift. Computer modeling enables the analysis of beam patterns, gain, energy consumption, and object detection capabilities under complex environmental conditions.

Key parameters include the shape and level of the main and side lobes of the beam pattern, gain, efficiency coefficient, and bandwidth adaptability across a wide frequency range. Proposed improvements include optimizing the geometry of antenna elements, using advanced materials, integrating active components for precise phase control, and implementing energy-saving control schemes. Enhancing sensitivity and dynamic range ensures reliable performance in noisy or jamming-prone environments.

The results confirm the significant influence of array structure and phase parameters on beam formation. The developed model provides a foundation for designing next-generation radar systems with enhanced characteristics. The study outlines directions for PAA modernization: more accurate scanning, better target discrimination, and reduced energy consumption.

IMPROVEMENT OF THE SNR-125M1 CONTROL COMMAND TRANSMISSION DEVICE BASED ON DIGITAL ELEMENT BASE

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The design and functioning of the control command transmission device SNR-125M1 is considered, it is shown that it is designed to convert control commands into radar signals that can be transmitted over a radio line to the missile.

When digital signal processing is implemented in the SNR, a problem arises in converting digital commands into an analog high-frequency radar signal.

In order to improve the equipment for transmitting control commands to the missile, the following proposals are made for its design based on a digital element base.

The encryption of control commands is proposed to be performed as follows. Four types of commands (K1-1, K2-1 for the first missile and commands K1-2, K2-2 for the second missile) will be generated in parallel by four digital controlled oscillators, each of which must generate two corresponding frequencies sequentially. The values of the frequencies and the time intervals for their generation will be determined by the codes and values of the commands received via the digital channel from the PBU.

The formation of a radio request pulse for the missile's responder must be tied to the pulse r0, which coincides with the moment of target sensing. The request pulse should be formed in the encoder-decoder and fed to the modulator of the high-frequency generator.

Thus, the submitted proposals will ensure the implementation of a digital-analog device for transmitting control commands by converting digital commands into an analog radar high-frequency signal.

DEVELOPMENT OF PROPOSALS FOR IMPROVING THE AIR TARGET ACQUISITION SYSTEM FOR AUTOMATIC TRACKING BY ANGULAR COORDINATES OF THE RADAR STATION OF A SHORT-RANGE ANTI-AIRCRAFT MISSILE SYSTEM

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Ways to improve radar signal processing algorithms: use of adaptive filtering algorithms to reduce noise and errors in determining the coordinates of an airborne target; application of machine learning methods to improve the accuracy of target recognition and tracking.

One of the areas of optimization of the antenna control system is the introduction of precision servo drives and feedback systems to respond more quickly to changes in the target's position. Switching to a digital antenna angular position control system with the ability to programmatically adjust the tracking parameters.

To increase the system's noise immunity, it is necessary to introduce adaptive methods of processing radar signals to separate the target from obstacles. Apply coherent signal processing technologies to reduce the impact of passive and active interference.

Improving the air target acquisition system for automatic tracking based on the angular coordinates of the radar station of a short-range anti-aircraft missile system significantly reduces the time of the combat crew. Therefore, it is one of the ways to improve the efficiency of anti-aircraft missile weapons. Improving signal processing algorithms, optimizing the antenna tracking system, modernizing the computer system, increasing noise immunity, and automating air target tracking processes will significantly improve the system's accuracy and performance. This will ensure more reliable detection and destruction of air targets in difficult combat conditions.

The developed proposals can be implemented in the modernization of existing and development of advanced radar stations of short-range anti-aircraft missile systems.

IMPROVEMENT OF THE METHOD OF TECHNICAL DIAGNOSTICS AND CONTROL OF RADIO EQUIPMENT OF A SHORT-RANGE SURFACE-TO-AIR MISSILE SYSTEM

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In the context of the rapid development of modern air attack capabilities – in particular, unmanned aerial vehicles, cruise missiles and other precision weapons – the importance of ensuring the effective functioning and reliable operation of air defense missile systems is growing significantly. Countering such threats requires a high degree of readiness and technical serviceability of existing systems. Currently, the Armed Forces of Ukraine operate both Soviet-made air defense systems that are morally and physically outdated and modern models provided by partner countries. Continuous and stable operation of these systems directly depends on regular monitoring of their technical condition, timely diagnosis of faults, and high-quality maintenance.

This report discusses the rationalization of the operation of modern surface-to-air missile weapons, which requires the widespread use of automated measurement tools capable of processing large amounts of data and visualizing information in a convenient format. This implies a transition from the use of individual measuring devices to the introduction of integrated systems – advanced control and inspection equipment of a new generation.

Such an approach is extremely important for the formation of a reliable system for monitoring the technical condition and technical diagnostics of surface-to-air missile systems.

DEVELOPMENT OF A MODEL FOR THE MOVEMENT OF AEROBALISTIC AIRSTRIKE VEHICLES AND THE STUDY OF THEIR MOVEMENT CHARACTERISTICS TO ENHANCE THE EFFECTIVENESS OF THEIR DESTRUCTION

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Aeroballistic weapons (ABW) are a significant factor in modern armed conflicts, including the Russo-Ukrainian war, where they are actively used by Russia to deliver high-precision strikes over long distances. This significantly impacts the course of hostilities and underscores the urgent need to develop effective countermeasures – detection, tracking, and neutralization of such threats.

One of the most promising approaches is the mathematical modeling of ABW movement. Creating accurate models that account for atmospheric conditions, altitude, speed, maneuverability, and angle of attack allows for the analysis of potential trajectories, prediction of strike directions, and development of effective interception tactics. Ukrainian air defense forces must constantly adapt, improving radars, early warning systems, and tracking algorithms.

The hybrid characteristics of ABW pose a particular challenge: high speed, variable trajectory, and maneuverability, similar to hypersonic weapons, which complicates their neutralization by traditional methods. This requires the implementation of innovative technologies, such as artificial intelligence and machine learning, for accelerated data analysis and response.

DEVELOPMENT OF PROPOSALS TO IMPROVE THE EFFECTIVENESS OF RADAR PROTECTION AGAINST ANTIRADAR MISSILES FOR A SHORT-RANGE ANTI-AIRCRAFT MISSILE SYSTEM

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One of the key means used by the enemy to neutralize air defense systems is precision-guided weapons, in particular anti-radar missiles (ARMs).

Effective counteraction to these threats requires a systematic approach to the protection of the objects being protected by air defense, in particular radar stations (radars), which are the primary targets for ARMs and unmanned aerial vehicles that can perform reconnaissance, targeting and fire adjustment functions. Defensive measures should cover a wide range of actions, from engineering masking and spreading out anti-aircraft missile systems (AAMS) in positions to reducing their radar profile using special materials or technologies.

This report analyzes the key vulnerabilities in the air defense structure and formulates technical and organizational recommendations for strengthening radar defense capabilities.

The use of active defense means, such as the creation of false radar objects, the use of electronic means of radio interference, and the use of distracting emitters or simulators, can significantly increase the probability of radar survival in the difficult conditions of modern combat. The highest level of protection is achieved with an complex approach that combines both active and passive defense methods adapted to a specific tactical situation.

DEVELOPMENT OF PROPOSALS FOR THE CONSTRUCTION AND APPLICATION OF ADVANCED CONTROL SYSTEMS FOR ANTI-AIRCRAFT GUIDED MISSILES WITH AN ACTIVE HOMING HEAD

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Successful fulfillment of the tasks assigned to anti-aircraft missile troops is achieved by maintaining surface-to-aire missile systems (SAMs) in constant combat readiness.

The principles of formation of modern and advanced missile-interceptor guidance systems are analyzed, with an analysis of active homing heads and directions for their modernization. The systems are designed on the basis of the separation theorem, which combines a linear state estimation filter with a deterministic controller.

The proposed homing loops include: the creation of control algorithms for precise target tracking. In the modeling, the missile and the target are considered as material points, and the control is a kinematic model of their relative motion. Combined heads operating in cm/mm ranges increase accuracy, object detection, and resistance to interference.

The fifth generation of high-precision weapons will be based on the use of the latest topological solutions in the construction of guidance systems. Such systems will implement control algorithms that require accurate measurement of the distance between the missile and the target. Promising technologies include dual-band semi-active/active homing heads (cm/mm range), as well as the transition of active homing heads to work in the 3.5 mm wavelength range.

PROVIDING TECHNICAL PROPOSALS FOR IMPROVING JAMMING RESISTANCE OF MISSILE CONTROL CHANNELS USING PSEUDO-RANDOM FREQUENCY HOPPING

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In modern conditions of combat operations, electronic warfare means have become widespread, which pose a serious threat to the effective functioning of control channels of high-precision weapons, in particular missiles. Radio interference can lead to a disruption of the stability of communication between the launch complex and the missile, which reduces accuracy or completely makes it impossible to hit the target. In view of this, it is urgent to search for and implement technical solutions to increase the noise immunity of control systems.

One of the most promising methods for protecting control channels is the use of pseudo-random frequency reconfiguration – FHSS (Frequency Hopping Spread Spectrum). This technology consists in dynamically changing the signal transmission frequency according to a predetermined pseudo-random algorithm, which is implemented equally on the transmitter and receiver. This approach complicates signal interception and jamming, since the enemy must either know the hopping algorithm precisely or cover the entire operating frequency range with interference, which is technically very difficult.

Mathematical modeling and experimental studies confirm that the use of FHSS allows reducing the probability of missile control disruption under interference conditions by several times compared to traditional fixed-frequency communication methods.

In conclusion, the introduction of pseudo-random reconfiguration of the operating frequency is an effective and technically sound means of increasing the survivability of missile control systems in conditions of intense electronic warfare.

DEVELOPMENT OF A METHODOLOGY AND MODEL FOR CALCULATING THE RANGE AND PROBABILITY OF TARGET ACQUISITION BY AN ACTIVE HOMING HEAD

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The methodology for determining the probability of target acquisition by an active homing head (AHH) is being developed to provide an ability to quickly assess the probability of detecting and tracking a target directly on board of a missile-interceptor. This methodology makes it possible to determine in real time the chances of correct detection or false alarm of the homing head, as well as to calculate the range at which the head can automatically capture the target for tracking. The methodology is based on mathematical modeling of the structure of the homing head operating in the millimeter wave range, with the possibility of its further integration into the model of the missile-interceptor guidance system.

The research also analyzes the model of the signal processing device (SPD), which is responsible for analyzing of the rf information and providing auto-tracking of the target. An important aspect is modeling the effects of interference, receiver noise, and coordinate measurement errors, which directly affect the guidance accuracy. It has been determined that noise plays the role of a fluctuating factor that causes errors in the measurement of angles.

The proposed methodology allows us to comprehensively cover all the key influencing factors that determine the efficiency of the homing head functioning and provides an accurate prediction of its performance characteristics.

Thus, the development of a modern model for estimating the range and probability of target acquisition by an homing head is a strategic direction for improving the efficiency of high-precision weapons.

IMPROVEMENT OF THE QUASI-CONTINUOUS SIGNAL PROCESSING CHANNEL OF THE RECEIVING DEVICE OF THE RADAR OF A SHORT-RANGE ANTI-AIRCRAFT MISSILE SYSTEM

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In the context of full-scale military aggression by the Russian Federation, there is a steady upward trend in the use of unmanned aerial vehicles for reconnaissance, fire control, air support of units on the battlefield and the creation of active and passive jamming.

The report considers the properties of the main radar signals, compares them, selects and justifies the signal that is most suitable for radar with increased requirements for operation in conditions of passive interference; analyzes radar information processing devices.

Based on the studies and comparisons of radar signals and their processing devices, proposals are made for the construction of a quasi-continuous radiation receiving channel in a short-range air defense radar station with increased requirements for operation under conditions of intense passive interference.

Having considered the measures of distinguishing abilities of several common signals in radar by comparing their autocorrelation functions, it is concluded that the use of coherent packets of narrowband radio pulses allows the selection of moving targets in a complex interference environment due to the presence of a large number of passive interference in space. This signal is advisable to use in radar receivers with increased requirements for interference protection against passive interference

To build a receiver with increased requirements for operation in conditions of passive interference, it is advisable to use correlation-filter processing of a packet of coherent radio pulses, which is reduced to pulse heterodyne and coherent accumulation of frequency-transformed radio pulses in a narrowband frequency filter.

IMPROVEMENT OF ANTENNA POSITIONING CONTROL SYSTEM IN SNR-125M1 BASED ON DIGITAL ELEMENT BASE

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The article deals with the design and functioning of the antenna positioning control system (APCS) of the SNR-125M1 missile guidance station, showing that this system is designed to transmit a given angular position to the antennas and align the line of sight of the antennas with the direction to the target. Functionally, the APCS consists of two systems for separate control of actuators in the azimuth (β) and elevation (ε). They are closed-loop control systems. In addition, correction devices are used in such systems to ensure stability and improve the quality of the control process.

The following proposals are made to improve the positioning control system for SNR antennas by using a digital element base.

The antenna positioning control system includes azimuthal and elevation motor tracking drives. The electromechanical elements of the drives (motor, reducer, sensors, etc.) and electronics are placed in blocks on the УНВ antenna post. The drives can be built on the basis of high-precision industrial servo converters and servo motors with built-in digital feedback sensors – encoders. To measure and indicate the current angular coordinates of the antennas, it is proposed to install digital angle sensors – encoders.

Thus, the tracking system will have two closed automatic control loops: The first loop will be a position control loop (azimuth or elevation). The second loop will be a speed control loop. This design of the antenna positioning control system allows for high precision control of the antenna positioning when tracking targets.

PROPOSALS FOR IMPROVING THE ALGORITHM OF RADAR INFORMATION VISUALISATION OF A THREE-AXIS RADAR SYSTEM

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Radar systems play a key role in monitoring moving objects both in the airspace and on the ground. Their technological evolution increases accuracy but complicates the use and analysis of the information received.

Algorithms for visualizing radar data from three-axis radars are relevant for air monitoring systems. Data visualization helps operators to effectively assess the situation and make decisions. Modern methods, such as integration with three-dimensional maps and added reality, expand the possibilities of analyzing the airspace and ground situation, which will speed up decision-making, which is important in the context of combat operations.

The thesis is devoted to the development of an algorithm for convenient display of radar information.

The research results can be used to improve the efficiency of airspace monitoring and decision-making by radar operators.

DEVELOPMENT OF PROPOSALS FOR CALCULATING THE LAUNCH RANGE OF MISSILES-INTERCEPTORS TO PREVENT FRAGMENT DEBRIS FROM FALLING ON CRITICAL INFRASTRUCTURE POINT FACILITIES IN THE BLACK SEA REGION OF UKRAINE

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The development of proposals for calculating the launch range of missiles-interceptors, taking into account the prevention of debris falling on point objects of critical infrastructure in the Black Sea region of Ukraine, should be based on the integration of aerodynamic modeling, analysis of flight paths, and prediction of areas of possible damage. It is necessary to take into account both the technical characteristics of the missile-interceptor (speed, type of warhead, height of detonation, engagement range of the air target) and the spatial location of critical objects, such as energetic, transport, water supply, communication hubs, etc. It is important to determine the allowable launch sectors and optimal interception points for air targets that minimize the likelihood of debris falling within the coordinates of sensitive objects. To do this, it is advisable to create a digital terrain model with the mapping of infrastructure and predicted areas of debris impact based on data about types of missiles, threat directions, possible interception altitudes, and weather conditions. Calculations should include a risk assessment for each launch option. It is proposed to use a multi-factor analysis system with elements of artificial intelligence to quickly process information in real time to improve decision-making in combat conditions and reduce the likelihood of debris falling on civilian objects.

STUDY OF POSSIBILITIES FOR IMPROVING THE CONDITIONS FOR DETERMINING THE TYPE OF TARGET THAT IS AUTOMATICALLY ACCOMPANIED BY AN GUIDANCE STATION SELF-PROPELLED GUN

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In target tracking radar self-propelled gun 9A310M1, spectral differences, energy differences, and velocity differences are used to recognize targets. But additional important differences are the geometric dimensions of the targets and their relative relationships, which are not yet used to determine the type of target.

An air target is generally an object of complex configuration, and therefore has many signal knockout points that are practically uncorrelated. The superposition of such signals leads to the wandering of the effective center of reflection of such signals, creating the so-called "angular noise" of the target, which is greater the larger the target. This fact is confirmed by the presence of fluctuations in the amplitudes of difference signals during automatic tracking of the target by angular coordinates by the amplitude monopulse direction finder (AMDF) of the automatic angular coordinate measurement system in the guidance radar.

To determine the angular dimensions of the target in the vertical and horizontal planes, the method of measuring the AMDF values of fluctuations in the amplitudes of difference signals is used, the ratio of which allows you to establish the types of targets by the ratio of their sizes.

The report provides the principle of implementation of the proposed method.

STUDYING THE POSSIBILITY OF PROVIDING TRACKING OF AIR TARGETS IN THE SPACE VIEW MODE OF THE RADAR STATION OF THE SELF-PROPELLED FIRING UNIT OF THE SHORT-RANGE ANTI-AIRCRAFT MISSILE SYSTEM

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The paper analyzes the functioning of the system for searching and tracking an air target by a radar station of a short-range anti-aircraft missile system.

The peculiarities of the functioning of the search system by angular coordinates in different modes are determined. The functional diagram and timing diagrams of the search system of the radar station of a short-range air defense missile system are presented.

The peculiarities of space survey in the quasi-continuous radiation mode are analyzed. The features of construction and functioning of the radar station survey receiver are determined.

The report describes the process of tracking air targets simultaneously with the space overview in the "Overview" mode. The principle of target tracking during the space survey by angular coordinates is analyzed. A processor for processing radar signals in the space survey mode at a high pulse repetition rate and a processor for processing radar signals in the space survey mode at an average pulse repetition rate are synthesized.

The results of the development of technical proposals for the implementation of the target tracking mode in the overview mode for a radar station using broadband signals are presented.

The synthesis of the structural diagram of the target tracking equipment during the survey for a radar station in the linear frequency modulation mode with a quasi-continuous signal is considered.

The developed proposals can be implemented during the modernization of existing and development of advanced radar stations of short-range anti-aircraft missile systems.

PROPOSALS FOR IMPROVING RADAR SYSTEMS TO ENHANCE THEIR PERFORMANCE CHARACTERISTICS IN UAV DETECTION

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The experience of combat operations during the full-scale invasion of Ukraine by the Russian Federation has demonstrated the urgent need to adapt radar systems (RLS) to the modern conditions of warfare. This requires a comprehensive approach to modernization and the integration of innovative technologies into radar detection systems.

The scope of unmanned aerial vehicle (UAV) usage is extremely broad – ranging from consumer drones to specialized military and scientific platforms. Despite their advantages, UAVs also pose significant threats, especially to critical infrastructure, due to their accessibility and low detectability.

However, the effectiveness of most detection systems is reduced due to the compact size of modern drones, which significantly complicates their identification.

Among the available detection methods, radar systems remain the most versatile, as they are capable of operating in low-visibility conditions such as fog, rain, darkness, and in the presence of background noise. Various types of radar operating at different frequencies and ranges are already actively used for UAV detection.

To improve the performance of radar systems in UAV detection, it is essential to focus on the implementation of advanced solutions, in particular:

– the use of adaptive antennas,

– the expansion of frequency ranges to ensure functionality in complex environments. The integrated implementation of such measures will ensure high efficiency, flexibility, and reliability of radar systems in countering the modern threats posed by UAVs.

RESEARCH INTO THE RISKS OF EXPOSING A COMBAT POSITION BY THE ENEMY FOR MAKING INFORMED DECISIONS DURING MANEUVER COMBAT OPERATIONS OF ANTI-AIRCRAFT MISSILE TROOPS UNITS

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In modern conditions of combat operations, the importance of anti-aircraft missile forces (ARF) as a key element of the air defense system is increasing. Given the active use of electronic reconnaissance, UAVs and high-precision weapons, the risk of exposing ARF combat positions increases, which threatens their destruction and reduces the effectiveness of the overall battle.

The purpose of the work is to develop a methodology for assessing the risks of exposing the combat positions of air defense units and provide recommendations for making informed management decisions during maneuver combat operations.

Tasks to be performed: Analyze modern enemy reconnaissance tools and methods for detecting air defense combat positions.

Identify the main factors affecting the level of risk of detection.

Develop a mathematical model for assessing the risk of detecting positions.

Propose a decision-making algorithm for the commander taking into account the risk assessment obtained.

Develop practical recommendations for reducing the probability of detection in conditions of maneuver operations.

DEVELOPMENT OF PROPOSALS FOR IMPROVEMENT OF THE ALGORITHM FOR SEARCHING AND LOCALISATION OF FAULTS IN THE CONTROL BODIES OF AK F2K USING CODAGRAMS OF INFORMATION EXCHANGE BETWEEN DEVICES OF THE 5N63S RELAY SWITCHGEAR

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Under modern conditions, the most important and urgent task of maintaining in good working order the weapons and equipment that have been in operation for more than 20 years is to find ways to improve their operational efficiency. One of the promising ways to increase the efficiency of operation of weapons and military equipment in the maximum permissible operational condition under resource constraints is to introduce more advanced and time-minimizing search options and schemes for detecting various types of equipment failures, especially those of the control units that are most systematically stressed.

Taking into account the experience of the Air Force of Ukraine's Air Defense units during air combat operations, requirements and recommendations of the Air Defense Command, there is a great need to improve fault detection algorithms due to the increased intensity of equipment and weapons and equipment failures, especially in conditions of frequent movement of equipment due to changes in positions and physical wear and tear of equipment. The speed of finding any equipment malfunction, which in most cases occurs after deployment and activation of equipment in a new position, directly affects the effectiveness of the unit in performing combat missions.

IMPROVEMENT OF THE SYSTEM OF AUTOMATIC RANGE SURVEILLANCE OF THE SHORT-RANGE RADAR AIRCRAFT MISSILE COMPLEX

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The analysis of the conduct of hostilities during Russia's full-scale aggression against Ukraine showed that the requirements for a modern combat environment, the improvement of the automatic long-range tracking system, require a comprehensive approach to the development and implementation of new technologies.

The report provides a justification for the need and possibility of improving the automatic range tracking system of a short-range anti-aircraft missile system; an analysis of the general principles of building a range tracking system is carried out, and the features of building automatic range tracking systems in pulse radar stations that use complexly modulated signals are analyzed.

Two variants of constructing automatic range tracking were considered – with one and two integrators. The limiting values of dispersion and the mean square acceleration values of the target, which can be tracked by automatic range tracking, were calculated. From the results of the calculations, a conclusion was made about the feasibility of using two integrators in the automatic range tracking used in a multifunctional radar station (a system with second-order astaticism).

DESIGN, OPERATION, AND MAINTENANCE OF THE RADIO-ELECTRONIC EQUIPMENT OF THE LAUNCHING INSTALLATION 9A83

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The purpose of the work is to analyze the operating principles of the 9V749 equipment, its constituent elements, and operating algorithms.

The 9V749 electronic equipment is designed to engage aerodynamic and ballistic targets.

The main functions of the 9V749 equipment are antenna guidance, target illumination, obstacle detection, command transmission to the missile, determination of the launch moment, and information exchange with the combat control station.

The 9V749 equipment can operate in the modes "Combat Operation", "Standby Mode" and "Training".

The 9V749 equipment includes: a specialized digital computer (SDC-3), a DP-20 transmitting system, an antenna control system (ACS), a 75M antenna-waveguide system, a firing direction input system, a control and monitoring system, and a DP60 receiving system.

The target illumination radio transmitter (TIRT) DP20 generates ultra-high-frequency signals for homing equipment adjustment, target illumination, and radio correction command transmission.

Klystrons are used in the DP20 TIRT, and control is carried out by a microwave switch.

An automatic frequency control system is used in the TIRT to ensure frequency stability.

The DP20 TIRT is equipped with cooling and temperature control systems.

PROPOSALS FOR IMPROVING THE OBSTACLE INDICATION DEVICE OF THE MEDIUM-RANGE ANTI-AIRCRAFT MISSILE COMPLEX AND EVALUATION OF THE RESULTS OF THE PROPOSED SOLUTION

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Analysis of modern jamming equipment used in military conflicts of the last decade has revealed the need to find ways to improve the jamming indication receiver of anti-aircraft missile systems (AMS). When considering this issue in relation to the S-300V1 SAM, it was proposed to use an improved jamming indication receiver (IIR) in the 9A83 launcher (PU).

The improvement of the PIP consists in building it on a modern element base, which will allow, in addition to reducing the weight and dimensions of the device, to introduce additional algorithms for protection against interference and increasing the accuracy of interference detection.

Regarding the PIP proposed for implementation in the 9A83 PU, the report provides proposals for a possible element base for use.

The improvement of the characteristics of the accuracy of obstacle detection, which are proposed to be implemented in the 9A83 PU when implementing the proposed solutions, is considered.

DESIGN, OPERATION, AND MAINTENANCE OF THE ANTENNA-WAVEGUIDE SYSTEM WITH QUADRATURE SELF-NULLING OF THE RADAR SET 9S32

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This course work is dedicated to the study of the antenna-waveguide system (AWS) of quadrature automatic compensation of the 9S32 target engagement radar.

The purpose, structure, principle of operation, and features of operation of this system are considered in the work.

The AWS provides the reception and transmission of radio signals, as well as the formation of antenna directivity patterns.

The quadrature automatic compensation system integrated into the AWS allows reducing the influence of spurious signals and increasing the accuracy of angular coordinate measurements.

The work contains a description of the functional devices, blocks, and units of the system, as well as their technical characteristics.

DEVELOPMENT OF PROPOSALS FOR IMPROVING THE INERTIAL GUIDANCE SYSTEM AND EVALUATION OF THE RESULTS OF THE PROPOSED SOLUTION

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Modern warfare and the development of air defense capabilities place increased demands on the accuracy, reliability and autonomy of missile systems. One of the key elements of such systems is the inertial control system, which ensures the stability of the flight path and resistance to external interference. In this context, the 9M83 missile, which is part of the S-300V air defense missile system, deserves special attention, namely its component, the 9B627 device, which is responsible for the accurate determination of motion parameters. The purpose of this research paper is to analyze the structure and principles of the 9M83 missile inertial control system, to study the features of the 9B627 device, and to study modern gyroscopic technologies that can be used to modernize such systems.

The study considers the main types of gyroscopes – mechanical, laser, fiber optic, vibration, as well as advanced digital gyroscopes based on microelectromechanical systems (MEMS). A comparative analysis of their characteristics, advantages, and disadvantages is carried out in view of the possibility of integration into new generation military systems. The obtained results allow us to conclude that it is expedient to move to more compact and energy-efficient digital inertial systems that can provide high navigation accuracy even in difficult conditions of electronic warfare.

RESEARCH ON METHODS OF STABILIZING SIGNAL PARAMETERS TRANSMITTED AND PROCESSED BY A MULTICHANNEL RADAR SYSTEM THROUGH IMPROVEMENT OF THE DEVICE FOR FORMING HETERODYNE AND CONTROL SIGNAL

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The device generates reference, heterodyne, trigger, and control signals necessary for the operation of the radar system. Signal generation is ensured by several blocks, including the generator, frequency converters, and switching devices. The trigger signals are transmitted to the transmission system, while the heterodyne signals are used for multiple frequency conversions in the receiving system. Control signals allow for checking the system's functionality and tuning. Frequency switching is performed quickly and controlled by the central computing machine. The accuracy of signal parameter estimation depends on the signal-to-noise ratio and is higher when the ratio increases. The system uses correlation methods and feedback to estimate the temporal characteristics of the signal. Different types of signals are used depending on the radar operation mode, including LFM, pulsed, and batch signals. The signals have a harmonic structure with specified voltage levels for each processing stage.

AUTOMATION OF DETECTION OF VARIOUS TYPES OF AIR TARGETS BY THE MEDIUM-RANGE SURFACE-TO-AIR MISSILE SYSTEM, TAKING INTO ACCOUNT THE INTERFERENCE ENVIRONMENT

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An analysis of existing medium-range surface-to-air missile systems used in military conflicts over the past decade has revealed the need to improve the technical condition monitoring systems of phased array antennas (PAA).

In addressing this issue, it is proposed to integrate an additional device for monitoring the condition of the PAA into the 9S32 multi-channel missile guidance station (MCGS).

The improvement involves adding a device to the beam control system that will process information about the number of faulty phase shifters, taking their location into account. Based on this data, it will be possible to model the radiation pattern and assess the impact of faulty phase shifters in the PAA.

Regarding the technical condition monitoring device for the phased array antenna, proposed for implementation in the MCGS 9S32, the report includes suggestions for possible upgrades to the component base.

Algorithms for diagnostics and modeling, which are proposed for implementation in the MCGS 9S32 as part of the proposed solutions, have been reviewed.

DESIGN, OPERATION, AND MAINTENANCE OF THE OPERATOR INDICATOR SYSTEM AND THE COMMANDER'S INDICATOR OF THE RADAR STATION 9S32

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Analysis of the Structure and Operation of the D83 Operator Indicator System and the SAM Battery Commander's Indicator within the 9S32 Target Engagement Radar.

This research is dedicated to the structure and operational principles of the D83 system and the indicator for the combat control station commander of a surface-to-air missile system. The importance of these systems in ensuring the effective operation of a medium-range anti-aircraft missile complex is substantiated.

Key Provisions: purpose of the D83 system; analysis of the air situation, target detection and tracking, visual monitoring of tracking quality.

Composition of the System: the blocks of the D83 system are described, including autonomous search indicators, sector scan indicators, and operator indicators.

Operating Modes: the modes of functional and autonomous control, and system synchronization, are investigated.

Commander's Indicator: the principles of displaying target and missile trajectories, target designation markers, and jammer indicators are described.

Image Generation Algorithms: the sequence of raster image generation on the indicators, ensuring the accuracy of information display, is presented.

RESEARCH ON IMPLEMENTATION METHODS OF A DEVICE SCHEME FOR DETECTION AND TRACKING OF BALLISTIC TARGETS BY A MEDIUM-RANGE SURFACE-TO-AIR MISSILE SYSTEM AND IMPLEMENTATION OF ITS OPERATION ALGORITHMS

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Taking into account the current realities of combat operations by air defense missile units and the challenges in neutralizing ballistic attack means (BAM), the development of a system for detecting and tracking ballistic targets using the medium-range S-300V1 surface-to-air missile system is a complex task that requires the integration of various technologies and algorithms. Due to the advancement of enemy aerial attack systems, effective detection and tracking of ballistic targets by medium-range air defense systems is of particular importance. The development and study of the structure of a device capable of ensuring the detection and tracking of ballistic targets, as well as the optimization of its operational algorithms to improve accuracy and speed, is a top priority. The use of methods such as mathematical modeling, digital signal processing, adaptive filters, and simulation testing using software like MATLAB or its analogs. The developed approach can be adapted to current and prospective models of medium-range air defense systems. The report presents an analysis of existing solutions in the field of ballistic target detection. A functional and structural scheme of the device has been developed. The effectiveness of the implemented algorithms has been assessed through simulation modeling, and options for hardware and software implementation of the system in real weapon models are proposed.

SUBSTANTIATION AND DEVELOPMENT OF THE FUNCTIONAL DIAGRAM OF THE DEVICE FOR TROUBLESHOOTING INTERCONNECTIONS (LOOP TYPE) OF F2K S-300P EQUIPMENT

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In the modern world, computing devices are not only a part of everyday life, but also an important component of security systems and military strategy. This is especially true for air defence systems, such as the S-300P air defence system, which protects large areas from airborne threats.

Troubleshooting the computing devices of such systems is a complex and critical task. Improving this process increases reliability and ensures timely response to threats in real time.

The paper considers the possibilities of improving diagnostics and fault detection in the computing devices of the S-300P air defense system. Modern approaches to maintenance, its optimisation and automation are analysed. The results can be used to create more efficient and reliable air defence systems.

Experience in the operation of weapons shows that SAM maintenance and scheduled repairs are often poorly organised. During the full-scale invasion of Russia and in the ATO (Joint Forces Operation), the need for rapid malfunction detection and prompt repair of equipment has increased.

Therefore, it is important to improve the maintenance system to meet the needs of the troops, which will ensure the combat readiness of equipment in the shortest possible time. This paper aims to develop practical proposals to improve the process of fault detection in the computing devices of the S-300P air defence system.

DEVELOPMENT OF A SIMULATION MODEL OF THE FUNCTIONING OF THE PATRIOT SAM OPERATOR'S WORKPLACE IN THE MODE OF FIRING SINGLE TACTICAL BALLISTIC MISSILES

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In modern combat environments, effective missile defense is a critical component of national security. Surface-to-air missile (SAM) systems, particularly the PATRIOT system, play a vital role in defending critical infrastructure and military assets against tactical ballistic missile (TBM) strikes. The developed algorithm is intended for integration into simulation software designed to emulate the operator's interface of a medium-range SAM system. The algorithm implements a logical sequence of functional blocks reflecting key phases of combat engagement.

The algorithm processes incoming threat parameters, such as the number and type of ballistic missiles, their spatial distribution, and the current air and electronic warfare (EW) environment. It configures SAM system operating modes, selects the firing doctrine and launch timing, and simulates the operator's response to the evolving tactical situation. During simulated engagement, the algorithm performs calculations to determine missile interception points, generates trajectories for both interceptor missiles and TBMs, renders the air situation on operator displays, and records operator actions - including manual override commands such as ceasefire.At the final stage, the simulation visualizes the outcome of the interceptor-TBM engagement, enabling evaluation of interception success.

Thus, the developed algorithm for simulating the operation of a medium-range SAM operator workstation during engagements with single TBMs serves as an effective tool for improving air defense operator training. The model supports behavioral analysis under missile attack conditions, allows for adaptation of training programs, and enhances decision-making quality in real-world combat scenarios.

DEVELOPMENT OF PROPOSALS FOR THE TECHNICAL IMPLEMENTATION OF IMPROVING THE INFORMATION CAPABILITIES OF THE DEVICE FOR DISPLAYING THE COORDINATES OF ACCOMPANIED TARGETS OF THE WORKPLACE OF THE AC F2K CAPTURE OFFICER DURING THE COMBAT OPERATION OF THE RPN 5N63S

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Taking into account the rapid growth and demand for technological and digitalization of processes in the modern world, where computing devices are becoming not only an integral part of our daily lives, but also critical for military strategy and security, the issues of rapid functioning of weapons and military equipment are becoming extremely important. The experience of using the S-300P during the Russian-Ukrainian war has shown its high efficiency, but due to the outdated element base, the equipment used for combat operations of the crews needs to be improved, especially in the conditions of massive air strikes by the enemy. Modernization of the existing devices for measuring and displaying coordinates is becoming an important element in ensuring the accuracy and speed of information about air objects to ensure the effectiveness of combat operations in such conditions. The development of a single device for calculating and displaying the height coordinates, displaying the range and speed of accompanying air targets in the F2K hardware container will allow personnel, namely the engagement officer, to quickly learn and control the height of detected targets without unnecessary actions and time delays that may affect the timely monitoring of the characteristics of accompanied and destroyed targets, as well as quick assessment of the results of firing three coordinates simultaneously in one place on a common display. This will improve the effectiveness of combat operations of the control room staff, led by the division commander, without wasting time calculating the height of the air target, which will increase the level of efficiency in shooting down targets and reporting on the progress and results of combat operations.

ANALYSIS OF THE STRUCTURE, FUNCTIONING, AND OPERATION OF THE 9S32 BSNR CONTROL AND SIGNALING SYSTEM

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The research is dedicated to the analysis of the structure, operating principles, and control and indication system of the multi-channel missile guidance station 9S32, which is a key component of the medium-range surface-to-air missile system.

Structural Design: The main components of the BSNR 9S32 are considered, including the antenna-mast system, signal processing equipment, and navigation-measurement system.

Functional Purpose: The main tasks of the BSNR 9S32 are identified – target detection, tracking, guidance command generation, and interaction with the launchers.

Operating Modes: The "Combat", "Training", and "Control" modes are described, along with the conditions for their activation during combat duty or exercises.

Control and Indication: The operation principles of the automated control system are outlined, including its response to typical malfunctions and indication of technical status.

Communication with PU and CP: The communication channels and data exchange between the BSNR and command points are described, including the use of encoded commands and backup channels.

Protection and System Recovery: The built-in self-diagnostics algorithms, emergency channel switching, and manual operator intervention procedures in case of failure are analyzed.

ENHANCEMENT OF THE TRANSMISSION PATH OF A MEDIUM-RANGE SURFACE-TO-AIR MISSILE SYSTEM UTILIZING A MODERN, LOCALLY PRODUCED COMPONENT BASE

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The transmission path (transmission system) in anti-aircraft missile systems is one of the main components for searching, tracking and guiding the missile to the target.

However, a number of the components used are either outdated or require import substitution. The main problems of the existing system are as follows:

– the use of foreign-made components, the availability of which may be limited.

– relatively high power consumption and size of power amplifiers.

Therefore, improving the transmission path of the medium-range air defence missile system using domestic components is an important task that will increase the reliability, resistance to interference, technological independence and efficiency of the system.

The S-300V1 medium-range anti-aircraft missile system uses a transmitter device made in the form of an amplifying circuit from the Razlyv monoblock, which includes a generator, converter and amplifier, and an output power amplifier on a KIU-97 klystron.

The report analyses the construction and operation of the BSNR 9C32 transmitting device and presents ways to improve it using a modern element base of domestic production.

DEVELOPMENT OF PROPOSALS TO IMPROVE THE RELIABILITY OF THE MEMORY DEVICE OF THE DIGITAL COMPUTING COMPLEX 5E26 OF THE S-300P SURFACE-TO-AIR MISSILE SYSTEM

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The digital computing complex 5E26 plays a critical role in the S-300P surface-to-air missile system, performing real-time data processing, storage, and computation of combat information. The memory device (MD) of this complex stores programs, data, operational tables, and computational results, and its reliability significantly impacts the stability of the entire system.

Analysis shows that the main reliability issues are:

moral and physical aging of the hardware (e.g., 130-series chips, ferrite memory cells);

high sensitivity to electromagnetic interference;

lack of modern diagnostics and self-monitoring tools;

inability to quickly replace or switch to backup modules in case of failure.

Introducing hot standby modules for the main memory blocks to reduce recovery time and increase system availability.

Improved Electromagnetic Resistance

As a result of these proposed measures, the failure rate of the memory device could be reduced by 30–50%, overall reliability of the 5E26 digital computing complex would increase, and the combat readiness of the S-300P system would be enhanced. This provides a timely modernization solution without requiring full system replacement, leveraging current technological capabilities.

PROPOSALS FOR ORIENTATION OF SAM RADAR USING MODERN NAVIGATION SYSTEMS

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The experience of the Russian-Ukrainian war has shown that the survivability of anti-aircraft missile units depends on reducing the time spent at the main or reserve position. A significant component in the time of bringing the anti-aircraft missile division No. 1 to readiness after the march is played by the operations of topographic reference and orientation of the main elements of the air defense system.

For timely and rapid determination of the topographic coordinates of the air defense systems and their orientation data, it is necessary to choose modern navigational means and systems.

The use of modern navigational means for determining the coordinates and orientation data of the air defense systems significantly improves the survivability of anti-aircraft missile units, primarily due to the reduction of the time for topographic reference and orientation at a new position.

IMPROVEMENT OF THE CONTROL DEVICE FOR MEDIUM-RANGE SURFACE-TO-AIR MISSILE SYSTEMS THROUGH THE DEVELOPMENT OF A UNIFIED DIGITAL COMPUTING MACHINE

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Modern requirements for medium-range surface-to-air missile systems (SAMs) demand high performance, reliability, and adaptability to electronic warfare conditions. In this context, an urgent task is the improvement of control devices for SAM systems, which perform computational and logical functions related to fire control, target tracking, and missile guidance. One of the promising directions for the development of such systems is the design of a unified digital computing machine (DCM) capable of centralized real-time data processing.

Unification of hardware and software significantly reduces the number of specialized modules, simplifies maintenance, lowers modernization costs, and enables the rapid updating of control algorithms in response to emerging threats. Such a computing system should feature high computational power, a modular structure, and seamless integration with communication systems, radar units, and other command and control elements.

The implementation of a unified DCM within medium-range SAM systems will enhance the accuracy and speed of decision-making, reduce response time to aerial threats, ensure effective operation under conditions of massive attacks and electronic interference, and enable the system to be scaled for various combat missions. Thus, the proposed technical solution aims to comprehensively improve the efficiency of SAM systems in the context of current and future military conflicts.

RESEARCH ON METHODS OF IMPLEMENTING A SYNCHRONIZATION SYSTEM SCHEME BASED ON MODERN COMPONENTS FOR A MULTICHANNEL RADAR STATION OF A MEDIUM-RANGE SURFACE-TO-AIR MISSILE SYSTEM AND IMPLEMENTATION OF ITS OPERATION ALGORITHMS

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Under current conditions, a priority direction is the modernization of Soviet-manufactured weapon systems, in particular components of surface-to-air missile systems such as the S-300V1. The issue lies in the absence of necessary spare parts and the physically outdated component base. Considering these existing problems, one of the promising approaches is the development of functional analogs using modern microelectronic components.

An analysis was conducted of the existing functional diagram of the synchronization system of the multichannel missile guidance station (MMGS) 9S32 and its role in ensuring coordinated operation of the main signal processing channels. A variant of building the synchronization system based on modern components is proposed, which includes a microcontroller featuring a highly stable timer and a digital memory device.

The advantage of the proposed architecture is the ability to flexibly adapt to changes in the configuration of the 9S32, as well as the implementation of built-in fault monitoring and self-diagnostic algorithms. Implementing the synchronization system on a modern component base increases the reliability, speed, and accuracy of generating highly stable synchronization pulses, simplifies maintenance and repair, and opens possibilities for further automation and integration with prospective SAM systems.

DEVELOPMENT OF PROPOSALS FOR STABILIZING THE PARAMETERS OF SIGNALS EMITTED AND PROCESSED BY A MULTICHANNEL RADAR STATION

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Modern armed conflicts demonstrate the increasing role of anti-aircraft missile units in the air defense system. Due to the widespread use of enemy electronic suppression tools, there is a need to develop and propose methods to stabilize the parameters of signals emitted and processed by a multichannel radar station. The survivability of weapon systems becomes a critical factor in ensuring the accomplishment of combat missions and preserving personnel and equipment. The qualification work includes an analysis of the functioning of existing radio engineering systems of anti-aircraft missile systems under the influence of active jamming. Modern methods and solutions for stabilizing emitted and processed signals are considered. Research has been conducted on modern principles of spatial selection and information redundancy to ensure the jamming resistance of radio engineering systems. Technical improvements have been proposed to enhance the performance of the multichannel missile guidance station. The measures are based on the analysis of combat operations in modern conditions, taking into account the development of advanced technologies and means of armed struggle. The implementation of the proposed technical solutions in the BSNR 9S32 will significantly increase the combat effectiveness of the SAM system in the conditions of electronic warfare.

DESIGN, OPERATION, AND MAINTENANCE OF THE ANTENNA COMPENSATOR CONTROL SYSTEM OF THE RADAR STATION 9S32

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The course work is dedicated to the study of the antenna control system (ACS) of the 9S32 target engagement radar.

The purpose, structure, placement, and technical characteristics of the ACS, its functional diagram, and its connection with other systems of the station are considered.

The modes and algorithms of the ACS operation are described, including manual control, automated control from a special digital computer, and synchronous control.

The mode of manual control of the antenna position is considered in detail, as well as the issue of eliminating antenna jerks when switching modes.

The control of the antenna position from the special digital computer and the locking of the antennas is described.

The functional control of the ACS, the principle of operation and design of the ACS units, as well as the power supply system are considered.

DESIGN, OPERATION, AND MAINTENANCE OF THE ANTENNA CONTROL SYSTEM OF THE RADAR STATION 9S32

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This course work is dedicated to the study of the antenna control system (ACS) of the 9S32 target engagement radar, its structure, operational principles, and features of operation.

The system ensures the positioning of the phased array antenna (PAA) in azimuth and elevation. Antenna control can be carried out automatically (using a special digital computer) or manually.

The ACS consists of blocks and drives such as D50-3, D50-4, D50-5, D19-1M, D51-4, and D51-5. The D19-1M unit digitizes the angular position of the antenna.

The system's operation is monitored, and functional control modes are provided. The ACS is powered by D95-2 and D95-3 units.

DESIGN, OPERATION, AND MAINTENANCE OF THE FUNCTIONAL CONTROL EQUIPMENT OF THE RADAR STATION 9S32

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The functional control of the 9S32 product is employed to verify the operability of the equipment and its readiness for combat missions, as well as for rapid troubleshooting. Two sub-modes of functional control exist: automatic (FCA) and semi-automatic (FCPA).

The functional control equipment encompasses control means integrated into the station's systems, alongside specially developed apparatus such as a functional control panel and a portable fault-finding device.

During system control, various methods are utilized, including tests and control signals. Control signals are employed to examine different systems of the station.

The control of the 9S32 product's systems includes the monitoring of the transmitting device, computing resources, tracking coordinate system, synchronization system, beam control system, primary signal processing unit, signal detection receiving device, amplitude-to-code converter, and other systems.

ENHANCEMENT OF SPATIAL RESOLUTION IN THE DETECTION OF ACTIVE JAMMING BY THE AN/MPQ-65 RADAR OF THE PATRIOT SYSTEM

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The PATRIOT surface-to-air missile system, actively deployed in the Russian-Ukrainian war to neutralize tactical ballistic missiles of the Russian Federation, performs its combat missions effectively under conditions of intense electronic countermeasures. Although the system's AN/MPQ-65 radar is equipped with counter-jamming capabilities, its angular resolution is limited by the beamwidth of its directional pattern.

A promising approach to enhancing angular resolution is the application of modern spatial spectral analysis methods. To substantiate the structure of a direction finder based on such methods, preliminary modeling and comparative analysis were conducted under conditions approximating the actual operational environment of the PATRIOT system.

A simulation model was developed to obtain quantitative assessments of the angular resolution of the AN/MPQ-65 radar. Comparative analysis of various spatial spectral analysis methods enabled the formulation of practical recommendations for upgrading this type of radar.

The results of this study are recommended for use in improving the equipment of current and next-generation medium-range air defense systems.

ANALYSIS ORGANIZATION OF INTERACTION OF THE RADAR STATION 9S32 WITH THE COMMAND POST AND THE PROCEDURE FOR ITS VERIFICATION

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This course work is dedicated to the study of the organization of interaction between the 9S32 multi-channel missile guidance station and the command post.

The reception and processing of information from the command post is considered, including message types (TS-1, TS-2, TS-3, TS-0) and their processing.

The processing of single messages (TS-1), the formation of operating and control modes, as well as target designation processing in the centralized control mode, are described.

The formation and transmission of information to the command post, including topographic coordinates, are investigated.

The work contains a list of symbols, units, abbreviations and terms used in the S-300V1 SAM system.

RESEARCH ON METHODS FOR SUPPRESSING THE IMAGE CHANNEL OF THE RECEIVER PATH OF A MEDIUM-RANGE SURFACE-TO-AIR MISSILE SYSTEM AND IMPLEMENTATION OF A SCHEME FOR QUADRATURE CHANNEL IDENTITY CONTROL AND ADJUSTMENT

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An analysis of the effective radar cross-sections of UAVs of the "Shahed" type in the operating wavelength range of the MMGS 9S32 revealed that, with the current characteristics of the station (emitted power, receiver path sensitivity), in order to increase the probability of detection and the stability of tracking with specified quality characteristics, the station requires improvement.

In the course of previous research, the use of a phase method for suppressing the image channel was proposed.

The principle of image channel signal compensation is as follows: signals of the main frequency add in-phase as they pass through the channels, while image frequency signals add out-of-phase and mutually cancel out. This ensures suppression of the image channel without energy loss in the main channel, allowing an increase in the energy of the useful signal by 2 dB. At the same time, it was found that the performance of the implemented scheme for this method significantly depends on the identity of its channels. Differences in amplitude and phase characteristics have a significant impact on the results of the scheme's operation. The results of calculations showing the influence of non-identical amplitudes, phases, and both amplitudes and phases in the scheme's channels are presented. To equalize the characteristics of the quadrature channels, a control and adjustment scheme is proposed, which operates by managing the gain coefficients of the channels and their electrical path length. Amplitude control is carried out through the implementation of negative feedback, which eliminates discrepancies in amplitude transmission coefficients of the paths, and phase adjustment is performed using tunable phase shifters.

DEVELOPMENT OF PROPOSALS FOR IMPROVING THE TECHNICAL CONDITION CONTROL OF THE PHASED ARRAY ANTENNA OF A MEDIUM-RANGE SURFACE-TO-AIR MISSILE SYSTEM, WITH AN ASSESSMENT OF THE RADIATION PATTERN CHARACTERISTICS BASED ON DIAGNOSTIC RESULTS

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An analysis of existing medium-range surface-to-air missile systems used in military conflicts over the past decade has revealed the need to improve the technical condition monitoring systems of phased array antennas (PAA).

In addressing this issue, it is proposed to integrate an additional device for monitoring the condition of the PAA into the 9S32 multi-channel missile guidance station (MCGS).

The improvement involves adding a device to the beam control system that will process information about the number of faulty phase shifters, taking their location into account. Based on this data, it will be possible to model the radiation pattern and assess the impact of faulty phase shifters in the PAA.

Regarding the technical condition monitoring device for the phased array antenna, proposed for implementation in the MCGS 9S32, the report includes suggestions for possible upgrades to the component base.

Algorithms for diagnostics and modeling, which are proposed for implementation in the MCGS 9S32 as part of the proposed solutions, have been reviewed.

CORRECTION OF TRIGGERING MOMENT OF THE PHASED-DOPPLER RADIO FUSE OF A COMMAND-GUIDED SURFACE-TO-AIR MISSILE UNDER THE INFLUENCE OF PASSIVE JAMMING

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Analysis of the combat employment of surface-to-air missile (SAM) systems that are using command guidance shows that the probability of target destruction depends on the effectiveness of the missile's warhead, specifically the alignment between the radio proximity fuze (RPF) activation zone and the warhead's lethal area. When passive jamming affects the RPF's operation, the performance deteriorates due to premature activation, reducing the probability of target destruction, therefore, there is a need to correct the RPF activation timing.

In the semi-active phase-Doppler RPF of the 5V55 missile, two frequency channels and one phase channel are used and warhead detonation occurs after all three channels are triggered. Under normal RPF operation (in the absence of jamming), the sequence of channel activation is as follows: the second frequency channel, the phase channel, and then the first frequency channel. Thus, the first two channels are arming channels, while the last one is the execution channel. In the case of passive jamming, the first frequency channel triggers immediately, followed by the phase channel, with the second frequency channel serving as the execution channel. However, since the RPF is designed to trigger when the target signal passes through the first frequency channel, it activates prematurely by the time interval between the activations of the second and first frequency channels based on the target signal.

Eliminating this effect under passive jamming can be achieved by measuring the time of premature RPF activation and subsequently delaying its activation by the measured time.

ALGORITHMS FOR FUNCTIONAL CONTROL OF THE RADAR STATION 9S32 AND ITS OPERATIONAL PROCEDURE

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Functional control of a radar station is performed to verify its operability.

Functional control has two sub-modes: automatic and semi-automatic.

Control includes checking various systems of the station using standard, built-in, and special equipment.

Systems such as the special digital computer, synchronizer, converters, receiving devices, and others are checked.

Control results are displayed on the functional control panel, indicator lights, and indicators on the units.

Automatic functional control is designed for general station control, while semi-automatic is for autonomous testing and troubleshooting.

In automatic mode, system control is performed sequentially according to a program.

Semi-automatic mode provides deeper system control, checks connections with the special digital computer, and includes special test modes.

BASIC PRINCIPLES, ALGORITHMS, AND OPERATING MODES OF THE RECEIVING SYSTEM OF THE RADAR STATION 9S32, PROCEDURE FOR ITS OPERATIONAL CHECK

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The receiving system of the 9S32 is designed to provide various surveillance modes adapted to the current situation and to effectively use the available energy potential.

The input device of the sum and difference channels receives probing pulses with a frequency of 150 MHz and amplifies them to a level of about 20 mV, necessary for the correct operation of the subsequent circuits of the receiving system in the combat mode.

Phase correctors are installed at the outputs of the filters to prevent parasitic amplitude and phase shifts.

The receiving devices are combined in the unit for forming the difference characteristics of amplitude direction finders.

The processing of low-frequency signals of the IIT type is carried out by an analog correlation-filtering method.

The receiver circuitry provides for three-mode operation of the signal processing channels to increase efficiency for different types of interference.

The receiving device has functional control modes – automatic and semi-automatic.

A troubleshooting device is used to locate faults in the semi-automatic mode.

ANALYSIS ORGANIZATION OF INTERACTION OF THE RADAR STATION 9S32 WITH THE LAUNCHING UNIT AND THE PROCEDURE FOR ITS VERIFICATION

M. Tsykalov; A. Romanov
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Analysis of the interaction between BSNR 9S32 and PU and KP, as well as the procedure for verifying this interaction according to the technical descriptions for BSNR 9S32.

The research is dedicated to the analysis of the interaction between the multi-channel missile guidance station 9S32 and the launching installation in the anti-aircraft missile complex.

Importance of communication: Reliable communication between BSNR and PU is crucial for the combat capability of the SAM. Any communication failures can lead to serious consequences, up to the impossibility of completing a combat mission.

Operating modes: The operating modes "Operation" and "Training" during the interaction of BSNR 9S32 with PU are considered.

Information exchange: The information exchanged between BSNR 9S32 and PU is described, including target coordinates, control commands, and PU status data.

Shooting methods: The standard and command-inertial shooting methods are analyzed. PU assignment: The procedures for manual and automatic assignment, reassignment, and release of PU are considered.

Information display: It is described how information about the PU status and targets is displayed on the control panels.

ANALYSIS OF THE CONSTRUCTION, FUNCTIONING AND OPERATION OF COMBAT EQUIPMENT IN THE S-300V1 ANTI-AIRCRAFT MISSILE SYSTEM

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Analysis of the construction of combat assets of the S-300V1 SAM system using technical and operational documentation for these weapon models.

The research is dedicated to the analysis of the principles of functioning of its constituent elements of the combat assets of the S-300V1 9K81 anti-aircraft missile system and operating algorithms with the aim of determining ways to increase the effectiveness of fulfilling the combat tasks assigned to it.

Purpose: BSNR 9S32 and PU 9A83: are key elements of the complex for engaging aerodynamic and ballistic targets in a wide range, providing their detection, tracking, and missile guidance.

Combat Capabilities: The BSNR is capable of simultaneously tracking up to 12 targets and engaging up to 6 with high accuracy of determining coordinates and motion parameters, while the PU conducts fire only on one target with one or two missiles.

Operational Flexibility: Combat operation modes are implemented for AC (autonomously and by target designation) and BC (by target designation), as well as the radar environment analysis mode (ARO) when using KIM or AIM.

PROPOSALS FOR INCREASING THE EFFECTIVENESS OF THE SAM RADAR TRANSMISSION PATH AND ESTIMATING THE POWER LOSSES OF THE SOUND SIGNAL BY USING HEADLIGHTS WITH OPTICAL EXCITATION

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The experience of the Russian-Ukrainian war has shown that the decisive factor in the fight of anti-aircraft missile systems with manned and unmanned enemy vehicles is the timeliness of detection and decision-making on the destruction of the target by the combat service of the anti-aircraft missile division.

Of the many characteristics of the SAM radar, the key factor when calculating the potential capabilities for detecting targets is the efficiency of the transmission path, which consists of the efficiency of the transmitter and the efficiency of the antenna device. It is important to choose such a variant of constructing the transmission path that will ensure the detection of targets to a given range with limited power of the power supply. This imposes some restrictions on the variants of constructing the transmission path and the radar as a whole. The real values of the efficiency of transmission systems in general do not yet exceed 20 ... 40%. The most promising way to meet the requirements set for modern radars is the use of phased array antennas (PHAs) in them.

DEVELOPMENT OF A DATA EXCHANGE CHANNEL TRANSMITTER TRACT MODEL BETWEEN THE MK-I LAUNCHER AND THE CTOC COMBAT CONTROL POINT USING THE GNU RADIO SOFTWARE

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In the NASAMS surface-to-air missile system, data exchange between the launchers and the combat control point is carried out using the multifunctional MV600 radio station. This station is based on the Software-Defined Radio (SDR) architecture, supports various communication protocols, and ensures a reliable communication channel under combat conditions. Thanks to the SDR architecture, the transmitter path of the MV600 radio station can be updated and configured via software without the need to replace hardware components, allowing for rapid adaptation of the system to new standards and technologies. This technology is widely used in military communications, telecommunications, amateur radio, and security systems, providing reliable communication in various conditions.

To analyze the technical characteristics of the transmitter path in the data exchange channel between the launchers and the combat control point of the NASAMS air defense system, a model was developed in the GNU Radio software. This model enables the study of transmitter path operation under different conditions and scenarios, the identification of weak points and problematic aspects, as well as the determination of opportunities for optimization and improvement. This approach is critically important for ensuring accurate data exchange and enhancing the efficiency of the NASAMS air defense system in modern combat conditions, thereby contributing to the strengthening of Ukraine's air defense capabilities.

DEVELOPMENT OF A TRIGGERING ALGORITHM SAFETY AND ARMING UNIT IRIS-T SLS ANTI-AIRCRAFT DUIDED MISSILE

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Analysis of the experience of using the IRIS-T SLM anti-aircraft missile system which includes launchers with IRIS-T SLS anti-aircraft guided missiles in the Russian-Ukrainian war, shows, that the system is highly effective in destroying such air targets as unmanned aerial vehicles and cruise missiles. At the same time, there is a need to improve the safety of the use of IRIS-T SLS, minimise the risks of emergencies and abnormal situations, and improve the effectiveness of air target engagement.

To solve this problem, it is necessary to study the technical characteristics, parameters and functioning of the radio fuze, the Safety and Arming Unit (SAU) of the warhead of the IRIS-T SLS and to develop an algorithm for the operation of the SAU of the IRIS-T SLS. However, such research is difficult due to the lack of design and technical documentation and relevant mathematical models.

The report discusses the main stages of the IRIS-T SLS SAU guidance and warhead triggering process. The algorithm of warhead triggering is presented and the results of estimating the delay time of the radio fuze triggering are given, which in turn allows to determine the necessary conditions for the missile warhead triggering.

The report describes the main stages of the IRIS-T SLS targeting process and the operation of the SAU. The algorithm for the operation of the warhead is presented and the results of estimating the delay time of the radio fuze are given, which in turn allows determining the necessary conditions for the operation of the missile's warhead.

The importance of the proposed algorithm lies in the following:

– the possibility of increasing the safety of missile use by minimising the risks of emergencies;

– ensuring the correct operation of the IRIS-T SLS air defence system even in difficult conditions;

– effective use of anti-aircraft missile weapons and reduction of missile costs in air-to-air combat.

Given the above, the developed algorithm is an important element in the study of the missile to ensure reliable and safe operation of the IRIS-T SLM.

ADAPTIVE COMPENSATION OF THE INFLUENCE OF IONOSPHERIC DELAY ON THE ACCURACY OF RADIO NAVIGATION SATELLITE MEASURED IN SINGLE-FREQUENCY USER EQUIPMENT ALGORITHM WITH USING INFORMATION FROM THE NETWORK OF CONTROL AND CORRECTION STATIONS

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Currently, for solving many applied problems, the problem of high-precision navigation-time determinations based on information from satellite radio navigation systems is becoming of great importance. The inhomogeneity of the dielectric constant of the ionosphere causes a curvature of the signal trajectory, which leads to an additional delay in the signal propagation time from the navigation satellite to the receiver. Thus, the use of the proposed approach allows to improve the process of making recommendations due to the constant evaluation of the efficiency of the algorithm.

There are a lot of methods for determining and taking into account the ionospheric delay. The most effective and accurate method is based on dual-frequency measurements.

A significant disadvantage of this method is the fact that the size of the working area of the control and correction station (CCS) is limited, and the consumer, when determining his position vector, cannot always be in the near working area of the CCS.

An algorithm has been obtained to compensate for the influence of ionospheric error, including its fluctuation component, on the accuracy of CCS in single-frequency consumer equipment using corrective information from the CCS network.

METHODOLOGY FOR STUDYING THE INFLUENCE OF THE TRANSMITTING MODULE OF PHASED ARRAY ANTENNAS IN THE COMPUTER AIDED DESIGN SYSTEM CST STUDIO SUITE

D. Grechko
Military unit A3730

Analytical methods allow to estimate the characteristics of an antenna based on the assumption of its isolation from external influences. However, in modern conditions, such approaches do not provide high-quality design of antenna radiators intended for use in phased array arrays (PA). Therefore, the current global trend in the field of antenna characterisation and development is the active use of computer-aided design (CAD) systems at the design stage, such as CST Studio Suite. This makes it possible to determine the parameters of elements and components of complex systems with high accuracy even before their development, which saves production and human resources. The paper proposes a methodology for studying the effect of the transmission bar of the headlamp in CST Studio Suite CAD, which includes:

– creation of a CAD model of the antenna radiator, taking into account the characteristics and parameters of the materials;

– breakdown of the antenna radiator structure using appropriate meshes (Tetrahedral or Hexahedral);

– calculation of the antenna radiation characteristics using the appropriate calculator (Transient Solver or Frequency Solver) and method (Finite Integration Technique, Finite Element Method);

– creation of a CAD model of the transmission module, taking into account the characteristics and parameters of the materials;

– creating the structure of the PAF using the System Assembly and Modeling (SAM) package;

– calculation of the directional characteristics of the light emitting diode (LED) with consideration of the directional characteristics of the transmitting modules and their mutual influence.

OBSERVATION THE CAPABILITIES OF RADAR SYSTEMS OF PARTNER COUNTRIES TO RECOGNIZE GROUP TARGETS FOR TARGETING AND RECONNAISSANCE

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Analyzing the events during the Russian-Ukrainian war, we can conclude that the enemy is actively using a variety of air attack weapons, which it is constantly improving, to carry out large-scale or localized air strikes. There is a particularly noticeable tendency to create new tactics for breaking through air defenses, in particular through the use of UAVs and cruise missiles, which operate in coordination as part of multi-level strike structures.

This indicates a growing threat from the air, as these means can cause significant losses. It is extremely important for anti-aircraft missile units to have a clear understanding of the scale and types of such threats in order to effectively neutralize them.

In order to detect and accurately determine the number of airborne objects in a timely manner, it is necessary to use high-precision radar with high resolution in all key parameters – range, speed and angular position. However, full access to the technical characteristics of foreign radars, including their radar data processing algorithms, is currently limited. This issue can be resolved with the help of the latest digital signal processing technologies that can improve the accuracy of group target recognition.

Improving the systems for recognizing such air objects can significantly expand the functionality of radars and ensure a more effective response from air defense units, which generally enhances the defense capability of the airspace.

ANALYSIS OF THE CAPABILITIES OF RADARS OF PARTNER COUNTRIES TO RECOGNIZE GROUP TARGETS IN ORDER TO IMPROVE INTELLIGENCE CAPABILITIES

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Based on the operational experience gained during the Russian-Ukrainian conflict, it becomes evident that the adversary employs a wide range of aerial attack systems in both large-scale and precision strikes, continuously refining their capabilities. Among the evolving tactics is the integration of UAVs and cruise missiles into layered offensive formations, often deployed in small, coordinated groups to breach air defense systems.

Given these developments, it is clear that such aerial threats can have a substantial impact on the dynamics of combat operations. Due to the destructive potential of UAVs and cruise missiles, air defense forces must possess accurate and up-to-date information regarding the types and quantities of these threats to ensure effective neutralization.

The detection and identification of grouped aerial targets require prompt discovery and precise estimation of their numbers within a designated operational zone. As a result, surveillance and fire-control radars must exhibit high resolution across angular coordinates, distance, and velocity parameters. However, limited access to comprehensive data on radar systems, particularly regarding signal processing techniques and algorithms, presents a challenge. Enhancing radar resolution can be achieved by integrating advanced algorithms that leverage multiple signal processing strategies to facilitate reliable target recognition.

Improved differentiation of grouped targets directly contributes to expanded situational awareness and enhanced accuracy of radar systems, thereby significantly strengthening the operational performance of surface-to-air missile units and the overall effectiveness of air defense networks.

DEVELOPMENT OF A MODEL OF THE RECEIVING PATH OF THE DATA LINK CHANNEL BETWEEN THE IRIS-T SLS LAUNCHER AND THE TACTICAL OPERATION CENTER (TOC) USING GNU RADIO SOFTWARE

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The analysis of the combat operations of anti-aircraft missile units armed with the IRIS-T SLS anti-aircraft missile system (AAMS) in the Russian-Ukrainian war showed the need to ensure a stable and secure exchange of technical data between launchers and the TOC combat control center with limited access and protection of information. This SAM is equipped with modern radio stations for the exchange of technical information, namely SDTR VR5000, one of the key components of which is the receiving path.

The development of a simulation model of the receiving path for data exchange between the TOC combat control center and IRIS-T SLS launchers is an urgent task, since modeling allows adjusting the parameters of the receiving path, such as sampling rate, bandwidth, sensitivity, and others. In this way, it is possible to increase the efficiency of the receiving path and adapt it to different signal transmission conditions. New or improved existing signal processing algorithms and more powerful processors can be used for this purpose. This will improve the reliability of signal reception and reduce the impact of noise and distortion, which is especially important during combat operations when the enemy uses electronic warfare (EW).

Evaluation of the technical characteristics of the receiving path will help identify its weaknesses and make the necessary improvements to increase the overall efficiency of the system. Systematic testing of the receiving path under different data transmission conditions will allow you to assess the compliance of the functioning with the specified technical parameters.

ANALYSIS OF THE EFFECTIVENESS OF THE THREAT EVALUATION AND WEAPON ALLOCATION ALGORITHM WITH USING THE BAYESIAN NETWORK MODEL

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Threat Evaluation and Weapon Allocation (TEWA) operators in air defense situations assigned threat values to detected targets, values that were used to make real-time decisions about the allocation of defensive resources to threat targets. Since TEWA systems operate in a critical environment where wrong decisions can have fatal consequences, systematic evaluation of the performance of automated (and semi-automated) TEWA systems becomes very important.

The specific implementations of algorithms for real-time threat evaluation and weapon allocation, the Bayesian network for threat evaluation and fuzzy logic algorithm for threat evaluation have been compared. The advantages of Bayesian network for threat assessment lies in the adaptive flexibility and learning of the system. Moreover, this approach allows to use kill assessment data to improve the system for next threat evaluation process.

In this paper the method of combination of Bayesian network for TEWA with method of expert evaluations for determining weight coefficients has been proposed.

The created Bayesian network model of the threat assessment in combination with variable weighting coefficients showed the ability to improve existing variants of the TEWA algorithm in various branches of science.

Thus, the use of the proposed approach allows to improve the process of making recommendations due to the constant evaluation of the efficiency of the algorithm.

AUTOMATED EVALUATION OF THE ELECTRONIC ENVIRONMENT IN SOFTWARE-DEFINED RADIOS USING THE SNMP PROTOCOL

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Effective assessment of the electronic warfare environment is critically important for the rational allocation and utilization of the radio frequency spectrum, as it helps prevent mutual interference between different users and services. Continuous analysis enhances overall readiness and adaptability in dynamic conditions, making automation a key aspect in processing large volumes of data.

Identifying sources of interference and disruptive factors is essential for optimizing the performance of electronic equipment.

To address these challenges, affordable software-defined radio (SDR) receivers such as RTL-SDR, Airspy, and HackRF One are increasingly being implemented. These devices offer flexibility and accessibility for monitoring and analyzing the electronic environment. Additionally, methods embedded in modern communication and data transmission systems such as the use of the Simple Network Management Protocol (SNMP) are becoming increasingly widespread.

This study explores the possibility of using the SNMP protocol in combination with modern SDR receivers to collect up-to-date information on the state of the electronic environment. Solutions for automating this evaluation process using the Python programming language are proposed. This approach leverages the capabilities of SDR and the flexibility of Python to create an automated system for monitoring electromagnetic conditions. Such automation is crucial for ensuring efficient spectrum usage, improving inter-service coordination, and enhancing the resilience of electronic systems against evolving electronic warfare tactics.

IMPROVEMENT OF THE SYSTEM FOR MAINTENANCE AND REPAIR OF RADIO-ELECTRONIC EQUIPMENT OF MODERN ANTI-AIRCRAFT MISSILE SYSTEMS

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High efficiency in the use of air defense systems cannot be achieved without maintaining the combat readiness of anti-aircraft missile forces' weaponry. This task is entrusted to the system of technical maintenance and repair. Until recently, most maintenance and repair equipment for anti-aircraft missile forces consisted of technology developed by manufacturers from the former Soviet Union and supplied to the forces alongside the weaponry.

Currently, partner countries have provided modern maintenance and repair equipment along with advanced anti-aircraft missile systems as part of their assistance efforts and have trained technical personnel. The primary focus of the training has been the use of operational documentation. However, access to technical documentation has not been fully provided by foreign partners, complicating the understanding of the principles and structural features of the new systems. This, in turn, prevents full technical operation of the components of the anti-aircraft missile systems, including restorative repairs in case of damage.

Based on these considerations, the report analyzes the existing system of technical maintenance and repair of radio-electronic equipment in anti-aircraft missile systems and proposes an approach for its improvement, taking into account recommendations from weapon manufacturers and technical operation experiences during combat.

DEVELOPMENT OF A PROPOSAL TO IMPROVE THE CAPABILITY OF THE AIR TARGET RECOGNITION CHANNEL BY USING AN LFM RADIO PULSE EXCITER

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The experience of the Ukrainian-Russian war has highlighted the importance of the enemy's use of various aerial attack means, operating both individually and in groups. During the hostilities, the effective work of air defense missile troops (ADMT) played a key role in countering these threats, allowing Ukraine to maintain control over its airspace and limit the enemy's capabilities in other areas of combat operations. As a result, the adversary was forced to reduce the use of manned aviation deep within Ukrainian territory, giving preference to unmanned aerial systems (UAS) and cruise missiles.

An important component of surface-to-air missile systems is radar stations that utilize linear frequency modulation (LFM) signals. Such radars are capable of detecting and classifying various types of aerial targets – aircraft, helicopters, cruise missiles, and unmanned aerial vehicles – even under conditions of massed aerial attacks. Analysis of the enemy's use of air attack assets revealed that one of the tactics to breach air defenses involves deploying groups of small-sized objects – UAVs and cruise missiles – operating in a coordinated manner.

In these conditions, the radar station's resolution becomes particularly important, as it defines the system's ability to distinguish targets located close to one another. This characteristic is critical to ensuring the high effectiveness of surface-to-air missile systems in combating group threats. Improving resolution capabilities enhances the timely detection and identification of dense groups of aerial objects, expanding the informational capabilities of the radar and increasing the accuracy of target engagement.

DEVELOPMENT OF A DATA EXCHANGE CHANNEL RECEIVING TRACT MODEL BETWEEN THE MK-I LAUNCHER AND THE CTOC COMBAT CONTROL POINT USING THE GNU RADIO SOFTWARE

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Data exchange between launchers and the combat control point in the NASAMS air defense system is provided by the MV600 multifunctional radio station, which is built on the principle of software-defined radio SDR. In which the settings of the hardware functions are carried out programmatically.

In this work, a model of the receiving path of the data exchange channel between launchers and the combat control point of the NASAMS air defense system was developed. During the development of the model, free open source software GNU Radio was used, which provides real-time signal processing and is widely used in the fields of telecommunications, scientific research and radio frequency analysis.

The developed model allows you to analyze and characterize the main parameters and properties of the data exchange channel between launchers and the combat control point.

The results obtained contribute to increasing the reliability and overall efficiency of data transmission and can be used to improve the communication capabilities of the NASAMS air defense system, and also create a basis for further research and optimization of the receiving path of the data exchange channel between the launchers and the NASAMS air defense system combat control point, which generally increases the combat capability and operational readiness of this air defense system.

STUDY OF THE EFFICIENCY OF THE TEWA ALGORITHM OF THE IRIS-T SLM AIR DEFENSE MISSILE SYSTEM USING THE BAESIAN NETWORK MODEL

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The report analyzes the generalized fire control algorithm of the IRIS-T SLM anti-aircraft missile system, highlighting the main stages and phases. It has been established that in the combat control point of the IRIS-T SLM anti-aircraft missile system, the process of capturing and destroying targets is divided into two components – aerial reconnaissance and combat mission control.

The paper considers the approach of complex consideration of capability parameters, intent parameters and parameters of the air enemy's position in time when assessing the threat to the covered objects. The proposed algorithm allows for a comprehensive assessment of the air enemy threat, which contributes to an increase in the level of protection of the covered objects.

A mathematical model of threat assessment and firepower distribution in the IRIS-T SLM anti-aircraft missile system is presented, which allows targeting and maximizing the total prevented damage to the covered objects with limited resources.

It is proposed to use a modified Hungarian method to solve the optimization problem, which allows to make an accurate decision quickly in real time and does not require significant consumption of machine memory and the number of operations in the implementation of calculations.

Further research is planned to improve the methods of analysis and increase the accuracy of estimates.

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ПЕРСПЕКТИВИ РОЗВИТКУ СИСТЕМИ ЗВ'ЯЗКУ, РАДІОТЕХНІЧНОГО ЗАБЕЗПЕЧЕННЯ ТА АВТОМАТИЗОВАНОГО УПРАВЛІННЯ ВІЙСЬКАМИ

Керівники секції: Ph.D. підполковник Дмитро КАЛІНОВСЬКИЙ
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ЗАСТОСУВАННЯ КОМП'ЮТЕРНИХ СИСТЕМ ДЛЯ ДЕКОДУВАННЯ ФОТОГРАФІЧНОЇ ІНФОРМАЦІЇ

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В сучасних умовах цифровізації, в умовах повномасштабної війни рф проти України, потреба в автоматизованих системах обробки та аналізу фотографічної інформації є надзвичайно високою. Актуальність таких систем зумовлена значним зростанням обсягів візуальних даних, що надходять із камер спостереження безпілотних літальних апаратів (БПЛА) розвідувальних органів та зменшенням наявного часу для декодування таких знімків.

Комп'ютерні системи декодування фотоінформації суттєво прискорюють процес інтерпретації зображень, підвищують точність та стабільність декодування у порівнянні з ручним аналізом. Сучасні алгоритми машинного зору та штучного інтелекту забезпечують високу точність розпізнавання об'єктів і сцен.

Комп'ютерна система для декодування зображень включає модулі попередньої обробки та оцифровки зображень (якщо декодуються паперові знімки), вилучення ознак і класифікації об'єктів. Важливою частиною такої системи є база даних еталонних образів для порівняння та навчання. Оптимізація обчислювальних ресурсів та підтримка роботи близькому до режиму реального часу є ключовими завданнями при розробці таких систем. Інтеграція з іншими цифровими платформами розширює функціональні можливості та сфери застосування. Розвиток комп'ютерних систем декодування фотографічної інформації сприяє підвищенню ефективності ухвалення рішень під час планування та виконання бойових операцій.

RESEARCH ON THE EFFECTIVENESS OF WIREGUARD AS A MODERN VPN PROTOCOL

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The study of computer network virtualization methods based on VPN is a relevant task in the modern technological field, as it ensures efficient management and optimization of network resources, improving security and scalability in the context of an increasing number of connected devices.

One of the most effective solutions in this area is WireGuard – a modern VPN protocol that provides a high level of security, performance, and ease of use. WireGuard has several advantages over traditional VPN solutions, such as OpenVPN. Unlike OpenVPN, which supports both TCP and UDP, WireGuard operates exclusively on UDP, which can create difficulties in networks with strict restrictions.

The WireGuard protocol is also distinguished by its simplicity of configuration and management. It operates on a peer-to-peer concept, where each node has its unique cryptographic key. This allows for a reduction in configuration complexity and facilitates integration into existing network environments. Furthermore, the protocol supports cross-platform use, making it compatible with most modern operating systems.

APPROACH TO INTEGRATING INFORMATION FROM DIFFERENT TYPES OF SOURCES AT THE STAGE OF AIR OBJECT TRAJECTORY DETECTION

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Currently, a system composed of diverse radar information sources, designed to supply primary data for subsequent processing within a radar information processing framework, is regarded as a viable and forward-looking alternative to multistatic radar systems. This approach enhances the quality of radar surveillance by leveraging measurement redundancy (in comparison with standalone radar units), while offering reduced complexity in terms of system design, deployment, and operational maintenance relative to multistatic configurations.

The greatest effectiveness of such systems is realized through the fusion of individual asynchronous measurements within the radar data processing system. In a general context, the radar information collection and processing subsystem, as part of specialized automated command and control systems, may integrate an arbitrary number of spatially distributed radar assets of varying functional types, frequency ranges, and operational modes.

The asynchronous nature of data integration necessitates the development of robust, adaptive algorithms for trajectory extraction based on irregular, non-synchronous, and variably accurate measurements originating from multiple heterogeneous sensor platforms. This methodology enables the generation of a reliable and coherent situational awareness of the aerial environment, even under conditions of incomplete, imprecise, or temporally inconsistent initial input data.

DEVELOPMENT OF A TELEMETRY SYSTEM FOR ADMINISTRATION AND MONITORING OF THE TECHNICAL CONDITION OF AUTOMATION EQUIPMENT COMPLEXES DURING OPERATION

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Automated control systems used in military operations are developed based on software and hardware complexes utilizing computers. This approach offers significant advantages in terms of flexibility, ease of maintenance, and system upgrades. However, it also has certain drawbacks. For instance, a failure in the computing platform, which serves as the foundation for automation tools, can render the entire system non-functional until it is fully restored. In terms of reliability, hardware and software components vary greatly in performance, with hardware being more susceptible to external influences.

The reliability and operational stability of automation systems become particularly crucial when these systems operate with minimal human intervention, remotely, or in combat environments. While software remains unaffected by environmental conditions, performs steadily when thoroughly tested, and does not degrade over time, hardware components deteriorate due to material aging and are highly sensitive to external factors such as temperature fluctuations, humidity, shocks, and electromagnetic interference. Unfortunately, the gradual deterioration of critical hardware components remains unnoticed by operators, leading to worsening system performance, instability, and even complete failure.

Thus, integrating telemetry systems for monitoring the technical condition of automation systems is a crucial step toward ensuring the stable and uninterrupted functioning of remote military equipment.

METHODS FOR CONSTRUCTING CONTROL SEQUENCES FOR CRYPTOGRAPHIC SYSTEMS IN THE FACE OF CYBER THREATS

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In this paper, we review approaches to creating control components for cryptographic systems that meet the requirements of data transmission security in situations where the system is subject to intense cyberattacks. In particular, algorithms are used to select polynomials over the field $GF(2^{32})$, which serve as the basis for forming control elements capable of withstanding current threats.

The report emphasizes that using these methods can significantly increase the level of protection, and the correct selection of field parameters and results provides greater resistance to mathematical attacks. It is important to fine-tune the parameters of encryption algorithms, and applying an adaptive approach to the design of transformations that allow for dynamic adjustment of parameters in accordance with changing radio line conditions is also emphasized.

The report also discusses methods that increase resistance to attacks, in particular, the use of algebraic and numerical properties of $GF(2^{32})$ fields. One key aspect is the use of adaptive mechanisms to generate control parameters, which allows for effective change to the encryption settings in response to changes in system conditions.

Implementing such adaptive mechanisms helps to increase the effectiveness of protection against hacking attempts and significantly reduces the likelihood of successful attacks by preventing structural vulnerabilities in cryptographic algorithms. At the same time, the inherent complexity of these methods makes it difficult to integrate them into real-world systems with high product requirements.

USING MULTIPATH TCP TO IMPROVE THE PERFORMANCE OF NETWORK CONNECTIONS

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The Multipath TCP protocol opens up new opportunities to improve the performance of network connections by allowing data to be transmitted simultneously over multiple channels. This approach not only increases the overall bandwidth, but also significantly improves the quality of communication, reducing the likelihood of interruptions and ensuring uninterrupted data transmission. MPTCP is the optimal solution for networks with high stability requirements, where even a short-term loss of connectivity can have consequences.

The effectiveness of MPTCP is manifested in its ability to adapt to changing network conditions by dynamically redistributing traffic between available channels, which reduces latency and improves call quality. MPTCP impacts performance in several key ways. It aggregates the bandwidth of all available channels, allowing more data to be transmitted per unit of time than using a single channel. MPTCP reduces latency by dynamically selecting the fastest path for each data packet, reducing average packet delivery time and improving connection reliability as traffic is instantly rerouted to another channel without interruption in the event of a link failure, reducing packet loss. This ensures that users have stable access to data even if one of the channels is overloaded.

The implementation of MPTCP requires solving compatibility issues with existing equipment and developing algorithms for efficient load balancing between asynchronous paths, which opens up opportunities for its use in systems. In the future, MPTCP may become a key element for the development of high-speed networks, facilitating integration with various technologies, as well as providing scalability and resilience.

РОЗРОБКА ВАРІАНТУ КОМП’ЮТЕРНОЇ СИСТЕМИ ДЛЯ ПЕРЕДАЧІ ТЕЛЕМЕТРІЧНИХ ДАНИХ

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Системи телеметрії забезпечують дистанційний збір, передачу та аналіз інформації. Мікроконтролери обробляють сигнали, що надходять від датчиків. Для вимірювання параметрів об’єктів або навколишнього середовища та перетворення аналогової інформації на цифрову використовуються сенсори (датчики).

Параметричні дані про об’єкт або навколишнє середовище відповідно до певного алгоритму упаковуються в телеметричні пакети стандартного формату. Для передавання таких даних застосовуються дротові (Ethernet) або бездротові канали зв’язку (GSM, Wi-Fi, LoRa). Передача може здійснюватися як у реальному часі, так і з буферизацією.

Програмне забезпечення для моніторингу віддалених об’єктів забезпечує декодування, фільтрацію та візуалізацію даних. Візуалізація реалізується через апаратні засоби відображення інформації: індикатор, монітор, веб-інтерфейси чи мобільні застосунки. Система може надсилати сповіщення та аварійні сигнали у разі порушення параметрів. Захист даних забезпечується через шифрування та авторизацію доступу.

Телеметрія широко використовується в промисловості, транспорті, медицині та екології. Такі системи підвищують ефективність роботи, обслуговування та управління віддаленими об’єктами.

Аналітика на основі телеметрії дає змогу прогнозувати відмови й оптимізувати процеси технічного обслуговування обладнання, що підвищує надійність функціонування автоматизованих комплексів, зокрема за рахунок зменшення кількості несподіваних відмов техніки, особливо у процесі бойових операцій.

RESEARCH OF TECHNICAL RESERVATION AS A METHOD OF INCREASING THE RELIABILITY INDICATORS OF SPECIAL-PURPOSE AUTOMATION SYSTEMS

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Ensuring the high reliability of special-purpose automated control systems (ACS) is one of the key tasks at all stages of their design, implementation, and operation. The reliability of such systems determines their ability to consistently perform functions of control, monitoring, data processing, and to ensure the safety of critically important processes. Given the continuous complexity of the architecture and the expansion of the functionality of special-purpose ACS, the issue of improving their reliability is becoming increasingly relevant.

To achieve high reliability indicators, various methods are used in ACS, with the method of redundancy being considered in detail as the most common and effective approach.

Redundancy involves the inclusion of additional components in the system that duplicate the main functions or subsystems. According to their mode of operation, redundancy can be classified as follows: active redundancy – redundant components operate simultaneously with the primary ones; passive redundancy – redundant components are activated only after the failure of primary elements; warm redundancy – redundant components are kept in a ready state for quick activation.

The application of redundancy significantly improves system reliability, which is particularly important in telecommunications networks, information systems, and industrial automated complexes.

THE PROCESS OF FORMALISING KNOWLEDGE ON BUILDING A ROUTE FOR THE MOVEMENT OF ANTI-AIRCRAFT MISSILE BRIGADE VEHICLES TO PERFORM AIR DEFENCE TASKS IN COMBAT OPERATIONS

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Anti-Aircraft Missile Forces are an important component of the Air Force in the current war in Ukraine, which is characterised by high intensity of hostilities, dynamic changes in the operational situation and widespread use of modern weapons, including cruise and ballistic missiles, unmanned aerial vehicles and electronic warfare systems. In such conditions, to successfully perform air defence tasks, anti-aircraft missile forces must demonstrate high flexibility, use automated control systems and integrate modern weapons.

The effectiveness of Anti-Aircraft Missile units largely depends on properly constructed routes that reduce the likelihood of enemy fire and promote the rational use of available resources. Manoeuvring in the combat zone is complicated by active enemy opposition, minefields, destroyed infrastructure, time constraints and adverse weather conditions. Therefore, the development of optimal routes for vehicles is a critical task to ensure the survivability of units and the effective performance of combat missions.

Taking all these factors into account, it is advisable to use the A* method in combination with modern databases, which will reduce the risk of loss of personnel and equipment, ensure efficient resource allocation and prompt response to changes in the combat situation. The implementation of these solutions is an important step in improving Ukraine's air defence system.

ANALYSIS OF METHODS FOR CONSTRUCTING ROUTES FOR UNMANNED AERIAL VEHICLE RECONNAISSANCE FLIGHT

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In the context of Russia's armed aggression against Ukraine, unmanned aerial vehicles have become an indispensable tool that has caused fundamental changes in the methodology of modern warfare. unmanned aerial vehicles are used to perform specialized tasks such as aerial reconnaissance, surveillance, tactical air support, and others.

The procedure for planning unmanned aerial vehicles routes requires an integrated approach that covers both the technical specifications of the aircraft and external factors, including meteorological conditions, terrain topography, and enemy influence. A comprehensive analysis of these factors is a prerequisite for ensuring the safety, effectiveness and successful completion of a combat mission. Efficient communication systems and data transmission channels between the aircraft and the operator play a critical role in maintaining control and coordination, especially in complex operating environments.

Continuous analysis and optimization of unmanned aerial vehicles flight paths are key to increasing operational capabilities and the effectiveness of combat missions. A comprehensive planning approach minimizes potential risks and maximizes the productivity of unmanned aerial vehicles. To optimize the process of building routes for reconnaissance unmanned aerial vehicles, it is proposed to use the Li wave algorithm, which will improve the intelligence system of the Armed Forces of Ukraine.

AUTOMATION OF THE PROCESS OF DETECTION AND MITIGATION OF CYBER THREATS IN AN INFORMATION AND COMMUNICATION NETWORK

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Recently, artificial intelligence (AI) has generated significant buzz and is being actively applied across various domains. It is used to optimize knowledge management, personalize services, and rethink how information and products are created and explored.

In the field of cybersecurity, however, AI has yet to make the substantial impact that many had anticipated. This presents a challenge, as cybersecurity systems accumulate vast amounts of data, and professionals aim to automate analysis processes as much as possible. Modern security workflows incorporate multiple steps using large language models (LLMs) – such as planning, summarization, and recommendation – yet no single model can handle the entire pipeline.

Open-source models play a crucial role: they enable task-specific fine-tuning, allow replacement or enhancement of components as needed, and support performance, latency, and reliability optimization. This is especially important in high-demand use cases like threat detection.

In contrast, closed models accessed via APIs present significant limitations: high costs, limited control, outdated models, and deployment difficulties on the client side. Many cybersecurity organizations require the ability to run AI models locally, without relying on external SaaS-based solutions.

This is where open models demonstrate their advantage – empowering organizations to independently deploy, manage, and secure their AI models.

РОЗРОБКА ВАРІАНТА КОМП’ЮТЕРНОЇ СИСТЕМИ ДЛЯ РЕЄСТРАЦІЇ ДОСТУПНОСТІ МЕРЕЖЕВИХ РЕСУРСІВ

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Стабільний доступ до мережевих ресурсів критично важли-вий для функціонування військових інформаційно-комунікаційних мереж і комплексів засобів автоматизації ЗСУ.

Збої у доступності мережевих ресурсів можуть спричинити затримки в обробці інформації, а іноді й серйозні проблеми в роботі таких систем, аж до повної втрати їх працездатності.

Використання підсистеми контролю доступності мережевих ресурсів, як частини системи діагностики обладнання та каналів зв’язку, дає змогу своєчасно виявляти та усувати неполадки, мінімізуючи простої сервісів. Актуальність такої системи ще більше зросла під час російсько-української війни, у процесі відбиття масованих повітряних атак противника, а також у зв’язку з розширенням сервісів в інформаційно-комунікаційних мережах ЗСУ.

Система моніторингу мережевих ресурсів забезпечує постійний контроль стану комутаційних каналів, каналоутворювального обладнання та інших мережевих вузлів. Основними функціями такої системи є перевірка доступності, часу відгуку, пропускної здатності вибраних мережевих маршрутів і аналіз рівня відмов.

Система моніторингу дозволяє автоматично повідомляти адміністратора у випадку збоїв або перевищення критичних часових інтервалів проходження інформації. До складу такої системи входять агенти моніторингу, центральний сервер, база даних подій та інтерфейс візуалізації. Додатково може застосовуватися система сповіщення адміністратора та аналітичний модуль.

RESEARCH OF INTELLIGENT TECHNIQUES FOR DETECTING NETWORK ATTACKS

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In the digital environment, network attacks pose a serious threat to information security, which requires intrusion detection system (IDS). Traditional methods no longer provide an adequate level of protection, so intelligent approaches based on machine learning (ML) and deep learning (DL) methods are being actively developed.

Network attacks are divided into several main types: DoS (denial-of-service attacks), Probe (network information gathering), U2R (gaining unauthorised access by impersonating a normal user) and R2L (gaining unauthorised access by exploiting network vulnerabilities). To recognise these attacks, various datasets are widely used to train, test, and evaluate the effectiveness of models.

Modern intelligent methods include machine learning algorithms such as decision trees (DT), support vector machines (SVM), neural networks (AI), unsupervised learning (clustering, anomaly detection), and deep learning (CNN, RNN). At the same time, IDS systems face a high level of false positives and difficulty in detecting unknown attacks. A promising area of research is the use of artificial intelligence to build self-learning network attack detection systems that can respond in real time to new, unknown threats.

Thus, intelligent attack detection technologies have significant potential and require further development for effective use in the face of growing cyber threats.

PECULIARITIES OF PLANNING THE FLIGHT ROUTE OF AN UNMANNED AERIAL VEHICLE USING INFORMATION TECHNOLOGY

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In today's environment, the use of unmanned aerial vehicles (UAVs) requires high accuracy and flexibility in decision-making. This necessitates the introduction of information technology (IT) capable of ensuring effective flight route planning in a changing combat environment. The purpose of IT is to support the decision-making process of the UAV operator at all stages of planning – from collecting information to forming an optimal route, taking into account external factors (weather, terrain, enemy activity, etc.).

The functional structure of the information technology includes processing, storage and analysis of information, formalisation of knowledge, and generation of recommendations for the operator. Particular attention is paid to knowledge formalisation methods: interval fuzzy sets and linguistic variables are used to translate expert opinions into an algorithmic form. This ensures the objectivity and adaptability of the system under conditions of uncertainty.

The flight strategy is formed on the basis of fuzzy logical statements that take into account the probable actions of the enemy, changes in weather conditions and terrain. Thus, the built-in IT contributes to the increase in the efficiency of reconnaissance operations, the speed of decision-making and the overall reliability of UAV control.

In this way, information technology ensures effective planning of UAV routes under conditions of uncertainty. The use of fuzzy logic increases the objectivity and adaptability of decisions. This contributes to the growth of reliability, efficiency and effectiveness of management.

КОМП’ЮТЕРНА СИСТЕМА ДЛЯ РОЗПІЗНАВАННЯ ЗАДАНИХ ОБ’ЄКТІВ З ПОТОКУ ВІДЕОІНФОРМАЦІЇ

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Як показав досвід російсько-української війни, своєчасне визначення міст розташування військових об’єктів противника грає ключову роль в успішності проведення військових операцій всіх видів. Переважний обсяг розвідувальної відеоінформації отримується з камер безпілотних летальних апаратів у вигляді відеопотоку в режимі реального часу.

Швидкий розвиток нейромережевих технологій та штучного інтелекту суттєво розширює можливості розпізнавання заданих об'єктів в відеопотоці, та скорочує час, необхідний для розпізнання.

Існуючі системи розпізнавання об'єктів в відеопотоці в продовж останніх років зазнали змін. Системи YOLO (You Only Look Once) різних версій здатні обробляти відеопоток зі швидкістю, яка не перевищує 100 кадрів за секунду. При цьому мінімальний розмір об'єкту для пошуку не повинен бути менш ніж 15 x 15 пікселів. В цілому це задовольняє вимогам сучасності і така система може працювати практично в режимі реального часу.

Використання сучасних матриць відеозображення з високою роздільною здатністю дозволяє значно покращити показники розпізнавання, але потребує значно більшої обчислювальної потужності, а також призведе до збільшення енергозатрат.

В даній роботі пропонується використовувати альтернативний варіант покращення показників розпізнання – використання існуючих спеціалізованих нейромережевих архітектур для конкретних сценаріїв розпізнавання. Впровадження таких систем здатно покращити ефективну роздільну здатність зображення в 4-8 разів, що зберігає деталі при складних умовах освітлення.

РОЗРОБКА КОМП'ЮТЕРНОЇ СИСТЕМИ АВТЕНТИФІКАЦІЇ КОРИСТУВАЧІВ НА ПУНКТІ УПРАВЛІННЯ

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В умовах постійного зростання кіберзагроз надійна автентифікація користувачів стає ключовим елементом інформаційної безпеки. Пункти управління є критично важливими військовими об'єктами, що потребують суворого розмежування та контролю доступу до робочих місць.

Були проаналізовані існуючі на цей момент традиційні підходи до автентифікації користувачів: однофакторна, двофакторна та багатофакторна автентифікація.

Однофакторна автентифікація на основі традиційного логіна та пароля визнана недостатньо надійною і не повною мірою відповідає вимогам сучасної безпеки. Автентифікація користувачів за допомогою апаратних засобів ідентифікації має кращий рівень захисту, але також має певні недоліки та вразливості.

Як експериментальна модель для розробки була обрана багатофакторна автентифікація, що поєднує пароль, фізичний токен і біометрію. Передбачається, що в системі використовуватимуться біометричні методи – розпізнавання обличчя та відбитків пальців. Обмін даними між системою авторизації та робочим місцем буде захищений за допомогою протоколу TLS, а паролі та біометричні шаблони зберігатимуться у зашифрованому вигляді з використанням алгоритму AES-256. Для відстеження та документування всіх дій користувачів планується ведення журналу аудиту.

З метою подальшого підвищення надійності системи автентифікації заплановано впровадження додаткової підтримки NFC-технологій.

RESEARCH ON THE EFFECTIVENESS OF NETWORK INTRUSION DETECTION SYSTEMS

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Today, with the rapid growth of computer network usage, the issue of securing these networks against external attacks is becoming increasingly critical. Therefore, this work proposes the use of intrusion detection and prevention systems, specifically Snort and Suricata.

To test the detection systems, a test environment was built in the form of a local network consisting of eight computers connected to a switch. These machines generated both normal network traffic and intrusion attempts, while a separate server was used to alternately run the Snort and Suricata intrusion detection systems.

For generating network attacks, the LOIC tool for DDoS attacks and the Scapy packet manipulation tool were used.

Testing was conducted on Linux 5.4 and FreeBSD operating systems under various traffic speeds and packet sizes.

The results of the comparative analysis of the intrusion detection and prevention systems obtained during testing provide a clear picture of the effectiveness of each solution. It is also worth noting that at speeds up to and including 1 Gbps, both programs successfully blocked all network attacks.

The solution recommended based on this comparison provides a reliable foundation for the secure deployment and use of local area networks.

ANALYSIS OF AN IMPROVED METHOD OF COMPRESSION OF VIDEO INFORMATION FLOW FROM RECONNAISSANCE UAVS IN REAL TIME IN THE CURRENT SITUATION

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Unmanned aerial vehicles (UAVs) are a rapidly developing technological innovation in the Ukrainian army. In an effort to meet NATO quality standards, we are actively integrating UAVs into our military systems. These systems are widely used in various fields, including military applications, geological exploration and agriculture. For example, NATO forces regularly use UAVs as standard military equipment, and we strive to achieve this high level. One of the key features of modern UAVs is their ability to transmit video information in real time. This has become possible due to significant progress in data transmission and image processing technologies. The continuous development of the video stream in UAVs is driven by the rapid growth of computing power and new artificial intelligence technologies. These achievements expand the possibilities of analyzing and interpreting video data, contributing to the creation of autonomous systems for the automatic detection of events and objects in video recordings. Thus, the flow of video information in unmanned aerial vehicles opens up new opportunities in various fields, significantly improving the capabilities of surveillance, reconnaissance and monitoring. Continued development of this technology is expected to bring even more benefits and expand opportunities for military operations in the future. In general, real-time video data transmission to UAVs is a significant technological breakthrough with wide applications in various industries.

DECISION SUPPORT SYSTEM FOR MANAGING A LARGE GROUP OF UNMANNED AERIAL VEHICLES

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The development of a decision support system (DSS) for managing a significant number of unmanned aerial vehicles (UAVs) in combat aims to improve their adaptability and the efficiency of decision-making. This is particularly crucial when the UAV group experiences issues or technical malfunctions in the unpredictable combat zone. The system utilizes machine learning algorithms and real-time data processing to ensure effective group management.

The research report details the benefits of incorporating adaptive mechanisms into the DSS. It shows that selecting the right parameters and adjusting management strategies promptly significantly increases resilience to unforeseen operational events and enemy actions. The report highlights the need for precise calibration of decision-making algorithms and the application of adaptive methods to dynamically alter UAV control parameters based on evolving battlefield scenarios.

Considerable attention is paid to techniques that bolster the robustness of UAV control systems against electronic warfare, signal jamming, and other battlefield threats. By employing adaptive mechanisms, the system can generate control parameters and efficiently revise mission plans in real-time, guaranteeing continuous UAV operation even in demanding circumstances.

SPECIFICATIONS FOR CYBER-PHYSICAL SYSTEMS FUNCTIONING AS AN INTELLIGENT MODULE WITHIN SPECIAL-PURPOSE AUTOMATED CONTROL SYSTEMS

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The term ‘Cyber-Physical Systems’ was introduced in 2006 by Helen Gill, Director of the US National Science Foundation, to refer to complexes consisting of physical objects, control subsystems and actuators (controllers). Cyber-Physical Systems in general are quite different from traditional control systems: they include, often, a greater number of redundant mechanisms, decision-making and recovery tools due to the lack of working staff or the desire to automate the process.

Moreover, it is important to highlight the significantly different requirements concerning targets, potential risks, their evaluation, and prediction. The referenced systems may vary considerably in terms of performance, reliability, and the operating systems or applications in use – many of which may be unconventional for standard network environments. Security mechanisms must ensure system integrity not only during normal operation but also under abnormal conditions, such as during cyber-attacks. Currently, commercially available Ethernet and IP-based devices are increasingly replacing older proprietary technologies in Cyber-Physical Systems, which in turn raises the risk of vulnerabilities and cybersecurity incidents.

Would you like this version made more formal or adapted for a specific context like a report or presentation?These systems implement new solutions to promote enterprise connectivity and remote access capabilities. The integration of physical and cyber space adds new capabilities, but provides less isolation of the system from the external world. While existing information and communications network solutions can prevent most threats, Cyber-Physical Systems require special security measures.

REVIEW AND COMPARISON OF EXISTING METHODS OF VIDEO COMPRESSION FOR FURTHER IMPROVEMENT

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In the context of the armed conflict on the territory of Ukraine, the ability to transmit video information quickly and reliably is of particular importance. The intensity of changes on the front line, the increase in data from intelligence and surveillance systems, and the limited bandwidth of communication channels pose serious challenges for video processing and transmission systems.

Efficient video compression is a key tool in overcoming these challenges. There are two main approaches: lossless and lossy compression. In the first case, for example, the use of the MJPEG format allows you to reduce the size of the video while maintaining the accuracy of the original, which is critical in areas where maximum reliability is required, such as forensic examination or diagnostics. This approach is based on methods that do not distort information, such as Huffman coding.

Instead, most application systems that focus on the ratio between the quality and volume of transmitted information use lossy algorithms. Among them are H.264 and H.265, which are widely used due to their ability to achieve high compression rates using a discrete cosine transform. The relatively new VP9 standard, developed by Google, allows you to achieve similar results, while eliminating the need for users to pay license fees.

Given the challenging conditions in which modern video transmission systems operate, further research should focus on creating flexible, adaptive compression algorithms that utilize the potential of artificial intelligence and machine learning. Particularly noteworthy are solutions that can dynamically adapt to changes in the parameters of the network environment, while maintaining the stability and quality of video transmission in critical situations.

PLANNING OF THE UNMANNED AERIAL VEHICLE (UAV) GROUP IN THE ISR OPERATIONS

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The paper presents an approach to planning missions for a group of unmanned aerial vehicles (UAVs) during aerial reconnaissance under limited time and energy resources. A two-level planning model is proposed, which includes an energy level and a topological routing level. The approach is based on adapting the traveling salesman problem algorithm for multiple UAVs, considering battery charge and discharge cycles, and without the need to return to the starting point. Special attention is given to optimizing mission time and reducing energy use when scanning specific target points.

The proposed approach allows for effective task distribution among UAVs, considering limited battery capacity, movement speed, and processing time at target points. Mission planning considers the number of observation points, their coordinates, and the need for regular returns to a charging base. Continuous reconnaissance is possible by alternating the operation of different UAVs.

The planning algorithm developed for a UAV group can be effectively used to organize flexible and energy-efficient area monitoring. In the future, this approach could be integrated into an automated air reconnaissance management system.

PROPOSALS FOR IMPROVING AUTHORISATION MONITORING SERVICES FOR THE INFORMATION AND COMMUNICATION NETWORK OF THE AIR FORCE OF UKRAINE

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In the current conditions of warfare, the issue of protecting the information and communication systems of the Air Force of Ukraine is critical, in particular, in terms of secure access to computers, servers and internal services. An effective system for monitoring authorisation processes plays a key role in cyber defence, but the main problems currently remain fragmented logs, the lack of a single event analysis centre, limited automation of incident processing and the low flexibility of traditional event logs, which require immediate improvement.

The first step to improving your cyber defence system is to implement centralised collection of authorisation logs from all network devices to a separate processing server using SIEM solutions such as Wazuh or Graylog. They provide flexible filtering, dashboarding, and automatic notification of suspicious activity (failed logins, access after hours, etc.). For centralised access control, it is advisable to implement a local user base (FreeIPA or Active Directory without Internet access), as well as multi-factor authentication with a password and a physical token. Correlation with DHCP logs, recording of behavioural patterns (e.g. time/location of connection), ARP inspection on switches, and 802.1X authentication will be used to detect attempts to circumvent control by spoofing MAC or IP addresses. Additionally, regular log auditing, retention of event logs for at least 6 months, backups, and periodic penetration testing to assess system resilience should be performed.

As a result of the implementation of these technical and organisational solutions, the level of security of the information and communication network of the Air Force of Ukraine will increase.parent and reliable.

MODERN TECHNOLOGIES FOR ANALYZING MINED TERRITORIES USING A SWARM OF UNMANNED AERIAL VEHICLES WITH ARTIFICIAL INTELLIGENCE

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The problem of mine danger is becoming increasingly relevant in the modern world, especially in the context of armed conflicts that lead to significant contamination of territories with explosive ordnance. Traditional demining methods are typically labor-intensive, time-consuming, and carry a high risk for sappers. In this regard, there is an urgent need to develop more effective technologies.

The existing development of unmanned aerial vehicles (UAVs) and artificial intelligence (AI) opens up new possibilities for solving this problem. The use of a swarm of multi-rotor UAVs, equipped with various sensors and intelligent systems, creates conditions for increasing the speed, accuracy, and safety of analyzing mined territories. In the field of demining, UAVs show promise in deploying mine detectors as a payload, as well as in using multispectral and infrared equipment for reconnaissance of the mine situation by detecting temperature differences between mines and the soil.

The integration of cloud computing with UAVs significantly expands their functionality, providing the necessary computing power for processing large volumes of data. Advanced research is aimed at developing UAVs with various combinations of sensors, including thermal imagers, ground-penetrating radar, and optoelectronic sensors, which expands their functional capabilities. An important direction is the optimization of AI, weight, and energy consumption of sensor equipment to ensure efficient and long-lasting operation of UAVs. This is key for their further implementation in the areas of demining, building up-to-date maps of mine threats, and safe routes of movement.

INVESTIGATION OF THE INTERACTION OF ICN EQUIPMENT FROM DIFFERENT MANUFACTURERS

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At the current stage of development of information and communication networks (ICN), the growth in scale and load leads to an increase in the amount of equipment from different manufacturers. The rising number of network hardware vendors – such as Cisco, Huawei, Juniper, MikroTik, D-Link, TP-Link, Ubiquiti, and others – makes the issues of compatibility and device interoperability increasingly relevant. This interaction may occur both between devices operating on the same layer and between devices at different levels, including client–access point interactions.

This research is dedicated to studying the challenges of interaction among equipment from different manufacturers under the real-world operating conditions of ICT networks. The objective is to identify existing difficulties caused by differences in protocol implementations, hardware and software configurations, to generalize information regarding interoperability, and to provide an overview of possible ways to mitigate such issues.

During the research, the interaction of devices from various manufacturers, as observed in the ICT networks of the Armed Forces of Ukraine, was analyzed. Special attention was paid to routing protocols such as OSPF and BGP, features of the implementation of the basic STP protocol, and tools that enhance performance parameters. The study also explored the interaction of devices using Wi-Fi (IEEE 802.11 standard) and the operation of VLAN-based connections.

The chosen research methods include the analysis of existing interaction features with subsequent implementation using the available technical infrastructure. Additionally, the work involved analyzing and identifying ways to overcome interoperability issues and configuring devices to ensure reliable and efficient network operation.

ENSURING RELIABLE AND ADAPTIVE COMMUNICATION AT THE TACTICAL LEVEL WITH THE HELP OF WEB SIP CLIENT-SERVICE IP TELEPHONY IN MILITARY OPERATIONS

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In today's combat environment, ensuring stable and efficient communications is one of the key conditions for effective troop management. IP telephony systems and web clients that use the SIP protocol are promising solutions for organizing communication between tactical operations centers and subordinate units. The adaptability and ease of integration of web-based SIP clients allows them to be used on a wide range of devices, including smartphones, tablets and laptops, providing high-quality communication using a standard web browser.

The main advantage of web-based SIP clients is that they operate without the need for specialized hardware. Modern IP telephony technologies ensure a high level of information security in the context of hostilities. This is especially important at the tactical level, where any disruption to the communication system can lead to disruption of the command and control (C2) system. The introduction of a web-based SIP client interface into the communications infrastructure will facilitate the rapid transmission of voice messages, location data, text messages, and multimedia files. As a result, commanders will receive up-to-date information for making management decisions in real time, which will significantly optimize their operations.

Further areas of development for these systems include expanding autonomous capabilities, integrating with artificial intelligence technologies, and increasing the level of resilience to cyber threats. The use of web-based SIP clients will help increase the efficiency, flexibility and reliability of military operations command and control processes.

VIRTUALIZATION AS A TOOL FOR OPTIMIZING RESOURCE USE IN SPECIALIZED AUTOMATED CONTROL SYSTEMS

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Modern specialized automated control systems require high reliability and performance under conditions of intensive data processing. However, an analysis of current resource usage shows that computational capacities are often underutilized, leading to reduced efficiency and increased risk of system failures. Traditional approaches to resource management are not sufficiently flexible to meet the demands of dynamic and critical operations.

One promising solution is the implementation of virtualization technologies, which enable more efficient allocation of computational resources and improve system responsiveness. The use of hypervisors allows multiple virtual machines to operate on a single physical server, enhancing workload distribution and reducing hardware dependency. Containerization technologies, such as Docker and orchestration platforms like Kubernetes, enable lightweight, scalable deployment of applications and ensure rapid adaptation to changing operational requirements.

Additionally, software-defined networks (SDN) enhance the flexibility and control of data flows within the system, enabling optimized communication between components. The integration of these technologies supports continuous system operation under increased loads and minimizes downtime, even during peak performance periods.

Thus, the adoption of virtualization technologies in specialized automated control systems significantly improves the efficiency of computing resource utilization, enhances system reliability, and provides the necessary flexibility to respond to evolving operational demands.

PROPOSALS FOR IMPROVING THE EFFICIENCY OF CLIENT-SERVER SPECIALIZED SOFTWARE THROUGH THE USE OF SPATIAL DATABASES

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Modern military information systems rely on client-server architecture to ensure efficiency in distributed software complexes. As data volumes grow, optimizing processing and storage is crucial for operational analysis and decision-making in combat conditions. High system loads, accuracy demands, and compatibility challenges require robust solutions.

A key factor in improving system efficiency is database optimization. Selecting the right DBMS, structuring data for fast access, and integrating query optimization techniques reduce computational costs and enhance performance. Advanced processing tools and optimization algorithms strengthen analytical capabilities.

Spatial databases are particularly valuable in this context. PostgreSQL with PostGIS enables deep spatial analysis and seamless integration with operational data streams. Efficient query planning, indexing, and a rich set of spatial functions accelerate complex computations, while multi-version concurrency control supports large-scale collaborative operations.

PostgreSQL/PostGIS applications in military systems demonstrate high efficiency in processing spatial data for critical scenarios such as radar coverage modeling, security assessments, and geospatial data integration. Ongoing technological advancements will further refine operational analysis and strategic decision-making in combat environments.

APPROACH TO ENSURING EFFICIENT ROUTING UNDER ADVERSARIAL DISRUPTIVE CONDITIONS

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The task of ensuring effective routing in special-purpose information and communication networks is associated with solving a number of complex challenges: the need for rapid route recovery after link loss, minimization of control traffic volume under frequent topology changes, and adaptation to limited computing resources and communication channels in field conditions. A particularly difficult challenge is ensuring stable network operation under conditions of system degradation – loss of nodes, communication lines, or their radio-electronic suppression by the adversary.

Classical routing algorithms, such as Dijkstra, A*, Bellman-Ford, and Floyd-Warshall, despite their widespread use and theoretical efficiency, exhibit significant limitations in dynamic networks affected by external destructive factors. Among modern adaptive pathfinding algorithms, D* Lite stands out as it is capable of efficiently performing localized route updates without requiring a complete reconstruction of the topological tree. An enhancement of the OSPF routing protocol is proposed by combining Dijkstra's algorithm, which is natively used by OSPF, with the algorithmic core of D* Lite.

A software model has been developed that combines network interaction simulation and testing, enabling a comprehensive comparison between the classical OSPF routing protocol (based on Dijkstra's algorithm) and the proposed adaptive solution OSPF* (which uses the D* Lite algorithmic core). Simulation results confirmed that OSPF* significantly reduces route recovery time after link failures, decreases control traffic volume, and ensures stable data transmission even under conditions of node or link loss compared to the classical approach.

DECISION SUPPORT FOR CYBERATTACK DETECTION BASED ON FUZZY COGNITIVE MODELLING

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Fuzzy Cognitive Modeling (FCM) is a method for analyzing complex, weakly formalized systems by combining cognitive mapping and fuzzy logic. The core of the method is a cognitive map, where nodes (concepts) represent key factors and links describe causal influences with weights in the range [–1; 1]. These weights may come from expert assessments or statistical data, allowing for modeling even when precise quantitative inputs are lacking.

FCM excels at processing incomplete, ambiguous, or dynamically changing information, making it ideal for cyber threat modeling, where scenarios evolve rapidly and involve hidden interactions. It enables threat development simulations, vulnerability assessments, and identification of critical influence points.

Amid Russia's war against Ukraine, where cyberattacks are part of hybrid aggression, FCM helps model interlinked technical, informational, and societal factors. For example, a map might show how bot activity, phishing campaigns, load on government servers, and social panic are interconnected – allowing for proactive response strategies.

Thus, FCM serves as an effective decision-support tool in cybersecurity under wartime conditions, offering comprehensive analysis, flexibility, and adaptability.

IMPROVING THE RELIABILITY OF DATA WAREHOUSE INFORMATION AT THE DESIGN STAGE

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When analyzing the information requirements of users and structuring the subject areas of a database, errors occur when there are undetected synonyms and homonyms of information elements, certain unaccounted-for elements and relationships between them, when the relationships between information elements are misunderstood; when subject area restrictions are not taken into account, as well as data integrity restrictions and relationships between them; when information elements that ambiguously identify data groups are selected as keys, and for other reasons. The presence of errors in the analysis of users' information requirements, respectively, leads to errors in the selected canonical database structure.

When implementing the successive stages of designing the canonical, logical and physical structures of a database, which are considered as processes of mapping one structure to another, the main errors are inadequate and incomplete reflection or loss of information elements and relationships, inadmissible combining of elements into records or files, in the structures of which it becomes impossible to implement separate access paths. Therefore, one of the main requirements for data structures when they are displayed is the requirement to ensure maximum completeness of storage of the types of information elements, data groups and links between them identified in the subject area.

The sources of errors in the input information are end users and employees of the database administrator service, limited reliability of technical means of data preparation and technical information carriers. Errors in the specifications of user queries are related to the incorrect use of data description and data manipulation languages, query languages, errors in data search and update algorithms, and the lack of data control and protection tools.

RECOMMENDATIONS FOR CHOOSING A DATA SYNCHRONIZATION METHOD IN DISTRIBUTED CRITICAL PURPOSE SYSTEMS

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Accurate data synchronization in distributed critical purpose systems, such as military or telecommunications networks, is critical to ensuring their reliability and efficiency. The lack of consistency in time parameters between nodes can lead to data transmission failures, disruption of coordination of operations, or complete loss of system functionality. Highly accurate synchronization is necessary to support the operation of modern technologies, such as LTE/4G, where even minimal time discrepancies can cause significant errors. This emphasizes the importance of choosing effective synchronization methods to ensure the stability of critical systems.

The NTP and PTP protocols, as well as the timesync and UniChron libraries, provide different levels of synchronization accuracy. NTP achieves 1–2 ms on local networks and 10 ms on global networks, but does not meet the requirements for high-precision systems, while PTP guarantees sub-microsecond accuracy (20–100 ns on LANs) thanks to hardware timestamps. The timesync library minimizes the impact of network jitter, providing millisecond accuracy, and UniChron offers sub-millisecond accuracy for distributed databases. For critical purpose systems, including multi-service networks of the Armed Forces of Ukraine, it is recommended to use PTP with boundary clocks and transparent switches to achieve the sub-microsecond accuracy required for LTE/4G. The integration of timesync provides jitter resistance, and UniChron provides efficiency in unstable conditions with sub-millisecond accuracy. In combat conditions, it is advisable to use redundant synchronization sources, such as atomic clocks, and cryptographic protection of timestamps. The combination of PTP and timesync increases the flexibility and reliability of synchronization.

MATHEMATICAL MODEL FOR COLLECTING AND ANALYSING REPORTING DATA IN A NETWORK ENVIRONMENT

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The growth of data volumes in modern networks causes congestion of communication channels, which complicates the processes of monitoring, managing and planning network traffic. As a result, there is a need for a simple but informative model that allows us to analyse the basic properties of data flows without the need for deep technical knowledge.

Network traffic is characterised by uneven packet transmission, periods of activity and inactivity, and statistical distributions with "heavy tails". These features make it difficult to apply classical models and require taking into account the fractal properties of traffic.

During the mathematical modelling, the used approach waййййй1s based on fractal self-similarity and key statistical parameters: average interval, dispersion and autocorrelation. This allows us to describe the general behaviour of traffic without excessive detail.

The data for the analysis was collected by using a simple testbed based on WireShark and MATLAB. Video and torrent traffic was analysed with an aggregation window of 0.5–1.0 seconds, which allowed to record the dynamics of changes in packet intervals.

The analysis showed that the distribution of packet intervals has lognormal features, as well as the presence of short-term autocorrelation in video streams. This shows the potential of using simplified models for basic traffic estimation.

In summary, the model based on average characteristics and fractal features provides an opportunity to quickly assess the state of the network and predict its changes with minimal calculations.

A METHOD FOR ORGANIZING SECURE VPN CONNECTIONS USING WIREGUARD AND QUIC

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The urgency of transitioning to new methods of using VPN connections attracts great attention, as current solutions for security and resilience of networks require new approaches. The main disadvantages of traditional solutions – OpenVPN, GRE in combination with IPSec – are mainly high latency and sensitivity to MTU restrictions, which is critical for mobile or tunneled networks.

The proposed combination of WireGuard and QUIC should solve these problems. WireGuard provides minimal latency, a compact code base, and secure encryption, while QUIC, as the foundation of HTTP/3, encapsulates VPN traffic as HTTPS, providing multiplexing, error correction, 0-RTT, and loss tolerance.

The key idea is to build a bridge in the form of a proxy server that collapses WireGuard traffic into a QUIC stream. At the other end, the client deploys it back, ensuring uninterrupted operation. This architecture allows you to implement fast and adaptive VPN tunnels that can work effectively in unstable connections, small MTU.

In practice, a similar method is used in Cloudflare WARP. This solution also has an open architecture, which allows its adaptation to specific tasks.

Prospects for further research lie in optimizing performance at small MTU and implementing mechanisms for better data protection.

DEVELOPMENT OF A METHOD FOR AUDITING SPECIAL-PURPOSE INFORMATION AND COMMUNICATION NETWORKS BASED ON DEEP PACKET INSPECTION (DPI)

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Monitoring network devices using statistical data in special-purpose information and communication networks is an important tool to ensure their safety and efficiency. In this work, a monitoring method was developed using Deep Packet Inspection (DPI) technology. This method helps analyze network traffic on all levels of the OSI model. It checks packet headers, content, and finds problems.

The monitoring algorithm supports multi-threaded packet processing, rebuilding fragmented data, and analysis of IPv4, IPv6, TCP, UDP, ICMP, HTTP, FTP, DNS, and TLS protocols. It collects data such as latency, traffic volume, number of packets per session, and IP geolocation using GeoIP. The adaptive device management method based on this data helps find possible threats, like low TTL or strange session behavior, which could mean unauthorized access or attacks.

Research shows that the proposed method can detect anomalies even in encrypted traffic, which is very important for special-purpose ICNs. Using parallel processing and protocol filtering reduces system load and improves performance. However, more improvements are planned: support for more protocols; recognizing data formats and application signatures; detecting suspicious domains in DNS automatically; and generating PDF reports.

These improvements will help build a complete adaptive management system that increases security and stability of special-purpose ICNs by quickly reacting to threats and optimizing network resources.

ANALYSIS OF THE METHOD FOR INCREASING THE STABILITY OF UAV CONTROL IN COMPLEX INTERFERENCE ENVIRONMENT

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The analysis of the conduct of hostilities by the units of the Armed Forces of Ukraine showed that UAVs are used by both sides on a massive scale, and their vulnerability is noted in case of enemy use of radio interference or electronic warfare systems (stations). One of the most vulnerable points in UAVs is the satellite navigation system, which can be easily neutralized (suppressed) by means of radio jamming (radio suppression).

Currently, there are several new approaches to improve the protection of the navigation channel from electronic warfare, including the use of angular measurements of an onboard direction finder operating on a beacon with known own coordinates; the use of software and hardware visual navigation modules using artificial intelligence; and the use of controlled radiation pattern antennas (CRPA).

A CRPA is a device that combines the received signals from several antenna elements to dynamically change the reception pattern by assigning an appropriate weighting to the pattern in the direction of the hostile electronic warfare device and true signals from satellite navigation systems (GNSS).

Based on the analysis of the use of this method, it can be determined that it is advisable to install antennas with a controlled radiation pattern of the CRPA type on board the UAV to improve the protection of satellite navigation systems from jamming and electronic warfare.

PROPOSALS FOR IMPROVING THE RESILIENCE OF TERRESTRIAL VHF RADIOCOMMUNICATION SYSTEMS BASED ON MANET-CLASS MOBILE NETWORKS

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The current conditions of combat operations in the war of Ukraine against the Russian Federation have demonstrated the challenges of information security and the need to ensure reliable communications in critical conditions, which requires constant improvement of radio communication technologies. The architecture of mobile self-organized networks MANET (Mobile Ad-Hoc Networks) demonstrates significant potential for tactical communications due to the ability to operate autonomously without a fixed infrastructure, but requires improvement in terms of resistance to external influences.

Currently, VHF (very high frequency) communication in MANET networks faces a number of significant limitations: vulnerability to ECM (electronic countermeasures), insufficient communication range in difficult terrain conditions, and problems with ensuring quality of service with increasing network load. To overcome these challenges, it is proposed to implement adaptive frequency change mechanisms and optimize routing algorithms taking into account the level of interference and energy efficiency. The use of directional antennas with dynamic control of the radiation pattern will significantly increase the system's noise immunity.

Particular attention should be paid to the development of advanced routing protocols, in particular hybrid solutions based on OLSR (Optimized Link State Routing Protocol) and AODV (Ad-hoc On-Demand Distance Vector), which take into account the energy parameters of nodes. Multipath routing ensures the availability of backup communication channels, and geographically oriented protocols optimize network operation in conditions of complex topography of the area.

To effectively protect against intentional interference, it is advisable to implement signal spread spectrum methods and cognitive radio technologies with automatic detection and avoidance of interference. A promising direction is the use of artificial intelligence algorithms to predict and prevent potential attacks on the network.

Significantly increasing the resilience of VHF radio communications is possible through the integration of MANET with other technologies, in particular satellite communications to expand the coverage area and unmanned aerial vehicles as mobile repeaters. The combination with Internet of Things technologies opens up additional functionality for tactical communications.

Practical implementation of the proposed solutions requires the development of clear technical requirements for VHF radio equipment and a methodology for assessing network efficiency. It is important to formulate recommendations for optimal deployment and configuration of MANET networks, taking into account the specifics of specific application scenarios.

The implementation of the complex of proposed technical and software solutions will significantly increase the stability of terrestrial VHF radio communications in conditions of active countermeasures and a complex electromagnetic environment. Further research should be directed towards the development of self-adaptive algorithms and optimization of power consumption of network nodes to ensure long-term autonomous operation.

IMPROVING THE NOISE IMMUNITY OF OFDM COMMUNICATION SYSTEMS USING CASCADED POLAR/LDPC CODING

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In today's environment, ensuring interference resistance in radio communication systems is of critical importance. One of the promising directions for improving the reliability of data transmission in multipath communication channels is the combination of orthogonal frequency division multiplexing (OFDM) with noise immune coding. Well-known codes include Reed-Solomon, LDPC (Low-Density Parity-Check), and convolutional codes. The so-called polar codes are also used.

LDPC codes demonstrate exceptional performance in broadband channels with large data volumes and are used in a variety of systems, such as 5G NR, Wi-Fi 6, DVB-S2, and Transend 800. The Reed-Solomon code is used in Link 16. Polar codes, on the other hand, are optimal for short blocks and are the basic element of the physical layer in 5G.

The best performance is characterized by cascade coding schemes that combine the Reed-Solomon code with convolutional code or LDPC.

The paper considers the generalized case of using a polar code as an outer code and LDPC as an inner code to effectively separate information protection. In combination with cascade coding, the paper proposes to use spectrum scanning to move to the interference-free region. The periodogram method is chosen as a spectral analysis method.

The simulation performed in MATLAB indicates an increase in the efficiency of the communication system, namely, a decrease in the bit error rate. It is of interest to generalize this scheme in the case of using known approaches to improve the efficiency of communication systems.

IMPROVEMENT OF THE EFFICIENCY OF THE MB-OFDM COMMUNICATION SYSTEM BY USING THE FAST HARTLEY TRANSFORM

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Modern requirements for wireless communication systems and telecommunication technologies, especially in conditions of limited spectral resources and multipath radio wave propagation, indicate the need to find new approaches to improve the efficiency of OFDM technology, which is based on dividing the input data stream into several sub-streams. A promising modification of this technology is Multiband OFDM (MB-OFDM) technology, which has the advantage of increased resistance to intersymbol and interchannel interference due to the ability to dynamically select the optimal frequency band.

MB-OFDM technology is one of the ways to move to ultra-wideband communication systems. However, the implementation of such systems is based on the FFT, which necessitates working with complex numbers. In this paper, we propose the use of the Fast Hartley Transform (FHT), which allows integrating calculations with real numbers and significantly reduces the computational complexity of algorithms. The use of pseudo-random adjustment of the operating frequency with adaptation allows us to allocate free spectrum regions from interference and ensure the operation of the FFT in accordance with the channel conditions.

The study showed that the proposed approach reduces the computational complexity by about 25-30% as compared to FFT-based methods and improves the system's noise immunity.

Prospects for further research are related with implementation using SDR technology, its application in MIMO systems, in communication systems with dynamic spectra allocation.

IMPROVING THE NOISE IMMUNITY OF DATA EXCHANGE CHANNELS BETWEEN AVIATION PLATFORMS WHEN USED IN THE MODE OF CORRELATED ACTIONS BASED ON EXPERIENCE OF THE RUSSIAN-UKRAINIAN WAR

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The analysis of combat operations conducted by the Armed Forces of Ukraine confirms the importance of the mass deployment of unmanned aerial vehicles (UAVs) from the early months of the active phase of the current armed conflict. At present, Ukraine’s Defense Forces have begun to widely utilize unmanned aerial systems (UAS) and are working on implementing algorithms for UAV operations in a correlated action mode. This technology allows for the simultaneous and effective use of a large number of reconnaissance-strike and reconnaissance UAVs to carry out operational-tactical missions.

Such a method of deployment is considered highly promising and offers practically unlimited potential in the future for the use of UAVs and UAS to gain air and battlefield superiority, conduct effective reconnaissance, and accurately strike ground targets with minimal material and human losses.

In these systems, UAVs employ various communication channels, typically operating at 2.4 GHz or 5.8 GHz frequencies, to provide coordinate correction, real-time data exchange, and control over each aerial vehicle, enabling operations in correlated action mode. The main issue with using these frequencies is the high vulnerability of radio communication channels to enemy electronic warfare (EW) systems.

The use of optical communication channels between aerial platforms – both manned and unmanned – that operate in correlated action mode represents a promising direction for achieving fast, reliable, and jamming-resistant data transmission. Optical links can provide efficient data exchange and accurate spatial correction of UAV positions due to their high transmission speeds and insensitivity to the emission spectrum exploited by EW and electronic countermeasure (ECM) systems.

This study explores the prospects for the use of optical communication channels, presents calculations of data transmission network parameters, models the impact of ECM and EW systems on data exchange channels between aerial platforms operating in correlated action mode, and substantiates the necessity of using optical communication channels to ensure coordination, data exchange, and control over each aerial vehicle.

DEVELOPMENT OF PROPOSALS FOR INCREASING THE STEALTH OF COMMAND POINTS OF THE ARMED FORCES OF UKRAINE THROUGH THE DEPLOYMENT OF A SEAMLESS WI-FI NETWORK

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In today's warfare environment, information technology plays a crucial role in ensuring the effective management of military operations. An urgent issue in their use is to ensure the secrecy of control points (CPs), which is a key factor in ensuring the life of CPs. One of the promising ways to increase the secrecy and mobility of the control system at the control point is the introduction of seamless Wi-Fi networks capable of providing high mobility in the deployment of the control point. Providing secrecy and data transmission speed and uninterrupted communication at the control points.

A seamless Wi-Fi network, due to its advantages – continuity of communication, configuration flexibility and the ability to deploy quickly – can become the backbone communication infrastructure in the air defence control centre. It should be borne in mind that its use is associated with certain challenges: vulnerability to cyber threats, limited coverage, and the need for careful monitoring and management.

In order to overcome these challenges, we offer secure wireless mesh networks that provide fault tolerance, scalability and security according to standards through the use of mesh topology and two-layer encryption. This will allow you to organise mobile command posts with a high level of protection and autonomy.

SUBSTANTIATION OF PROPOSALS TO INCREASE THE INTERFERENCE IMMUNITY OF RADIO COMMUNICATIONS EQUIPMENT BY USING A REPEATER

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Analysis of the combat experience of the Ukrainian Defense Forces units against the troops of Russia and its satellites confirms the urgency of using ground-based radio communications in the tactical command and control. In these conditions, the enemy constantly uses active and passive jamming technologies to disrupt the data transmission and control system.

The rapid development of unmanned aerial vehicle (UAV) equipment in modern warfare is directly related to the effectiveness of their use, the ever-growing need for improved methods of control, tactical reconnaissance and fire strikes against the enemy.

Among the principles and methods of improving the reliability of ground radio communications, in the conditions of enemy use of VHF networks, the technology of using airborne repeaters to ensure the transmission of voice messages and reliable operation of ground radio networks stands out. This will significantly increase the radius of operation of radio equipment operating in the meter and decimeter bands, improve noise immunity, ensure communication and frequency efficiency of radio channels.

The use of unmanned aerial vehicles as a platform for placing repeaters in the tactical communication system is an effective means of ensuring the control of units directly on the line of combat.

INCREASING THE RESILIENCE OF THE RADIO COMMUNICATION NETWORK TO ENEMY ELECTRONIC COUNTERMEASURES WITH THE HELP OF SILVUS RADIOS

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The experience of combat operations during the repulsion of the armed aggression of the Russian Federation has shown that regular radio communications equipment was not effective enough in countering modern means of electronic arson. In this context, a promising way to improve the efficiency of the control system is to introduce modern foreign-made communication equipment, in particular Silvus radio stations.

Particular attention should be paid to the MANET Interference Avoidance (MAN-IA) functionality. The advantage of MAN-IA is the support of a full-fledged MESH-type network architecture. MAN-IA continuously scans the spectrum within a user-defined frequency range to identify sources of electronic interference and then changes the operating frequency.

Silvus radios provide high bandwidth, which is critical for transmitting real-time video streams and large amounts of data with minimal latency. This level of bandwidth makes it an appropriate choice for integration into UAVs as an airborne repeater to extend network coverage and ensure reliable communication in difficult radio environments.

Thus, the use of Silvus communication equipment significantly increases the survivability, flexibility and efficiency of the communication system of mobile tactical units and allows them to maintain combat capability in conditions of intense enemy electronic warfare.

DEVELOPMENT OF A PROSPECTIVE MODEL FOR THE ORGANIZATION OF AVIATION VHF BAND RADIO COMMUNICATION FOR AIRCRAFT CONTROL AT LOW AND ULTRA-LOW ALTITUDES

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In view of the experience of the russian-Ukrainian war, where the widespread use of enemy air defense and electronic warfare assets forces aviation to operate at low altitudes, an urgent need has arisen to ensure reliable air radio communication and effective control of aerial vehicles.To address this, it is proposed to create a multi-layered, protected, and adaptive communication system that will integrate

UHF/VHF Software-Defined Radios (SDR) utilizing frequency hopping spread spectrum (FHSS), voice message and data encryption. Modern communication technologies and Artificial Intelligence for automated channel management, ensuring real-time data transmission and control under intense interference conditions.

The use of narrow-beam antennas with an electromechanical steering system for precise pointing towards an aircraft. The application of aviation band radio stations with an integrated GSM gateway. The deployment of UAV-mounted and aerostat-mounted relays. Such an approach will significantly improve air radio communication with aircraft crews at an altitude of 50 m and a range of up to 60 km, while enemy EW assets will be less effective in influencing communication means.

DEVELOPMENT OF PROPOSALS TO ENHANCE COMMUNICATION STABILITY FOR A DIGITAL HF RADIO STATION IN MOTION USING NVIS ANTENNAS

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Ensuring stable communication during movement is a critical requirement for modern military radio communication systems. This is particularly relevant for the operation of high-frequency (HF) radio stations, where significant interference exists due to terrain and rapid changes in transmission conditions. A solution to this problem may be the use of a combination of MIMO NVIS technologies (Multiple Input Multiple Output Near Vertical Incidence Skywave).

MIMO (Multiple Input Multiple Output) – a multi-antenna communication technology that can increase data transmission speeds by up to 2.27 times and reduce connection failures by more than 3 times.

NVIS (Near Vertical Incidence Skywave) – a communication technology utilizing near-vertical ionospheric wave propagation. It enables stable communication over distances of 30–250 km, where communication would otherwise be impossible due to the HF communication dead zone.

Therefore, by combining these technologies, it is possible to improve signal quality, reduce the impact of ground-based interference, ensure more stable coverage, increase data transmission speeds. These improvements, in turn, will enhance communication stability during movement.

DEVELOPMENT OF PROPOSALS FOR PROVIDING AIR RADIO COMMUNICATION FOR AIRCRAFT CONTROL IN SPECIFIC COMBAT ZONES AT LOW AND ULTRA-LOW ALTITUDES USING TACTICAL COMMUNICATION NODE

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The combat experience gained during the Russo-Ukrainian war, as well as the specific tactics of Air Force aviation deployment, demonstrate that effective mission execution requires flights at low altitudes. However, this significantly limits the range of air radio communication, which may lead to a loss of control over aircraft.

In modern conditions, alongside reliable voice radio communication, the transmission of tactical information in real time is a key element in the control of aircraft. This is achieved through the use of high-speed data exchange channels both between ground-based aviation control points and between these points and aircraft in flight.

The implementation of advanced electronic communication technologies and modern types of radio stations into tactical communication node (TCN) ensures secure transmission of both voice messages and data, preventing interception or decryption. Such integration enables effective operation even under intense electronic warfare conditions, while the use of JTIDS/MIDS systems with tactical data links (TDL) provides continuous real-time information exchange.

COMPARATIVE ANALYSIS OF THE EFFECTIVENESS OF SPECTRUM SPREADING METHODS UNDER INTENTIONAL INTERFERENCE CONDITIONS

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Interference protection of radio communication systems in the conditions of the Russian-Ukrainian war is achieved through methods that reduce the impact of interference on the quality of information transmission.

The report examines the effectiveness of the main spectrum spreading methods under the influence of intentional interference. The advantages and limitations of direct sequence systems (DSSS), frequency hopping systems (FHSS), and combined solutions in countering intentional interference are analyzed.

Research demonstrates variable effectiveness of spectrum spreading methods in interference countermeasures. DSSS provides better interference immunity against narrowband interference, but degrades under wideband impacts. FHSS systems are more effective against barrage jamming, but vulnerable to adaptive electronic suppression means.

Simulation modeling confirms the advantages of combined methods that integrate DSSS/FHSS with adaptive algorithms and cognitive radio. Such solutions increase interference immunity by 35-40% compared to classical approaches. The implementation of dynamic frequency resource management with artificial intelligence elements ensures a channel availability coefficient of 0.92-0.95 even under intensive interference conditions.

Combined spectrum spreading methods with adaptive machine learning algorithms demonstrate the highest effectiveness in countering intentional interference in conditions of intensive electronic warfare. Further research will focus on optimizing the energy efficiency and performance speed of these systems.

METHODS FOR IMPROVING THE TACTICAL CHARACTERISTICS OF DISPATCH RADAR SYSTEMS FOR LANDING BASED ON THE USE OF COMPLEX SIGNALS

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An urgent issue in ensuring the operation of state aviation is the improvement of the resolution capabilities of DRL landing radar systems. In the context of modern aviation, where the demands for control stability and flight safety are increasing, the enhancement of DRL becomes especially significant.To improve the tactical characteristics of DRL, the use of complex broadband signals is proposed, particularly phase-shift keying and frequency-modulated pulses, which allow for significantly higher range resolution without reducing the energy characteristics of the signal.

Taking into account the use of such signals and the analysis of their parameter influence on detection range, resolution, and interference immunity, the implementation of these signals will enhance the accuracy of aircraft positioning during landing approach, reduce the impact of noise and interference through optimal signal processing, and ensure higher efficiency under conditions of intense air traffic, especially in adverse weather conditions.These signals have a narrow autocorrelation function, which helps to reduce range measurement errors.

IMPROVEMENT OF THE AZIMUTH CHANNEL OF THE SHORT-RANGE NAVIGATION RADIO SYSTEM IN ACCORDANCE WITH INTERNATIONAL STANDARDS

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Due to the aggravation of the military-political situation and active combat use of aviation, modernization of radio equipment, in particular short-range navigation systems such as RSBN-4N, is of particular importance. One of the priority areas is the improvement of the azimuth channel, which ensures accurate orientation of aircraft during landing and combat missions. The study analyzes the principles of azimuth channel construction of domestic and foreign systems, such as TACAN, VOR, DVOR, E-329 and RSBN-4N. It is established that the accuracy of TACAN is five times higher than that of VOR, and that of modern DVOR systems is 10-15 times higher. The highest accuracy is provided by E-329 and RSBN-4N systems, but the latter does not meet ICAO standards, has an outdated element base and limited compatibility with foreign onboard equipment.

The analysis of the RSBN area of operation revealed the presence of an inverted cone dead zone that does not meet international standards. To eliminate this problem and improve the characteristics of the channel, it is proposed to introduce a directional mode of operation. The azimuth measurement accuracy is improved by reducing the scale factor and optimizing technical parameters. The improved system includes ground and onboard equipment that provides stable azimuth determination based on the phase method. The introduction of the new short-range navigation system will improve the efficiency and safety of navigation support for combat flights, ensuring compliance with international requirements

ANALYSIS OF THE CURRENT STATE AND TRENDS IN THE DEVELOPMENT OF STEALTH RADAR SYSTEMS OF AIRCRAFT LANDING

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The radar system of landing aircraft is a critical element of ensuring flights of state aviation, especially in difficult weather conditions and limited visibility. However, in the current military threats, these systems become a potential target for the enemy, since their radiation is easily detected by electronic means of intelligence. The increase in stealth is an important factor in ensuring the combat capabilities of radar facilities (radar). The main problems of using RLS are fixed location and lack of protection from electronic suppression (RAP). Among the modern solutions to increase the secrecy, we can distinguish the following areas: Reducing energy visibility (adaptive power control), using broadband or tunable signals, using stealth antennas and reducing the duration of active radiation. In addition, an important role is played by imitation tools – fake MLRs that distract the enemy's means. Trends in the development of raliolocational landing systems include mobility, modularity, digital signal processing using concealment algorithms, integration with artificial intelligence and deep interaction with other elements of the air traffic control system. The development of stealth radar systems landing aircraft is an urgent problem of today, which combines engineering, software and tactical solutions to improve stability and efficiency in today's threats.

RESEARCH OF RADIO APPROACH SYSTEMS OF ILS AND MLS TYPE

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The study of radio-based approach systems, in particular ILS (Instrument Landing System) and MLS (Microwave Landing System), is relevant in the context of growing requirements for air traffic safety and efficiency.

Radio-based approach systems such as ILS and MLS are a set of ground-based and onboard radio devices that provide aircraft with the information necessary to control them during the approach and landing process. The growth in air traffic intensity necessitates the improvement of automatic landing systems.

The need to improve existing ILS is caused by their inherent shortcomings and limitations: the ability to provide only one landing trajectory and unsuitability for aircraft with vertical takeoff and landing; small size of sectors within which the dependence of information parameters on the deviation of the aircraft from the nominal landing trajectory is ensured, which limits the airfield capacity; relatively large overall dimensions of the antenna systems; significant influence of the earth's surface on the quality of the systems' functioning; small number of frequency channels; inability to select the optimal landing trajectory directly on the aircraft itself; inability to use in mountainous terrain.

The analysis of the two systems shows that ILS, being a time-tested technology with a strong infrastructure base, is still limited in providing flexible navigation, which is important in the modern aviation environment. At the same time, MLS, while having a number of technological advantages, is not widely used due to the significant financial costs associated with modernizing airports and equipping aircraft.

PROPOSALS FOR INCREASING INFORMATION PROTECTION AND MONITORING OF FIBRE OPTIC COMMUNICATION LINES

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The use of fibre-optic communication lines (FOCLS) to build trunk and local communication networks has made it possible to meet the needs of government and departmental organisations, companies and private users in providing electronic communication services. The ability to access the information transmission network is important for the functioning of military communication networks, which are built mainly using optical cable communication lines.

Fibre-optic communication is not as secure as it is commonly perceived. There are several known methods and technologies for obtaining (inputting) information from (into) FOCLS without physically damaging the cable or cutting the optical fibre, connecting it to listening equipment, and then connecting it to the communication line. Controlling the health of FOCLS and monitoring the transmission of data flows is an urgent research task, since detecting the fact of connecting or tapping an optical fibre is a rather complex software and hardware task.

Proposals to improve the security of information transmitted via fibre-optic communication lines:

– traffic encryption, use of IPSec, MACsec and TLS protocols to protect data;

– physical access control – protection of cable channels, equipment, wells, couplings from unauthorised access;

– installation of systems for detecting signal interception in fibre (e.g. changes in signal strength, delay, etc.);

– monitoring of optical parameters – measurement of optical signal characteristics in real time.

RESEARCH OF ACCESS NETWORK TECHNOLOGIES AND DESIGN OF A SUBSCRIBER NETWORK BASED ON PON TECHNOLOGY

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The subscriber access network provides both physical and logical connection of the end user (subscriber) to an electronic communication network – either public (such as the Internet) or private (corporate, service-based, or with restricted access) – and enables the delivery of telecommunications services such as data, voice, video transmission, etc.

Fiber-optic access means that end users are connected to telecommunications equipment at a network node via fiber-optic lines. Depending on how close the fiber is laid to the user, access can be categorized as FTTB (Fiber to the Building), FTTP/FTTH (Fiber to the Premises/Home), among others – all collectively known as FTTx broadband network technologies.

In an Active Optical Network (AON), active network devices (switches, routers, multiplexers) are used to distribute the optical signal, ensuring that traffic is delivered directly to the intended recipient. This configuration implements a point-to-point optical connection.

In a Passive Optical Network (PON), which uses a point-to-multipoint topology, active equipment is located at central nodes and at the end user's premises. Optical signal distribution is achieved using a fully passive component – an optical signal splitter.

The further evolution of PON includes technologies such as GPON, EPON (Ethernet PON), GEPON (Gigabit Ethernet PON), WDM-PON, XG-PON, 10G-PON, and several others.

DEVELOPMENT OF PROPOSALS FOR THE USE OF TROPOSPHERIC COMMUNICATION MEANS

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At present, the communication nodes of command posts of units (subunits) of the Armed Forces of Ukraine located in the areas of combat operations are connected to the information and communication network of the Armed Forces of Ukraine mainly through the use of satellite communications. It should be noted that satellite communications services are provided by commercial (private) companies. As an alternative (backup) data transmission system, it is appropriate to use tropospheric communication equipment based on small-sized, digital, high-speed tropospheric communication terminals for organising data link and transmission lines.

The report substantiates proposals on the options for the use and modes of operation of tropospheric communications equipment on trunked, unified communication lines under the influence of enemy electronic jamming (EW). To combat the freezes that occur in the operation of tropospheric communications, it is proposed to use a fourfold spatial spread of the signal using one transmitting and receiving mirror antenna with two irradiators that form two beams each.

One of the priority areas for the development of tropospheric communication systems and equipment is the development, production and equipping of small-sized, noise-proof, software-controlled, digital tropospheric communication stations (terminals) for the communication and information systems of the Armed Forces of Ukraine.

METHODS OF IMPROVING THE NOISE IMMUNITY AND MODERNISATION OF THE SECONDARY CHANNEL OF CONTROL RADARS IN A COMPLEX ELECTROMAGNETIC ENVIRONMENT

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Radar landing systems (RLS) play an important role in ensuring flight safety. In the conditions of intensive use of electronic jamming (EW), there is a growing need to improve the noise immunity and secrecy of the secondary channel of the DRL-10MA (-ML) system. In the course of the analysis, it was found that the main technical shortcomings of the existing secondary radar system of control radars include a limited operating frequency range, lack of mechanisms for adaptive adjustment under the influence of electronic jamming means, and insufficient sensitivity of the receiving paths in an interfering environment.

The paper proposes a set of engineering and technical measures to improve the noise immunity of the secondary channels of modern RSs: introduction of adaptive phased array antennas with the ability to form zero directivity patterns to interference sources; implementation of pseudo-random frequency hopping (FHSS) to increase resistance to active interference; use of coherent digital signal processing methods and adaptive filtering algorithms; application of cryptographically secure request-response protocols to counteract simulated influences. The directions of technical modernisation of DRL-10MA (-ML) are substantiated: application of highly sensitive receiving paths with low-noise amplifiers; expansion of the frequency range of the secondary channel; automatic optimisation of the parameters of the system devices in a complex electromagnetic environment.

DEVELOPMENT OF PROPOSALS TO IMPROVE THE OPERATIONAL CAPABILITIES OF THE SYSTEM OF OBJECTIVE CONTROL OF GROUND-BASED COMMUNICATIONS AND ELECTRONIC WARFARE BASED ON THE EXPERIENCE OF THE RUSSIAN-UKRAINIAN WAR

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The relevance of the topic is due to the need to increase the stability and efficiency of the objective control system (OCS) in wartime, in particular, during attacks by enemy electronic means.The war in Ukraine has demonstrated the critical importance of constant monitoring and rapid diagnostics of the state of ground-based communications and radio equipment to ensure the continuous operation of air traffic control systems.

The main threats to ATC in wartime are disruption of communication channels, physical damage to equipment, cyber threats and electronic warfare (EW).The experience of combat operations has shown the need to create mobile (portable) objective control posts capable of operating autonomously in the face of loss of stationary infrastructure.

It is proposed to integrate the OCS with digital telemetry and remote control systems, which will ensure remote detection and elimination of failures, even if physical access to the equipment is lost.

In order to increase the system's resilience, it is recommended to duplicate key elements of the SOC, as well as to introduce secure and redundant data transmission channels.

The war experience has confirmed the need for regular training of personnel on how to act in conditions of electronic suppression and loss of communication.

The modernisation of the JFC should be carried out with due regard to the principles of cyber resilience, modularity and rapid adaptation to changes in the operational situation

DEVELOPMENT OF PROPOSALS FOR IMPROVING THE INFORMATION DISPLAY EQUIPMENT OF THE AIR TRAFFIC CONTROL RADAR AT FLIGHT CONTROL WORKSTATIONS

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Improving the information display equipment of air traffic control radar systems at flight control workstations is a key factor in enhancing the efficiency, reliability, and safety of air traffic management. Modern challenges associated with the intensification of aviation traffic demand high accuracy, promptness, and convenience in the visual representation of radar information. The modernization of display technologies not only improves data processing quality but also reduces the workload on air traffic controllers, enabling a faster response to emergency situations. Based on the analysis of current trends and technologies, the following directions for equipment improvement are proposed. Implementation of multifunctional high-resolution monitors. This will improve the detail of the air situation display and allow for the simultaneous presentation of various types of information – radar, meteorological, and navigational.Use of touchscreens and adaptive interfaces.Integration of intelligent situation forecasting systems. Automatic air traffic analysis systems can warn about potential conflicts between aircraft, forecast the development of situations, and provide the controller with decision-making options.The implementation of these measures will significantly enhance the quality of air traffic control, reduce the risks associated with human factors, and increase the overall level of flight safety

IMPROVEMENT OF THE LONG-RANGE CHANNEL OF THE RADIO NAVIGATION SYSTEM OF SHORT-RANGE NAVIGATION

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At present, the main system of this type in the Air Force of Ukraine is and remains the RSBN-4N beacon. RSBNs are designed to provide close navigation, inter-aircraft navigation and landing of aircraft in simple and difficult meteorological conditions. The navigation parameters of short-range navigation systems – azimuth and range – are determined on the aircraft relative to the radio navigation point (RNP) where the beacon is located. Given a known flight altitude, this data is sufficient to determine the position of the aircraft in space. In other words, short-range navigation systems belong to the class of angle-measuring, range-finding or azimuthal-far-finding systems.

One of the key components of such systems is the range-finding channel, whose function is to determine the distance between the aircraft and the ground beacon. The accuracy, reliability and speed of the rangefinding channel significantly affect the efficiency of the entire navigation system.The distance from the aircraft to the ground radio beacon is determined by a pulse-type radio rangefinder (which operates on the request-response principle) by measuring the total propagation time of the request signal from the aircraft to the ground radio beacon and the response signal from the ground radio beacon to the aircraft. The key areas for improving the rangefinder channel are the use of broadband signals, which ensures high accuracy of distance measurement and reduces the impact of interference, implementation of digital processing methods, in particular, correlation analysis of signals, which improves resolution and noise immunity.

DEVELOPMENT OF PROPOSALS FOR IMPROVEMENT OF THE AZIMUTHAL CHANNEL OF THE RADIO-TECHNICAL SYSTEM OF SHORT-RANGE NAVIGATION IN THE CONDITIONS OF COMPLEX JAMMING ENVIRONMENT

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Radio-technical systems of short-range navigation are designed to determine navigation parameters that characterize an aircraft's position in a polar coordinate system (azimuth, range) relative to a radio navigation beacon (RSBN ground station) with precisely known coordinates.

The RSBN-4N system plays a critical role in providing accurate orientation and navigation for aircraft of the Ukrainian Air Force. Under constant exposure to both active and passive jamming, particularly during combat operations, the system's effectiveness is significantly degraded. The azimuth channel is one of the most jamming-vulnerable components of the RSBN-4N. The current anti-jamming methods implemented in the system are not always sufficiently effective and rely on obsolete hardware components, highlighting the need to develop new approaches to enhance the azimuth channel's jamming immunity.

Modern technologies enable substantial improvements in jamming resistance through advanced hardware and software solutions for distinguishing useful signals from active and passive interference. However, successful modernization requires precise identification of which specific electronic components and technological solutions should be implemented.

IMPLEMENTATION OF IMPROVEMENT OF THE EQUIPMENT FOR DISPLAY OF THE LANDING RADAR INFORMATION AT THE WORKING PLACES OF THE FLIGHT MANAGEMENT GROUP

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At present, in our country, in the context of Russia's armed aggression against Ukraine, radio communications support (RCS) for state aviation flights is widely used. Modernisation and improvement of the avionics system is one of the main tasks of the Air Force development, which involves the introduction of modern information display equipment.

Taking into account the above, the following measures to improve the RCS system can be identified:

reservation of equipment for workplaces of the flight control group;

procurement and re-equipment of airfields with the latest remote means of collecting, processing and displaying information (ACDP, equipment of the Tsyfra-R software and hardware complex), which will ensure high reliability, information content and improvement of the tactical characteristics of the RCS system;

use of mobile equipment for remote indicators, including in protected areas;

the introduction of a digital radar modem (DRM) that converts an analogue video signal into a digital format for further processing and display of information;

the implementation of a network structure with client terminals connected to a local information network for displaying digital radar information.

The implementation of the proposed measures will create a modern, efficient and safe system for displaying information at the workplaces of the flight control group.

DEVELOPMENT OF PROPOSALS TO IMPROVE THE STEALTH OF THE AIRPORT RADIO STATIONS

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Having analyzed the experience of combat operations acquired during the repulsing of armed aggression of the rf application, the systems of electronic suppression have acquired, which make it impossible to perform combat tasks of the state aviation of Ukraine, which significantly affect the quality of management and safety of flights. Therefore, for the further effective use of radio navigational systems, it is advisable to increase the secrecy of the airlift radio station PAR-10, which is used in the air forces of the Armed Forces of Ukraine. For more effective use of the Emergency situations Service, it is possible to define several organizational and technical methods of increasing the secrecy of the drive airfield radio station, one of the effective solutions is the transition from a permanent to a situational mode of operation, when the transmitter is activated only in the case of following the aircraft in the PARn zone of action. This significantly reduces the radiation time and the probability of technical detection. It is also advisable to mask elements of the antenna system with the help of radio-absorbing materials or dual-purpose structures. Reducing the power of the transmitter at night or in low visibility conditions reduces the radius of technical detection of the station without losing its functionality. The modernization of the station with the introduction of a narrow-band frequency conversion and imitation of civil signal formats is relevant. This makes it difficult to identify the station as a military facility. It is also promising to use the reservation of navigation information through the use of alternative sources (for example, GBAS), which will improve the reliability of functioning in difficult conditions of electronic warfare. The proposed measures can be implemented in stages, taking into account the available technical resource, and significantly increase the secrecy and stability of PAR-10.

METHOD FOR IMPROVING THE SECRECY OF THE EMERGENCY 21ST COMMUNICATION CHANNEL

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After analyzing modern powered airfield radios (PAR) used to support the flights of the state aviation of Ukraine, it can be concluded that the operation of the emergency 21st communication channel requires secrecy of the information channel of the powered airfield radio (PAR) by using pseudo-random signals, taking into account the influence of electronic warfare and intelligence of the enemy

Based on the analysis of existing approaches to improving signal concealment in the conditions of radio reconnaissance and radio countermeasures, a method of signal masking and binary message recovery in a 21-way channel is proposed. The key requirements for a receiving device for working with pseudo-random signals are outlined.

Particular attention is paid to the use of nonlinear dynamics methods to increase the secrecy of transmission, in particular, to reduce the probability of signal detection by approaching the parameters of white noise. For this purpose, it is proposed to use analytical chaotic sequences, the creation and analysis of which is based on the study of attractors using nonlinear dynamics methods. It has been determined that signals generated through analytical chaotic processes are practically impossible to detect or decipher, which significantly increases the level of secrecy of the 21-way channel.

According to the results of modeling the algorithms for generating pseudorandom signals and recovering a binary message, it is established that the methods and signals used provide an improvement in the security of the PAR-ARC system.

DEVELOPMENT OF PROPOSALS FOR IMPROVEMENT OF THE AZIMUTHAL CHANNEL OF THE rADIO-TECHNICAL SYSTEM OF SHORT-RANGE NAVIGATION IN THE CONDITIONS OF COMPLEX JAMMING ENVIRONMENT

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In response to the increasing demands for accuracy and reliability of navigation systems in aviation, as well as in accordance with ICAO standards, there is a growing need to modernize the transmitting devices of the azimuth channel in ground-based equipment of short-range navigation systems. One of the key directions involves upgrading the component base – specifically, replacing outdated analog components with modern digital modules. This allows for enhanced stability of signal parameters, reduced noise levels, and adaptation to changes in the external environment. Another critical direction is the implementation of advanced signal modulation methods (e.g., phase or frequency-pulse modulation), which ensure higher resistance to interference and improved azimuth angle determination accuracy. Compliance with international ICAO standards enables the adaptation of the modernized device to global aviation safety requirements.The proposed solutions aim to enhance the operational efficiency of ground-based navigation equipment, which is a critical factor in ensuring accurate aircraft landing approaches, particularly under adverse weather conditions.

DIRECTIONS OF IMPROVEMENT OF THE SYSTEM OF REMOTE CONTROL OF RADIO TECHNICAL SUPPORT OF STATE AVIATION FLIGHTS

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The current systems (means) of radio technical support (RTZ) for state aviation flights in Ukraine do not meet NATO and ICAO standards for remote control (RC) systems, which creates obstacles to the use of aircraft from member and partner countries and other modern aviation equipment. The problems of improving the remote control system by means of RTZ are caused by the use of outdated field cables such as P-274 and P-270 with low transmission speed, high vulnerability to electromagnetic interference and the need for constant maintenance. The existing telecontrol and telecommunication systems (TCTS) use different coding principles, which complicates their integration and automation.

The solution to improve the remote control systems of RTW means is the introduction of fiber-optic communication lines that provide high transmission speed, interference protection and signal stability, integration of Tsifra-R equipment to ensure compatibility of digital and analog systems, and the use of automated command and control centers for centralized control. It is proposed to improve the TU-TS equipment (to harmonize signal formats, introduce digital data processing technologies, increase resistance to external influences), which will ensure secure communication, redundancy of key elements). The use of TACAN beacon remote control units and the TTLS system will increase the efficiency and reliability of the TTS system and will contribute to improved management and personnel safety.

DEVELOPMENT OF THE WEB APPLICATION "LEGAL SUPPORT SERVICE FOR MILITARY SERVANTS AND THEIR FAMILY MEMBERS"

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In the current conditions of a full-scale war in Ukraine, the need for fast and affordable legal support for military personnel and their family members is growing. A web application can become an effective tool for legal assistance in a remote format, especially for people from remote regions or people who cannot personally attend an offline meeting. The architecture and implementation of the web platform "Legal Support Service for Military Personnel and Their Family Members" is proposed, which provides the ability to create applications, receive consultations and interact with lawyers in real time. The application implements personalized accounts for users, provides role processing (user, manager) and storage of consultation history.

The technical implementation is based on modern web technologies: Node.js, Express and PostgreSQL are used for server logic. Particular attention is paid to data security according to OWASP recommendations, as well as accessibility according to WCAG. The service has the potential for scaling, integration with government resources and further expansion of functionality.

Thus, the web service is an effective digital tool that provides timely, accessible and convenient legal support to military personnel and their family members. Clear logic, user-friendly interface, separation of user roles and thoughtful functionality make the system practically meaningful and easy to use, as well as scalable.

USING BLOCKCHAIN TECHNOLOGIES FOR NETWORK AUTHENTICATION

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Blockchain technologies are an effective tool for ensuring reliable and secure authentication in computer systems. They create a decentralized platform that is based on cryptographic methods, including digital signatures and consensus algorithms (Proof-of-Work, Proof-of-Stake), as well as self-sovereign identity (SSI) mechanisms for access control.

In military operations, blockchain plays a key role in providing authentication protection between command centers, units and critical home systems. The technology creates attack-resistant identification systems that counteract the interception of credentials and identity falsification. For example, blockchain-based SSI allows for the rapid and secure verification of mobile military groups in combat conditions.

Blockchain effectively protects strategic network nodes, such as command centers or satellite communication systems, eliminating dependence on centralized servers. Lightweight consensus protocols provide energy-efficient identity verification in tactical networks, which is especially important in field conditions.

During cyberattacks, blockchain technologies, in particular smart contracts with cryptographic authentication, neutralize threats such as unauthorized access or data manipulation. Zero-knowledge proofs guarantee identity confirmation without transmitting confidential data, significantly increasing the protection of national cyberspace from hostile actions.

DIRECTIONS OF IMPROVEMENT OF TRANSMITTING DEVICES OF CONTROL RADARS OF RADAR LANDING SYSTEMS

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Dispatch radar (DRS) is designed to provide flight control group personnel with radar and radio direction finding information in order to regulate the movement of aircraft in the near zone of the airfield.

To improve the transmitting devices of the radar landing systems, the following is proposed: replacement of tube (magnetron) generators with solid-state (semiconductor) generators, which reduces the size of the device, increases its reliability and reduces power consumption: optimization of signal modulation (use of modern modulation methods, such as pulse-code or frequency-pulse signals), which increases the resistance of sensing signals to interference and improves the separation of objects: adjustment of pulse parameters (change of time Improving the efficiency of signal transmission directly affects the accuracy of detection, identification and tracking of airborne objects.

Improving the transmitting device of the control radar is a prerequisite for increasing flight safety and reliability of airspace control systems.

RESEARCH OF FACTORS INFLUENCING NETWORK PERFORMANCE

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In today's digital environment, the performance of computer networks is a critical factor in ensuring the efficient operation of information systems. A variety of factors, such as hardware, network configuration, software, and external influences, can have a significant impact on data transfer rates, latency, and overall network stability.

The main factors affecting network performance include: bandwidth, latency, traffic congestion, and the quality of the equipment (routers, switches). In addition, software aspects, such as inefficient data transfer protocols, incorrect configuration of network settings, or insufficient protection against cyber threats, have a significant impact, which can lead to network congestion.

Various methods are used to analyze and optimize network performance, including monitoring network traffic, modeling and simulating network processes, and using intelligent algorithms. The latter include machine learning (ML) methods for predicting peak loads, detecting traffic anomalies, and optimizing routing. A promising area is the development of adaptive network management systems that can respond in real time to changes in the network environment and automatically optimize its parameters.

Thus, the study of factors affecting network performance and the introduction of intelligent methods for their optimization are key to ensuring the reliability and efficiency of modern information systems in the face of growing demands on network infrastructure.

RESEARCH OF ROUTING PROTOCOLS IN COMPUTER NETWORKS

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Routing protocols in computer networks are one of the key components of modern communication systems, designed to ensure fast and secure data transmission. They form an integrated platform that combines algorithms such as OSPF (Open Shortest Path First) for calculating the shortest paths, RIP (Routing Information Protocol) for simple networks, BGP (Border Gateway Protocol) for global connections.

In military conflicts, routing protocols such as OSPF and BGP play a critical role in ensuring seamless communication between command posts and units. Their applications cover a wide range of scenarios, including protecting against route poisoning attacks on infrastructure, providing communications for mobile military columns via EIGRP (Enhanced Interior Gateway Routing Protocol), and coordinating operations on the front lines using rapid OSPF convergence.

These protocols can be effectively used to protect strategically important network nodes, such as command centers, where BGP provides routing between different military networks, or satellite communication systems, where OSPF quickly adapts to topology changes. They can also guarantee stable connectivity for mobile units, using energy – efficient RIP in small tactical networks, and forward operating points located in a war zone.

Additionally, in the event of an adversary cyberattack, routing protocols such as BGP with RPKI (Resource Public Key Infrastructure) support can be used to neutralize threats, such as traffic interception or route spoofing that pose a threat to one's own systems. OSPF with authentication mechanisms can also provide protection for national cyberspace from aggressive actions by hostile hackers or illegal entities.

RESEARCH OF VULNERABILITIES IN COMPUTER NETWORKS

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The number of hacker attacks worldwide is increasing every year. Continuous research into vulnerabilities in computer networks enhances the prospects for reducing cyberattacks and ensuring information security. Currently, the most common cyberattacks include DoS (Denial of Service), Man-in-the-Middle, malware, fileless attacks, and phishing. There are several methods for detecting, blocking, and preventing attacks. The first and most widespread method is detecting prolonged attacks. The second approach is to prevent attacks before they are executed. The third method involves detecting and preventing repeated attacks.

Thanks to these detection methods, it is possible to counter vulnerabilities using the following approaches: traffic analysis – monitoring network data to identify anomalies, for example, using tools like Wireshark; port scanning – identifying open (unprotected) ports in a network that could serve as entry points for vulnerabilities; network testing – simulating cyberattacks on a system and assessing its resilience to identify weak points; audit – verifying the configuration of network equipment and software against security standards; host-based attacks – targeting a specific network node; network-based attacks – targeting an entire network or a network segment.

Based on the conducted research, security guidelines can be proposed, such as mandatory data encryption and regular network testing for resilience against attacks. Thus, the investigation of vulnerabilities in computer networks forms the foundation for ensuring network security in the face of increasing threats.

APPROACHES TO DETERMINING THE CAPABILITIES OF COMPLEX MILITARY-TECHNICAL SYSTEMS

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The functioning of a military-technical system (MTS) is determined by a vector indicator of the state, and the controlling influences set the direction of its operation. The choice of influence at a certain time interval according to a given technology determines the resource required for this. Such an impact is possible only if the required resource does not exceed the available ones. The task is to determine the possible outcomes, taking into account resource constraints, or to find the limit values without them. Effective management requires analyzing the relationship between results, resources and external factors to optimize the system's performance.

We propose the following content and options for solving the problem:

1. Analysis of the achievable results of the MTC by means of analytical and simulation modeling, which allows to establish the relationship between the used resource and the result, but requires taking into account the structure and information-functional relations of the system.
2. Calculation of the set of achievable states of the CTS, which requires an in-depth analysis of management processes and structure options, and therefore requires simplification.
3. Analysis of the "resources-results" relations without calculating the areas of the state of the CTS, based on models for assessing the results of the given resources, which avoids modeling details.

Thus, the analysis of "resources – result" relations is the key in the structure of the analysis of the use of CTS, as it allows to assess the quality of the system and management efficiency without the need to detail the components of management processes.

ANALYSIS OF THE EFFECTIVENESS OF THE SYSTEM OF OPERATIONAL SUPPORT FOR THE ACTIONS OF COMBAT PERSONNEL

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In modern military conflicts, operational management and decision-making play an extremely important role. The ever-increasing volume of data and rapid changes in the situation on the battlefield create a need for improved information technology. Automated control systems help to optimise the processes of collecting, processing and analysing information, increasing the effectiveness of military operations.

Rapid decision-making in intense combat operations requires prompt provision of commanders with the necessary information. This leads to the integration of information technology into military management, which reduces the workload of military personnel and improves the accuracy of decisions.

Modern military operations are characterised by high dynamics, which makes it difficult to analyse and predict threats. The use of mathematical models and data processing algorithms allows for timely assessment of the situation and adjustment of combat operations in accordance with changes in the situation.

The use of modern information technologies in the design of an operational decision support system allows to minimise the risks of emergency situations, optimise the interaction of all elements of the management system and ensure effective decision-making even in difficult conditions. The proposed model of the operational decision support system allows to increase the efficiency of management in conditions of information saturation and lack of time for decision-making.

APPLICATION OF ERROR-CORRECTING CODING FOR INFORMATION RECOVERY IN THE UAV – CONTROL STATION CHANNEL

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In the context of the Russian-Ukrainian war, ensuring reliable information transmission between Unmanned Aerial Vehicles (UAVs) and the control station is critically important, especially under the influence of enemy electronic warfare (EW) systems and adverse radio signal propagation conditions. This study aims to evaluate the potential effectiveness of error-correcting coding for enhancing the reliability of data transmission under unfavorable information transfer conditions and the impact of enemy EW assets.

To determine and conduct a comparative analysis of the bit error probability (BEP) during information transmission in the UAV-to-control station channel with and without the application of Hamming error-correcting code, it is proposed to transmit identical signals within the low signal-to-noise ratio (SNR) range (from 5 dB to 15 dB). These low SNR values will correspond to the conditions of enemy EW influence in the far-field region of the antenna radiation pattern, which will allow for the determination of conditions for adapting the transceiver equipment to changes in the communication channel quality.

The simulation results will enable the evaluation of the practical advantage of employing the Hamming code and the development of recommendations for its utilization. Further research will focus on investigating the effectiveness of other error-correcting coding methods and their combinations to optimize the characteristics of the UAV-to-control station communication channel.

ENHANCING THE DATA PROTECTION SYSTEM FOR AERIAL RECONNAISSANCE

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Aerial reconnaissance generates critical data, including video streams, high-resolution imagery, and geographic coordinates. Inadequate protection risks data interception by adversaries, mission compromise, or even threats to operators' lives.

A robust security system is fundamental to ensuring confidentiality and the success of reconnaissance operations.

To strengthen data security, advanced encryption methods like AES-256 or elements of quantum cryptography should be employed. Secure communication channels, such as satellite networks or highly protected VPNs, are essential. Additionally, implementing real-time intrusion detection and prevention systems (IDS/IPS) enables prompt responses to cyber threats.

An enhanced data protection system improves the reliability, speed, and efficiency of aerial reconnaissance while minimizing leakage risks. However, it demands significant financial investment, complex technical implementation, and skilled specialists. Looking forward, integrating artificial intelligence for threat analysis and automated protection could significantly bolster security and streamline system management.

Adopting international cybersecurity standards, such as ISO 27001 or NIST frameworks, ensures compliance and strengthens system resilience. Collaboration with global partners facilitates the exchange of best practices and technologies, enhancing protection against sophisticated cyber threats. Such cooperation also fosters the development of interoperable systems, critical for joint reconnaissance missions.

APPLICATION OF ARTIFICIAL INTELLIGENCE FOR MONITORING INFORMATION AND COMMUNICATION NETWORKS

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Modern special-purpose information and communication networks (SPICNs) are characterized by high complexity, dynamic loads, and strict security requirements, which necessitate intelligent methods for monitoring and predicting their behavior. The growing number of cyber threats, limited resources, and the need for rapid response require automated solutions capable of effectively analyzing large volumes of data and detecting anomalies in real time.

This report presents the development of the intelligent NetWatch system for predicting SPICN behavior using artificial intelligence (AI) technologies. It explores the functional principles of SPICNs, including reliability, security, adaptability, optimal resource utilization, traffic prioritization, interoperability, and scalability, as well as the specifics of behavioral prediction at each level of the OSI model. AI methods are analyzed, particularly machine learning algorithms such as Support Vector Machines, Decision Trees, Random Forest, Neural Networks, and K-means clustering, for traffic classification, load forecasting, anomaly detection, and fault management. The choice of the K-means clustering algorithm for NetWatch is justified by its simplicity, speed, and ability to work with unlabeled data, making it ideal for detecting DoS attacks in real time. The proposed approach offers advantages such as high performance, security, cross-platform compatibility, and real-time anomaly prediction, which are critical for SPICNs. Its limitations relate to K-means clustering's challenges in predicting complex patterns and the need for high-quality training data. This work demonstrates the potential of AI to automate the analysis and prediction of SPICN behavior, offering a practical solution to enhance cybersecurity and the resilience of critical infrastructure in the face of modern challenges.

DEVELOPMENT OF AN ADAPTIVE ROUTING ALGORITHM BASED ON ARTIFICIAL INTELLIGENCE FOR ENHANCING THE EFFICIENCY OF SPECIAL-PURPOSE MESH NETWORKS UNDER CONDITIONS OF ELECTRONIC WARFARE

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The experience of the Russian-Ukrainian war highlights the critical necessity for high-performance, reliable, and secure special-purpose information and communication networks, the operation of which must account for the conditions of modern warfare – dynamic combat and the active use of enemy electronic warfare (EW) assets. Existing approaches to managing Mesh networks, particularly the DSR algorithm, are ineffective under conditions of rapid situational changes and EW influence, necessitating the development of adaptive routing methods.

This paper proposes a modification of the Dynamic Source Routing (DSR) algorithm through the integration of artificial intelligence (AI) technology. The developed neural network analyzes current signal-to-noise ratio (SNR) values and their dynamics to predict information transmission routes in a special-purpose Mesh network, minimizing information transmission time and maximizing its reliability under the influence of enemy EW.

The outcome of this work is a modified DSR routing algorithm with an integrated neural network, as well as an evaluation of its advantages over the standard DSR in terms of timeliness (latency), reliability (bit error probability), and resilience to interference under simulated conditions.

ANALYSIS OF TASK ASSIGNMENT AND SCHEDULING METHODS IN DISTRIBUTED SYSTEMS

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At present, several software systems are known that can be oriented towards managing complex applications with a workflow structure in distributed computing systems (DCS). To solve such problems, scheduling methods are generally used, which consider knowledge of the problem-oriented specifics of the tasks that make up computational processes, such as the Kim and Brown algorithm, the DSC algorithm. However, this class of algorithms is applicable to tasks executed on a single processor core of a multiprocessor system. Accordingly, the development of methods and algorithms for resource management in distributed computing automated control systems (ACS) for aviation and air defense, considering the specifics of the subject area, determining the volume of partial stages in a task, and using the possibility of parallel execution of independent tasks is a relevant issue.

There is a large number of scheduling methods designed for use in DCS. Promising directions include the development of resource scheduling tools in problem-oriented environments, which allow for the creation of effective and efficient resource scheduling systems.

Methods used for resource scheduling in distributed computing systems can be classified according to various characteristics: from the point of view of the architecture of the components involved in scheduling; the policies used; objective functions; application models; quality constraints; strategies applied to resources with dynamic behavior; and others.

DEVELOPMENT OF A SECURITY AND NETWORK STATUS MONITORING MODULE FOR THE AIR FORCE CNI OF THE AFU BASED ON THE ZABBIX SYSTEM

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With the increasing complexity of information and communication networks (ICNs) and the growing demands for their security, the implementation of effective and adaptive monitoring software becomes particularly relevant. One of the promising tools for ensuring control over the state of ICNs is the Zabbix system, which combines the functions of data collection, processing, visualization, and real-time analysis. The aim of this research is to improve the monitoring software of the Air Force ICNs of the Armed Forces of Ukraine (AFU) by implementing new functional modules into the Zabbix system, with a particular focus on enhancing network security and resilience to potential threats. During the study, modern approaches to ICN monitoring were analyzed. The advantages of using plugins for vulnerability detection (such as Vulners), open port scanning, web scenario checks, SSL certificate validity verification, and integration with external systems like OpenVAS and Nessus were identified. The use of monitoring templates for network devices and the application of Low-Level Discovery mechanisms for configuration automation were found to be expedient. Special attention was paid to the development of an extended monitoring module for BGP and OSPF routing protocols. An anomaly detection algorithm was proposed, based on the analysis of route changes, detection of incorrect announcements, unauthorized subnets, and suspicious changes in routing tables. This approach enables the implementation of an early warning system for potential attacks on the ICN.

The developed solutions enable a transition from passive monitoring to active security control, significantly increasing the reliability and protection of the Air Force ICNs of the AFU.

SOLVING THE PROBLEM OF IMAGE PARTITIONING FOR SUBSEQUENT RECOGNITION BY MACHINE VISION IN REAL TIME

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This study considers the creation of an information system for solving the problem of image partitioning for subsequent recognition by machine vision in real time in order to increase the time efficiency of recognition of certain types of objects on the ground using aerial photographs. Based on the analysis of modern methods intended for solving problems of segmentation, digital image partitioning and clustering, on the one hand, and the characteristics of the considered types of objects and background, as well as the conditions in which the images are obtained, a two-stage method is proposed based on the use of both known segmentation methods and the proposed algorithms for approximating objects and fragmenting the image. At this, at the preprocessing stage, segmentation of objects is performed using the accelerated method considering the photometric and metric characteristics of objects and background. Further, at the first stage of solving the problem under consideration, each segmented object is approximated by a minimal convex hull in the form of a rectangle with axes parallel to the coordinate axes. At the second stage of solving the problem, the input image is divided into fragments that are uniform in shape and number of convex hulls they contain. To solve problems at these two stages the time efficient algorithms have been developed. After this, the fragments of the input image that contain approximately the same number of the sought-after objects are transferred to post-processing, which is performed in parallel with respect to all the obtained fragments; in this case, they are subjected to high-precision segmentation, and then the segmented objects are transferred for recognition (identification) by comparison with the existing reference objects.

IMPROVING AZURE IOT LAMBDA ARCHITECTURE WITH AI/ML AND COMBINED PIPELINES

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Lambda architecture is a popular approach to real-time and batch processing of large amounts of data. In the context of the Azure Internet of Things (IoT) platform, it is used to ensure scalability, reliability, and performance of analytical systems.

The Internet of Things generates massive amounts of structured and unstructured data from millions of sensors, devices, and gateways. This data has a different frequency, value, and volume, which requires an efficient architecture for collecting, processing, and analyzing it. The lambda architecture combines the benefits of batch and stream processing, but has limitations that can be mitigated by using Azure tools.

Lambda architecture remains a powerful model for working with big IoT data. At the same time, its classic look needs to be modernized. Microsoft Azure tools reduce complexity and increase performance through unified processing logic, containerization, AI/ML, and combined pipelines. In the Microsoft Azure environment, this model is used to simultaneously implement real-time processing and batch analysis of historical data. However, with the development of cloud technologies, artificial intelligence (AI), and machine learning (ML), there is a need to modernize the classic lambda architecture to increase its adaptability, accuracy, and scalability.

Integrating AI/ML into the classic IoT lambda architecture in Microsoft Azure allows you to build more flexible, adaptive, and intelligent systems. The combination of batch and stream processing, automated pipelines, and edge intelligence opens up new opportunities for managing distributed data in real time. This allows not only collecting and analyzing data but also responding to it effectively.

ANALYSIS OF THE WAYS OF EFFICIENCY IMPROVEMENT OF THE SATELLITE COMMUNICATION SYSTEMS

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Today, satellite communications (SC) plays an important role, especially in the context of the deployable communication and information systems. Starlink satellite terminals are widely used. They are characterised by the use of a phased array antenna (PAA), the presence of a beamforming mode, and the use of MIMO technology. A special feature of the Starlink system is that its satellites are low-

Earth orbit (LEO). The terminals can be installed on aviation platforms (aircraft, UAVs). One drawback of the system is the dependence of the connection speed on weather conditions.

In order to improve the efficiency of the satellite communications system, signals from several satellites located on different orbits (LEO, MEO, GEO) are currently used. In addition, the use of signals from several satellite systems (Eutelsat/OneWeb, SES, Hisdesat, Viasat) is relevant.

In order to improve the efficiency of the SC systems, it is advisable to use the principle of software-defined radio (SDR), transition to digital and smart antenna arrays. The implementation of smart is simplified by the use of phased or digital antenna arrays in terminals. In addition, it is advisable to use OFDM technology or its variants. However, the influence of the Doppler effect should be taken into account.

The efficiency analysis was carried out by means of modelling, which determined the impact of the use of communication technologies on the BER value. The analysis confirms the feasibility of implementing OFDM technology and smart antenna arrays.

СЕКЦІЯ 5

УДОСКОНАЛЕННЯ ЗАСОБІВ, КОМПЛЕКСІВ І СИСТЕМ РАДІОЛОКАЦІЇ ТА СПОСОБІВ ЇХ ЗАСТОСУВАННЯ

Керівники секції: д.т.н. с.н.с. полковник Геннадій ЗАЛЕВСЬКИЙ
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EXPERIMENTAL VERIFICATION OF A DECIMETER-WAVE ACTIVE JAMMING EMITTER SIMULATOR

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This paper presents a comparative analysis of the active jamming systems (AJS) used by the Armed Forces of the Russian Federation. These systems are examined in the context of their potential application for suppressing decimeter-wave radar stations operated by the Radio-Technical Troops (RTT) of the Air Defense Forces of the Armed Forces of Ukraine.

The primary means of individual and group protection for modern fleets of aircraft and helicopters within the electronic warfare (EW) units of the Russian Aerospace Forces include airborne systems such as "Khibiny-M", "Khibiny-V", "Himalaya", "Porubshchik", as well as EW systems based on the Mi-8PPA helicopter platform.

To prepare RTT Air Defense specialists for operations under conditions involving the adversary's use of EW systems, it is advisable to employ compact, cost-effective in manufacturing and operation, AJS simulators.

The report proposes a block diagram of a functioning prototype of an AJS simulator developed using COTS (Commercial Off-The-Shelf) technology. The simulator's implementation involves identifying optimal technical solutions for generating a noise signal with specified spectral characteristics, modulation methods, and emission parameters.

An assessment was conducted regarding the feasibility of technically implementing adjustable output signal parameters to simulate various types of jamming signals potentially employed by adversaries. The integration of the jamming simulator into the training process for radar station (RLS) operators is under consideration.

PROPOSALS FOR IMPROVING TARGET DETECTION EFFICIENCY BY ENSURING THE OPERABILITY OF THE MAIN ANTENNA CHANNELS OF THE P-18 RADAR

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During combat operations, particularly in the Russo-Ukrainian war, radar stations are often exposed to mechanical and combat damage, negatively affecting their performance. One key component is the antenna, which forms the radiation pattern that determines radar effectiveness in detecting and locating air targets.

This study evaluates how damage to waveguide channels in the P-18 radar antenna – caused by enemy attacks on radar unit positions or mechanical impacts during deployment – affects radiation pattern formation.

The analysis shows minimal distortion occurs when two edge channels on one side or one on each side fail. The most severe distortion is caused by failure of the two central channels, which significantly reduces detection range, coordinate accuracy, and resolution.

Based on these results, it is recommended to ensure the operability of the central waveguide channels, as they are critical for maintaining a radiation pattern close to nominal, thereby preserving the radar's tactical and technical characteristics.

DEVELOPMENT OF PROPOSALS TO DEVELOPMENT OF PROPOSALS TO REDUCE MANEUVER TIME OF A SEPARATE RADAR PLATOON (SRP) BASED ON THE EXPERIENCE OF THE RUSSO-UKRAINIAN WAR IN ORDER TO ENHANCE ITS SURVIVABILITY

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Ensuring the effective functioning and combat readiness of a separate radar platoon (SRP) is one of the key tasks in modern combat conditions, where rapid decision-making and adaptation to sudden changes in the air situation play a crucial role in conducting radar reconnaissance. It is necessary to revise maneuvering methods considering the capabilities of the enemy.

Given the variety of aerial attack means, an analysis has been conducted of enemy actions aimed at detecting and striking elements of the SRP's combat formation. This makes it possible to reasonably select positional areas for the unit with minimal risk of detection and destruction.

To reduce the time required for the SRP to maneuver, proposals have been developed aimed at improving the setup and takedown times of the radar station, particularly using the example of the P-18 "Malakhit" radar. One such solution is the production of special supports for the antenna-mast device (AMD), which allows the preparation time of the AMD trailer for relocation to be reduced several times.

DEVELOPMENT OF AN INTERACTIVE TRAINING APPLICATION FOR THE PREPARATION OF WORKSTATION OPERATORS OF THE "VIRAZH-PLANSHET" SYSTEM IN RADAR TROOPS UNITS

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The paper substantiates the necessity of developing an interactive training application for the preparation of workstation operators (planchettists) working with the "Virazh-Planshet" automated workstation (AWS) system, which is operated in the units of radio-technical troops (RTT).

The relevance of this development is driven by the increasing demands for the training level of specialists in combat control and the automation of primary radar data processing. The application is intended to serve as a tool for developing practical skills in working with the AWS, including parameter configuration, signal reception and processing procedures, as well as understanding the functional capabilities of the system interface. Particular attention is paid to the sequence of actions when working with primary information, the accuracy of data input, time tracking, and the coordinates of aerial objects.

The application includes interactive hints and informational modules that facilitate better material assimilation and enable self-guided learning. This approach allows for the formation of a comprehensive understanding of the operator's tasks, improves the quality of training, and ensures readiness for the practical operation of the AWS as part of combat crews in air defense units.

INCREASING THE SURVIVABILITY OF RADIO ENGINEERING UNITS DURING COMBAT MISSIONS

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Recently, in order to break through the air defence system of Ukraine, the enemy has been trying to destroy weapons and military equipment of the radio engineering troops of the Air Force of Ukraine by using barrage munitions of the "Lancet" type. The destruction of weapons and military equipment of radio engineering troops will allow the enemy to create corridors for air attack and strike at important state (critical) and military facilities.

Successful solution to the task of protecting weapons and military equipment of radio engineering troops from barrage munitions of the "Lancet" type requires a comprehensive approach from commanders of radio engineering units. A comprehensive system for countering and combating barrage munitions of the "Lancet" type should consist of a detection and warning subsystem and a subsystem for active and passive protection of weapons and military equipment of radio engineering troops.

The paper presents the structure of a comprehensive system for countering and combating barrage munitions of the "Lancet" type. It is shown that the detection and warning subsystem may include radar reconnaissance, radio-technical reconnaissance, optoelectronic reconnaissance and acoustic reconnaissance, which, under conditions of high-quality organisation of interaction and exchange, will significantly increase the intelligence capabilities of such a subsystem. The subsystem of active protection of weapons and military equipment of the radio engineering troops consists of the drone-to-drone system, electronic warfare and destruction means, and passive protection includes the use of false positions, pit-type shelters, bunding of weapons and military equipment of the radio engineering troops, metal, polymer and camouflage nets.

FEATURES OF HOMING HEADS USED IN CRUISE MISSILES MANUFACTURED BY THE RUSSIAN FEDERATION

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During the large-scale war waged by the Russian Federation against Ukraine, the adversary uses a large number of cruise missiles of various types to strike targets across the territory of our country. Among this arsenal, many are high-precision strike systems. The accuracy of a missile’s impact largely depends on the type of homing head used in the strike system.

High-precision strike systems include those cruise missiles that have a circular error probable (CEP) from the designated target center of no more than 10 meters. If this value exceeds the mentioned range, the missile is not classified as a high-precision weapon.

Among the cruise missiles produced by the Russian Federation that are classified as high-precision strike systems are the following: X-55, X-59, X-101, P-800 "Oniks", and 3M14 "Kalibr". All of them are equipped with a combined homing head comprising an inertial navigation system and the GLONASS satellite guidance system. In some types of cruise missiles, radar homing heads are also used to increase targeting accuracy.

The X-55 cruise missile is equipped with an autocorrelation inertial guidance system integrated with a terrain contour matching trajectory correction system. The X-101 missile utilizes a combined inertial guidance system with electro-optical correction at the terminal flight stages. "Kalibr" cruise missiles feature radar homing heads for target acquisition at the final flight stages.

PROPOSALS FOR IMPROVING THE EFFECTIVENESS OF SPATIAL ADAPTIVE SIGNAL PROCESSING BASED ON ESTIMATION OF THE WEIGHT VECTOR OF COMPENSATION CHANNELS

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The enemy considers electronic warfare (EW) to be a key component of the entire combat operations complex. Currently, all strike aircraft and missiles are equipped with EW systems. In such conditions, the combat use of RTV (radio technical troops) equipment becomes significantly more complicated. The practical implementation of a protection system against active interference for the P-18 "Malakhit" radar of the meter wavelength range is being discussed.

It is shown that the interference compensation device is a four-channel automatic interference compensator with correlation feedback of the quadrature type. The interference compensator in the P-18 Malakhit radar is analog, although further processing is carried out in digital form.

Proposals have been developed to improve the effectiveness of the protection system against active interference. These involve transitioning from analog spatial processing to digital, replacing the automatic compensator with a gradient adaptation algorithm with an automatic compensator using a recurrent algorithm for maximum likelihood estimation of the correlation matrix of active interference. This ensures real-time estimation of the correlation matrix and eliminates the shortcomings of automatic compensators with gradient adaptation algorithms.

SUBSTANTIATION OF METHODS FOR ASSESSING COORDINATES FOR ADVANCED ANTI-UAV S-BAND RADAR

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Comparative characteristic of tactic unmanned aerial vehicles (UAVs) as radar objects is carried out. Reconnaissance and strike UAVs which russian army use against Ukraine were considered. Radar cross section (RCS) and trajectory parameters (height, velocity) of mentioned UAVs were analyzed based on the generalization of the experience of using the Ukrainian Armed Forces units armed with radars of different types.

Reconnaissance UAVs of the "Orlan-10", "Zala", "Supercam" types and attack UAVs of the "Geran-2" ("Shahed-136/131") type are characterized by low RCS values. Their velocity make values about 80-180 km/h, which makes it difficult to separate the signals reflected by them against the background of passive interference. The flight altitude of these UAVs can vary from 200 m to about 3000 m.

During 2023-2025, the Armed Forces of Ukraine successfully use RPS-42(82) and ELR55307 mobile radars to detect and track the UAVs in question.

The analysis indicates the need to develop an advanced specialized highly mobile compact radar designed for detecting and tracking UAVs.

The report analyzes the known methods of air objects angular coordinates assessing. The parameters of the phased array antenna of an advanced S-band radar capable to provide information about reconnaissance and attack UAVs (their distance, azimuth, and height) with an accuracy that will increase the effectiveness of their destruction by surface-to-air missile systems, mobile fire groups and strike drones are substantiated.

DEVELOPMENT OF RECOMMENDATIONS FOR THE COMMANDER OF A RADAR UNIT ON DETERMINING THE SEQUENCE OF ACTIONS WHEN SELECTING A POSITION IN CASE OF ITS SUDDEN RELOCATION, BASED ON THE EXPERIENCE OF THE WAR OF RUSSIA AGAINST UKRAINE

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During the Russian-Ukrainian war, the relocation of radar stations has become an integral part of preserving the lives of unit personnel and maintaining the integrity of equipment. Ensuring uninterrupted radar coverage and enhancing the survivability of radar units during emergency redeployment to alternate positions is achieved by reducing radar station teardown time and deploying equipment with the use of camouflage measures and engineering fortifications. This includes camouflage nets and aerosol screens to reduce the visibility of the deployed unit or an individual radar platoon.

For effective position selection, it is necessary to consider terrain masking angles, the use of flat terrain for meter-band radar systems, and the placement of centimeter-band radar systems on hills or the highest points of the terrain.

This work presents the application of primary, alternate, and reserve positions with consideration of the maximum utilization of the radar systems' tactical and technical characteristics. It also includes the expansion of radar coverage at low and extremely low altitudes using digital terrain maps such as Google Earth and the calculation of radar coverage using the "Virage-RD" software.

In conlusion, the approach to position selection was based on a combination of tactical requirements, engineering preparation, camouflage, and the assurance of operational stability of radar units of the Air Force of the Armed Forces of Ukraine, even under conditions of active use of air attack weapons by the aggressor state.

PROPOSALS FOR IMPROVING THE SYSTEM OF AUTOMATIC TUNING OF THE RADAR FREQUENCY USING A MODERN ELEMENT BASE

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To improve the quality of operation of the radar of the old fleet, one of the tasks is to improve the performance characteristics of the electromechanical automatic frequency adjustment system (AFS) of the transceiver and transmitting path. The electromechanical system of the FM of the generator must provide a minimum deviation of the intermediate frequency from its nominal value for the signal to enter the bandwidth of the narrowband resonant amplifier of the intermediate frequency.

The use of modern stepper motors allows you to improve the accuracy of electromechanical control of the generator frequency, and speed in comparison with classic DC and AC motors. The main advantages of the stepper motor are the accuracy of operation, ease of control of the rotor position and the speed of its rotation. Such accuracy can be achieved with a relatively simple design and low cost of the finished solution. The torque of the motor is very high at low rotational speed. There are no brushes in the design of the motor, which ensures its high mechanical strength and increased reliability. One of the most significant disadvantages of the stepper motor is its power consumption. Power is required, both when driving and when stopping.

Digital methods of modeling and research of nonlinear automatic control systems using modern tools allow you to quickly obtain a result without significant difficulties that are inherent in analytical methods. To prevent difficulties in selecting the values of the AFC system parameters, it is advisable to use a nonlinear SIMULINK model system.

PROPOSALS FOR IMPROVING THE PROTECTION SYSTEM OF 35D6 TYPE RADAR AGAINST PASSIVE INTERFERENCE BASED ON ADAPTIVE DIGITAL FILTERS

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The effectiveness of target detection against a background of passive interference has been analyzed for a radar system equipped with a Moving Target Indication (MTI) system based on a discrete Fourier transform (DFT) processor and burst-wise modulation of the pulse repetition frequency (PRF) of probing pulses.

It is shown that the MTI system of the 35D6 radar type implements a non-adaptive clutter suppression filter for mitigating reflections from local stationary objects, as well as incoherent integration of pulse energy within the burst structure of the input signal.

These conditions result in a degradation of the signal-to-(interference + internal noise) ratio.

A structural design is proposed for an inter-pulse period (IPP) processing system based on a dedicated interference suppression filter with incoherent integration of its output signals.

The performance of the proposed optimized IPP system architecture for processing Gaussian signals in the presence of Gaussian passive interference has been simulated.

The feasibility and effectiveness of implementing such systems based on a dedicated interference suppression filter with incoherent integration of its output signals are demonstrated.

DEVELOPMENT OF PROPOSALS FOR IMPROVING THE TECHNICAL CHARACTERISTICS OF THE RECEIVING PATH OF RADARS

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The experience of the Russo-Ukrainian war demonstrates a significant increase in the use of small-sized unmanned aerial vehicles (UAVs) with low effective radar cross-section (RCS), which complicates their detection. For the Radio-Technical Troops, it is necessary to have radar stations capable of reliably detecting such aerial targets at extended ranges.

Transmit-receive systems are integral components of any radar system. The key tactical and technical characteristics of weapon complexes largely depend on the technical parameters of these transmit-receive systems. One of the critical indicators of the radar receiver is its sensitivity, which directly affects the detection range and accuracy of target acquisition. Therefore, improving the sensitivity of the receiving unit through the use of modern components with enhanced quality and stability is a vital task.

This work considers and analyzes methods of digital signal synthesis. Based on the analysis, it is shown that for generating highly stable local oscillator signals in the receiving path of VHF radar systems, it is advisable to use digital methods employing synthesizers based on Direct Digital Synthesis (DDS). Mathematical modeling and analysis of the modern AD9910 synthesizer have been conducted, focusing on quantization noise and sampling noise, which are inherent to digital methods, using the "Mathcad 14" software package. Graphs have been obtained showing the dependence of distortion levels (quantization noise) on the digital-to-analog converter (DAC) resolution.

USING INTERACTIVE REFERENCE GUIDES TO ENHANCE AWARENESS OF RADIO ENGINEERING TROOPS SPECIALISTS

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The use of electronic interactive reference guides for various enemy weapons, their classification by types, tactical and technical characteristics of weapons and military equipment of the Armed Forces of Ukraine, as well as the main governing documents regulating the daily and combat activities of the Armed Forces of Ukraine, will significantly simplify and accelerate the training of personnel (including those called up through mobilization), reduce the time for processing documents of radio engineering units by eliminating the need to search for necessary data in a significant number of paper directive documents.

Modern methods of training radio engineering troops specialists, both officers and non-commissioned officers and enlisted personnel, involve the extensive use of IT technologies, creation of various interactive applications and reference materials. The constant updating of weapons nomenclature used in combat operations, both by Ukraine and the Russian Federation, and, accordingly, the need to know their tactical and technical characteristics, requires personnel to continuously update their knowledge and quickly search for necessary information.

Also, instructors in military educational institutions and training centers are required to convey to trainees the purpose, tactical and technical characteristics, and tactics of using new types of weapons. Therefore, it is relevant to create an electronic database of weapons used both by the Armed Forces of Ukraine, including those received from partner countries, as well as enemy weapons.

DEVELOPMENT OF PROPOSALS FOR INCREASING THE COEFFICIENT OF TRACKING AIR OBJECTS WITH A LOW LEVEL OF RADAR OBSERVABILITY BY OPTIMIZING THE RADAR FIELD BASED ON THE EXPERIENCE OF THE RUSSIAN-UKRAINIAN WAR

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The experience of the Russian-Ukrainian war has led to the widespread use of low-level radar-observable aerial targets, such as unmanned aerial vehicles (UAV) and cruise missiles. In view of this, increasing the rate of detection of such targets through radar systems is an important task for ensuring the effectiveness of air defense and airspace protection.

Based on the results of studying the experience of the enemy using UAVs, it was determined that the most frequently used UAVs were "Zala", "Orlan", and "Geran-2". By accumulating experience in combating these UAVs, their tactical and technical characteristics, methods of their use, and methods of combating them were determined.

The construction of the combat order of radio engineering units aims to create a continuous radar field with an appropriate overlap coefficient at the heights of combat use of air attack means, which ensures their timely detection and stable tracking. It is advisable to use radar stations of different ranges at one position (for example, 19Zh6 and P-18MA).

The implementation of these proposals, along with the constant improvement of technologies, will significantly increase the effectiveness of the radar reconnaissance and air defense system as a whole.

APPLICATION OF MULTISTATIC SYSTEMS IN AIR DEFENSE RADAR UNITS UNDER CONDITIONS OF THE RUSSIAN-UKRAINIAN WAR

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Based on combat experience during the Russian Federation's aggression against Ukraine, there is a critical need for new approaches to radar reconnaissance systems, particularly multistatic radar systems (MSRS).

The growing complexity of enemy air attacks – especially small, low-speed, low-altitude aerial threats with reduced radar cross-section (RCS < 1 m²), such as Shahed-136 UAVs, Molniya-type drones, quadcopters, and Kalibr missiles – demands high-precision, jamming-resistant detection capabilities from air defense forces.

The multistatic concept involves spatially distributed radar stations integrated into a unified information system, enabling multi-angle airspace surveillance, enhanced accuracy, stable tracking, and better detection in advanced electronic warfare conditions.

MSRS use reduces blind spots, enhances coverage redundancy, and maintains functionality if individual radars fail. Synchronization within the same frequency spectrum prevents mutual interference and ensures stable data exchange.

Optimizing radar topology, elevation, and fields of view, combined with adaptive signal processing and digital filtering, increases sensitivity to low-RCS targets and adaptability to terrain, weather, and countermeasures.

In summary, integrating MSRS into Ukraine's air defense radar forces is crucial to effectively countering asymmetric aerial threats and improving airspace protection.

DEVELOPMENT OF VISUAL-SIMULATION MODELS OF THE "OLD PARK" RADARS MOVING TARGET SELECTION ALGORITHMS TO IMPROVE THE DETECTION OF LOW-RADAR-VISIBILITY AIR OBJECTS BASED ON THE EXPERIENCE OF THE RUSSIAN-UKRAINIAN WAR

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In the context of the wide use of unmanned aerial vehicles by the enemy, which usually operate at low altitudes, the improvement of technologies for recognizing moving targets becomes particularly important. The reliability of such systems determines the prompt detection of air targets against the background of signals reflected from the surrounding terrain.

To explore methods for enhancing the resistance of radar stations to passive interference, it is effective to use the MATLAB software environment with the Simulink module. This is an interactive platform that enables modeling, simulating, and analyzing complex dynamic processes using various model types – from discrete to nonlinear and hybrid.

In Simulink, algorithms for the functioning of moving target detection systems were implemented and adapted for different types of radars currently in service with the radio engineering units of the Air Force of the Armed Forces of Ukraine. The analysis of their performance under various air scenario conditions made it possible to assess the effectiveness of the proposed solutions and to outline the prospects for their further optimization.

ANALYSIS OF CONTEMPORARY WEAPONS AND MILITARY TECHNOLOGIES FOR COUNTERING UNMANNED AERIAL VEHICLES IN THE CONTEXT OF THE RUSSIAN-UKRAINIAN WAR EXPERIENCE

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Combat experience in Ukraine has demonstrated the extensive use of unmanned aerial vehicles (UAVs) by the Russian Federation for reconnaissance, electronic warfare, precision strikes, target acquisition, and communication signal relay.

The capabilities of reconnaissance, firepower, and electronic warfare assets within the radio-technical troops of the Ukrainian Air Force have been assessed, particularly in countering unmanned, and especially strike, aerial platforms. These capabilities are grounded in the deployment of weapons and military hardware by radio-technical units.

To detect and identify small-sized UAVs, the application of radar systems – specifically short-range surveillance radars and gap-filling radars – as well as passive detection tools (UAV detectors), is proposed within the framework of radio-technical troop operations.

Kinetic countermeasures are achievable through the use of anti-aircraft artillery systems with sufficient performance characteristics: effective engagement range and altitude, the capability to target objects with a radar cross-section below 0.02 m^2, and a favorable cost-effectiveness ratio.

Electronic warfare systems remain a fundamental element in counter-UAV operations, with key performance indicators including jamming range, sector coverage, operating frequency band, mobility, and physical footprint.

The proposed integrated counter-UAV system features the necessary characteristics to enhance the survivability and operational resilience of radio-technical troop units.

ANALYSIS OF THE USE OF MOBILE AIR DEFENSE FIRING GROUPS

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During nearly three years of full-scale war, Ukraine's air defense forces have gained unique experience that no other country has ever experienced. Constant attacks using ballistic and cruise missiles, kamikaze drones, and air target simulators are depleting air defense resources.

In response to these threats, Ukraine has been actively using mobile fire groups, which have become a key element of air defense. These units are highly mobile and can quickly change their location according to the threat, which allows them to effectively destroy air targets.

Mobile fire groups are armed with a variety of equipment, which provides flexibility in performing combat missions. They can use both anti-aircraft weapons and small arms, which makes them versatile in the face of air threats.

The groups are equipped with thermal imagers and target detection systems. At night, they additionally use special searchlights to detect drones.

Faced with the threat of kamikaze drones such as the Shahed-136, Ukrainian units have adapted their tactics. One of the key tactics is information sharing. When a target is detected, data is quickly transferred between units. This increases the chances of successful destruction of the object.

Thus, mobile fire groups have become an integral part of Ukraine's air defense system, demonstrating high efficiency in countering modern air threats.

MEASURES TO ENHANCE THE SURVIVABILITY OF RADIOELECTRONIC EQUIPMENT OF RADIO TECHNICAL TROOPS BASED ON COMBAT EXPERIENCE

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The experience gained from countering armed aggression demonstrates that one of the primary methods employed by Russian armed formations against the radar assets of the Air Force of the Armed Forces of Ukraine involves optical reconnaissance using unmanned aerial vehicles (UAVs) of various types, followed by fire engagement through artillery, rocket-artillery systems, and loitering munitions such as the "Lancet".

One of the key approaches to improving the survivability of stationary radar systems is the reduction or distortion of information about targets, which is collected and processed by enemy reconnaissance systems. This is primarily achieved through the employment of electronic warfare (EW) systems, aerosol countermeasures, and engineering fortification of positions.Additionally, practical implementation of other protective measures involves the use of camouflage and decoy assets, including camouflage nets, mock-ups of military equipment, radar corner reflectors, thermal decoys, disruptive paint schemes, standard-issue and improvised camouflage means.

An equally important aspect of enhancing radar survivability is the physical protection of radar assets against fire damage. This includes the construction of shelters, earthen embankments for antenna trailers, and fragmentation protection for equipment shelters. To ensure the safety of personnel, the use of remote-control systems for radar operation and data processing is recommended.

Units that have implemented a comprehensive approach to survivability enhancement have shown significantly higher resilience and reduced vulnerability to direct enemy fire.

INCREASING THE ACCURACY OF RANGE ASESSING IN "OLD PARK" RADARS BY IMPROUVING A PRIMARY RADAR SIGNAL PROCESSING

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The current radar situation in Ukraine’s airspace is marked by the intensive and large-scale use of small-sized aerial targets such as UAVs and various types of missiles. This imposes high demands on the tactical and technical characteristics of radar systems, particularly regarding resolution and coordinate measurement accuracy. To improve these parameters, the following development directions are proposed:

1. Use of Wideband (Complex-Modulated) Probing Signals in Radar Systems: Wideband signals offer significantly better range resolution compared to narrowband signals. This enables radar systems to more accurately determine the distance between closely spaced objects, which is critically important for detecting and tracking small targets like UAVs that may operate in groups or at short distances from one another.

2. Implementation of Automatic Signal Detection in the Receiving Path Using Modern (Digital) Components: One modernization approach for legacy radar systems involves replacing outdated cathode-ray tube (CRT) circular scan indicators with modern displays, such as laptop monitors. This not only improves ergonomics and operator convenience but also directly affects the accuracy of target coordinate determination.

3. Use of Modern Display Equipment Based on Contemporary Monitors: Modern display equipment using IPS or LED matrices enables larger-scale visualization of the radar picture within the detection zone, significantly improving the accuracy and resolution of signal display on the screen.

DESIGN AND IMPLEMENTATION OF A SERVO-DRIVEN ROTATIONAL MECHANISM FOR A COMPACT DIRECTIONAL ANTENNA IN ELECTRONIC WARFARE APPLICATIONS USING THE ARDUINO PLATFORM

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The operational analysis of electronic warfare (EW) systems employed during the Russian-Ukrainian war has confirmed their effectiveness in countering unmanned aerial vehicles (UAVs) of various classes.

At present, tactical reconnaissance UAVs and FPV (first-person view) strike drones are among the most commonly used aerial threats. Their widespread deployment presents a considerable challenge for radar stations (RS) operated by the Radio-Technical Troops of the Air Force of the Armed Forces of Ukraine. Owing to their compact size and low-altitude flight profiles, such UAVs are often difficult to detect and track reliably using conventional radar systems.

Moreover, the Russian military actively exploits all available means to identify RS positions and conduct targeted strikes against them, aiming to degrade the overall effectiveness of Ukraine’s air defense network.

To mitigate these threats, it is imperative to implement measures that improve the protection, mobility, and survivability of radar systems. One of the approaches involves integrating auxiliary equipment such as spectrum analyzers and mobile EW stations.

Given that EW stations typically utilize directional antennas requiring precise targeting of UAV activity zones, this study proposes the implementation of a servo-driven antenna rotation mechanism based on the Arduino hardware-computing platform.

APPLICATION OF PASSIVE RADIO SYSTEMS FOR DETECTING UNMANNED AERIAL VEHICLES

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The experience of the Russian-Ukrainian war demonstrates a steady trend toward the growing use of remotely piloted and low-cost reconnaissance and strike assets, among which unmanned aerial vehicles (UAVs) of various purposes play a key role.

Modern UAVs belong to the category of small-sized and low-flying targets, which makes their detection by traditional radar means much more difficult.

Considering that UAV onboard equipment uses GPS and generates electromagnetic radiation, it is reasonable to use data from passive sources such as multi-position positioning (MLAT) systems. For this purpose, it is proposed to deploy a network of broadband SDR receivers in the most vulnerable areas, with the possibility of joint processing of incoming information in conjunction with radar data.

The essence of MLAT technology is to determine the coordinates of the object by time delays of the signal received at several spatially separated stations. The proposed SDR receivers operate in the range from 24 to 1750 MHz, which overlaps the most commonly used ranges of UAV control and data transmission (from 433.05 MHz to 2.4 GHz).

The report shows the possibilities of using MLAT technology, which, in combination with radar, makes it possible to improve the efficiency of UAV detection and expand the capabilities of the airspace control system in the face of modern threats.

PROPOSALS ON CONSTRUCTION OF POWER AMPLIFIYER FOR TRANSMITTER OF ADVANCED S-BAND RADAR

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Radar stations (RS) are critical components of air defense systems, providing detection, tracking, and classification of aerial targets. The experience of the war in Ukraine has demonstrated that radar systems are facing new challenges: the use of low-observable targets, drones, cruise missiles, and the active operation of electronic intelligence tools. Detection of objects with low radar cross-sections becomes especially difficult under conditions of interference and noise.

To address these issues, both structural and algorithmic improvements are required. From a technical perspective, a primary step is the transition to coherent transmitters based on gallium nitride (GaN) or silicon carbide (SiC). GaN and SiC technologies offer efficient heat dissipation, increased reliability and durability, and reduced size and weight of equipment.

Replacing outdated vacuum tube amplifiers with compact and powerful solid-state transmitters based on GaN or SiC not only significantly reduces the size and weight of the equipment, simplifying operation and maintenance in the field. Most importantly, coherent transmitters based on GaN or SiC provide significantly higher output power and a wider range of operating frequencies. This enables radar systems to generate precise probing signals with improved characteristics, directly enhancing the detection range of low-observable targets with small radar cross-sections.

The integration of modern component bases (GaN or SiC) with advanced digital signal processing methods significantly enhances the combat capabilities of radar systems in real combat conditions.

PROPOSALS FOR THE DEVELOPMENT OF TRAINING AND SIMULATION EQUIPMENT FOR THE P-37 RADAR

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Given that the training and simulation equipment of old-generation radar systems is morally outdated and incapable of providing adequate training for young radar operators, the authors have developed a functional diagram of a modern radar simulator for the P-37 system.

During the development of proposals for creating the simulator, particular attention was paid to the features of modeling the air and interference environment. This environment must meet modern requirements and ensure effective radar operator training. The software for this simulator is proposed to be implemented based on the specialized software of the "Virage-RD" integrated training exercise system, which is currently used by the Air Forces of the Armed Forces of Ukraine.

When designing the functional scheme of the P-37 radar training and simulation equipment, special emphasis was placed on the interface device between a personal electronic computing machine (PC) and the radar system. It is proposed to use Arduino boards, which are cost-effective (approximately $20) and offer expandable software and hardware capabilities.

Thus, the developed functional diagram of the P-37 radar simulator will serve as the basis for designing a modern training and simulation complex. This, in turn, will allow: reducing training costs for analog radar operators by decommissioning energy-intensive, morally and physically outdated standard simulators; providing training for analog radar operators within a unified tactical environment (a common air and interference situation) by employing a networked approach.

THE USE OF MODERN TECHNOLOGIES TO OPTIMIZE THE PROCEDURE FOR CONDUCTING RECONNAISSANCE OF ALTERNATE POSITIONS OF RADIO-TECHNICAL UNITS IN CONDITIONS OF WAR

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The experience of Ukraine’s war against Russia has demonstrated that the current procedure for conducting reconnaissance operations, aimed at ensuring the deployment of radio-technical units in designated areas (positions), requires modifications under modern conditions.

An analysis of the redeployment processes of radio-technical units, as well as the methods employed by the Russian Federation’s air assault systems against the positions of the Radio-Technical Troops of the Air Force of the Armed Forces of Ukraine, indicates that the use of weaponry and military equipment has become increasingly dynamic and technologically advanced, particularly through the use of modern technologies such as unmanned aerial vehicles (UAVs).

An assessment was conducted on the current procedures for reconnaissance of positions of groupings, units, and subunits of the Radio-Technical Troops of the Air Force of the Armed Forces of Ukraine, as well as the potential for remote reconnaissance of alternate positions and access routes.

A series of organizational measures has been proposed to revise the reconnaissance procedure, incorporating low-cost technical methods for route scouting and terrain assessment for the selection of alternate positions for radio-technical units. These measures are based on the integration of modern technologies, such as information and computational systems and unmanned aerial vehicles.

ANALYSIS OF ENEMY AIR TACTICS FOR STRIKES AGAINST THE GROUND FORCES. INTERACTIVE APPROACH TO TRAINING OPERATORS OF THE 35D6M RADAR UNDER MODERN AIR THREAT CONDITIONS

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Currently, the Russian Federation actively uses strike drones of the "Shahed" type and other unmanned aerial vehicles to carry out attacks on the territory of Ukraine. Detecting them is an extremely challenging task, as these drones usually fly at very low altitudes and have a low radar cross-section, complicating their detection by conventional radar systems.

The arsenal of the radio-technical troops of the Armed Forces of Ukraine includes radar stations such as the 19Zh6 radar and its upgraded version – the 35D6M. While personnel are already experienced with the 19Zh6 radar, the newer 35D6M model requires more in-depth training. Due to its updated control structure, additional functional capabilities, and interface differences, operators often find it difficult to quickly master its use.

To improve operator training effectiveness, a decision was made to develop an interactive training application. This application was created using Microsoft PowerPoint, allowing the training material to be presented through structured slides with visual elements. The app includes a brief description of the radar's characteristics, usage instructions, control element demonstrations, and examples of typical scenarios. This approach helps personnel better absorb the material, practice in a virtual environment, and improve their proficiency without using real equipment.

AZIMUTH MARKER GENERATOR FOR THE SIMULATION COMPLEX FOR THE TRAINING OF ANALOG RADAR OPERATORS

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When the enemy uses a massive air attack during the russian-ukrainian war, a complex airborne interference situation (AIS) is formed on the screens of radar all-round view indicators which are in service with radio engineering troops. In such conditions, proper training of radar operators is required for high-quality radar reconnaissance through visual acquisition of radar information. One of the conditions for such training is the use of simulation equipment that would be capable of modelling the AIS of varying degrees of complexity. Today, the simulators in the radars of the ‘old’ fleet are virtually inoperable.

One of the solutions to this issue is to create computer-based training and simulation complexes for analogue radars. A corresponding structural scheme is proposed, consisting of a computer-based AIS generator (using the Virage-RD system), a conjugation device, and an analogue P-18 radar.

One of the tasks of the conjugation device is to form azimuth marks (AM). For this purpose, the device offers a diagram of the corresponding generator, which receives azimuth codes and north marks. The output of the generator creates pulses corresponding to azimuthal directions in multiples of 0, 10 and 30 degrees.

It is proposed to implement the MA generator on the basis of the Arduino Due board, which has the necessary characteristics and low cost. The existing Arduino IDE software library was used for the software developing of the MA.

PROPOSITIONS ON THE STRUCTURE OF ADVANCED RADAR FOR THE TACTIC AND OPERATIONAL-TACTIC UAVS DETECTION

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Extremely active use of UAVs at altitudes up to 1000 meters currently, and the prospect of similar flight intensity up to 5000 meters in the near future, necessitates effective improvements in airspace control systems. The rationale for creating new radar systems to detect low-altitude, low-visibility aerial objects is substantiated. The main objective of this work is to systematically describe the technical features that, in combination, will provide critically important advantages over existing radar systems.

The article highlights trends in the development of radar systems for detecting and tracking aerial objects at low and extremely low altitudes. The necessity of developing multifunctional radars incorporating the latest scientific and technological advancements, modern information technologies.

The work focuses on the construction specifics of radar systems and the importance of applying new functional and informational capabilities that improve the detection and tracking of low-visibility aerial objects at low and extremely low altitudes. The critical importance of employing solid-state microwave equipment in radar transceiver modules is discussed. The requirement to adopt modularity principles, open architecture, and Commercial Off-The-Shelf technologies is also emphasized to ensure reliability, maintainability, reduced life-cycle costs.

The article addresses the pragmatic integration of network technologies and the transition to advanced information technologies at the stages of secondary/tertiary radar information processing. The importance of creating compact, mobile UAV detection radars with high operational stealth is noted.

A significant portion of the article is dedicated to discussing various aspects of radar protection. interference.

PROPOSALS FOR MODERNIZATION OF THE ANTENNA-FEEDER SYSTEM OF THE 19G6 RADAR TO IMPROVE THE SAFETY OF DEPLOYMENT BASED ON THE EXPERIENCE OF THE RUSSIAN-UKRAINIAN WAR

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The experience of the Russian-Ukrainian war shows that the 19G6 radar is widely used as part of separate radar platoons. The design of the 19G6 antenna-feeder system allows for quick deployment and folding during redeployment, due to the use of rigid waveguides and coaxial cables. When a reconnaissance UAV is detected moving towards the position of a separate unit or performing maneuvers near the position area, the command promptly decides to deploy the unit and remove it from the attack to a safe distance. The combat support must be rapidly dismounted and redeployed to a new position both during the day and at night to avoid being hit. This requirement and the exhaustion of the combat crew leads to the fact that the personnel make mistakes and miss operations when performing operations to deploy the 19G6 radar. A frequent mistake is to skip the process of disconnecting the flexible waveguide of the antenna-feeder system, which leads to damage to the radar.

The work presents proposals for the protection of a flexible waveguide to prevent its mechanical damage when the antenna-feeder system is folded.

We propose to protect the flexible waveguide with a safety limit switch that will block the voltage supply to the antenna folding motor if the flexible waveguide is not disconnected.

The proposal is expected to improve the reliability of the antenna-feeder path of the existing 19G6 radars.

DEVELOPMENT OF PROPOSALS FOR THE CONSTRUCTION OF A DIGITAL SIGNAL SYNTHESIZER FOR MULTIFUNCTIONAL RADARS WITH ADAPTIVE SCANNING MODES

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In the context of the Russian-Ukrainian war, the enemy is actively deploying numerous aerial assets, including reconnaissance and attack unmanned aerial vehicles (UAVs), guided aerial bombs, cruise missiles, aeroballistic missiles, and ballistic missiles, which consistently infringe upon Ukraine's state borders and airspace. Consequently, the ongoing advancements in air attack capabilities and their tactical deployment demand further improvements in the efficiency of radio-technical troops (RTT) systems.

This work analyzes the requirements for the dynamic range of probing signal parameters in contemporary radar systems (RLS). It demonstrates the need for rapid adjustments to signal parameters and swift transitions between different operational modes. Existing techniques for generating complex signals are examined, concluding that signal synthesizers in modern radar systems (RLS) should be based on digital methods. Various construction approaches for these synthesizers are analyzed, and a comparative study of different types of digital signal synthesizers (DSS) is presented.

Furthermore, the operation of digital signal synthesizers is mathematically modeled. A mathematical model is developed to objectively evaluate the quality of digitally generated signals, considering both discretization and quantization errors. Utilizing this model, the analysis focuses on the level of distortions introduced by quantization, specifically examining its dependence on the resolution (bit depth) of the digital-to-analog converter.

RECOMMENDATIONS ON THE USE OF MOBILE NETWORKS ON THE FRONT LINE

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With the beginning of the full-scale aggression of the russian ederation against Ukraine, the problem of ensuring the covert movement of troops and the safe location of personnel in positions in the face of enemy electronic intelligence (EW), both ground-based and airborne, has arisen. This should take into account the availability of mobile phones used by military personnel to control units as a backup.

A study was conducted to detect the accumulation of mobile phones by enemy electronic warfare means, including the use of unmanned reconnaissance aircraft near the line of contact during the russian-ukrainian war.

During the study, mobile phones were used in false positions, which were switched on and off remotely for a certain period during the operation of enemy ground-based electronic warfare systems. In addition, mobile phones were turned on when reconnaissance aircraft were detected on the screen of the automated workstation of the command and observation post, as well as when unmanned aerial vehicles were visually observed in the area of false positions.

On the basis of the study, the safe distance from the line of combat contact at which mobile phones can be used by the unit was determined. The types of unmanned reconnaissance aircraft that detect mobile phone signals are roughly defined (in addition to the known ones). Recommendations are given on the safe duration of use of mobile phones within the reach of enemy weapons, as well as the use of the maximum number of simultaneously switched on mobile phones, to which there is no reaction (fire impact) of the enemy.

DEVELOPMENT OF AN IMPROVED NOISE JAMMING SIMULATOR FOR VHF-BAND RADAR SYSTEMS

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The analysis of the use of radar weapons during the Russian-Ukrainian war shows a tendency to increase the growth of electronic warfare (EW), which requires an increase in the efficiency of electronic equipment, radar facilities and information processing and transmission systems in the face of natural and deliberate interference.

Simulating signals and interference in radar systems is crucial for testing and evaluating the performance of radar systems in various scenarios. By simulating different signals and types of interference, engineers can ensure that radar systems operate efficiently and reliably in real-world environments. Another important aspect of using signal and jamming simulation systems is the education and training of radar operators, which allows them to improve their skills in different conditions and situations.

A scheme of a noise generator based on bipolar transistors is proposed in this paper. The main elements of the circuit have been calculated, and mathematical modeling of the device has been carried out. As a result of the mathematical modeling, the time and spectral representation of the signal at the output of the noise generator has been obtained. An analysis of the noise characteristics of the circuit has also been performed, showing that the spectral noise density is nearly uniform within the frequency range from 1 Hz to 200 MHz. The proposed circuit is advisable to use as a noise generator in interference simulation systems during the modernization of meter-range radar units.

DEVELOPMENT OF PROPOSALS FOR IMPROVING THE EFFICIENCY OF INTERPULSE SIGNAL PROCESSING IN 35D6 TYPE RADARS

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The interpulse processing system of the 35D6-type radar has been analyzed. It has been shown that such radars use non-adaptive filter-based moving target indication (MTI) compensation systems with fixed rejection zones, which do not take into account the current characteristics of passive interference.

Staggered pulse repetition frequency causes varying inter-pulse phase shifts within the pulse groups of a packet. The "semi-coherent" accumulation of energy from the pulses in the incoming packet results in losses in the signal-to-(interference + internal noise) ratio.

An adaptive suppression filter based on digital auto-compensators has been proposed. These allow the interpulse signal processing system to adapt to the shape of the interference power spectrum, its intensity, and radial velocity. Such advantages provide not only improved efficiency in suppressing passive interference but also a higher radar target visibility index under jamming conditions.

Fully coherent processing of the pulses in the incoming packet is implemented by using the standard discrete Fourier transform (DFT) module solely as an energy accumulation filter, with minor adjustments to the DFT algorithm.

VISUAL-IMITATIONAL MODELING OF ALGORITHMS FOR PROCESSING COMPLEX ECHO SIGNALS IN THE П-18МА AND П-18 "МАЛАХІТ" RADARS WITH THE PURPOSE OF IMPROVING THE DETECTION OF AIR OBJECTS WITH A LOW LEVEL OF RADAR VISIBILITY BASED ON THE EXPERIENCE OF THE RUSSIAN-UKRAINIAN WAR

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Currently, the task of comprehensive study, research, and evaluation of the efficiency of complex echo signal processing algorithms in the П-18МА and П-18 "Малахіт" radar stations remains relevant to improve the detection of airborne objects with a low radar visibility level. To address the full range of issues related to this task, it is proposed to use visual-simulation Simulink models that simulate the behavior of digital processing algorithms for complex echo signals in these types of radar systems.

The report presents general approaches to creating visual-simulation Simulink models for modeling digital processing algorithms of complex echo signals implemented in the П-18МА and П-18 "Малахіт" radar systems. The visual-simulation modeling was carried out using the Simulink package from the MATLAB system library. The operability of the Simulink models was verified through a series of experiments, the results of which do not contradict known conclusions.

The proposed visual-simulation Simulink models allow for the assessment of the efficiency of existing digital processing algorithms and offer extensive opportunities for improving and optimizing them.

PROPOSALS FOR IMPROVING THE EFFICIENCY OF A PORTABLE GROUND SURVEILLANCE STATION THROUGH DIGITAL MODERNIZATION OF THE RECEIVER UNIT

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In the context of the increasing role of low-altitude and small-sized enemy aerial attack means on the battlefield, the task of promptly detecting UAVs to ensure the protection of critically important infrastructure is gaining particular relevance. This necessitates the comprehensive development of the Defense Forces' capabilities, in particular the modernization and improvement of existing radar systems capable of detecting low-altitude air targets and classifying their types regardless of the time of day or weather conditions.

The article presents the results of experimental studies on the effectiveness of using the PSNR-5 portable ground surveillance station for detecting small-sized aerial objects. It was established that the limiting factors for the further practical application of this radar are its outdated component base, non-compliance with modern combat requirements, and the lack of integration with current systems for data collection, processing, and transmission.

In order to eliminate the identified shortcomings and improve the efficiency of radar stations, a transition from the outdated analog component base to modern digital receiving devices is proposed. This transition enables the fundamental possibility of implementing a wide range of digital signal processing methods that enhance noise immunity, accuracy, and operational reliability. In particular, this includes: adaptive filtering to suppress noise-like and narrowband interference; coherent processing using Doppler filters to detect moving targets; and detection algorithms based on the maximum likelihood criterion to improve the recognition of weak signals.

PROPOSALS FOR THE CONSTRUCTION OF A RECEIVING DEVICE FOR A RADAR WITH A HIGH RANGE RESOLUTION

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Given the experience of the russian-ukrainian war, we can say that the tactical, technical, economic, functional and other capabilities of electronic means used in the combat zone are largely determined by their design and production technology. Therefore, there is a need to revise outdated approaches and take into account modern requirements for the design and manufacturing technology of weapons and military equipment, including radar, which was done in this paper.

Unlike other signals, radar signals have their own characteristics. The reflected signals are usually very weak and always contain interference. The sources of the latter can be the Earth, the atmosphere, space, and artificial sources of interference. The receiver adds its own noise to this. There may also be random distortions of the signal parameters. All of this places specific requirements on radar receivers, such as high gain, low noise figure, consideration of the Doppler spectrum of the signal, and optimal or consistent processing.

The receiver in question is tasked with providing information about the presence or absence of a target and ensuring the specified probabilities of false alarm and correct detection. The latter is achieved by normalizing the signal and ensuring the required signal-to-noise ratio. To increase the detection range, a phase-code-manipulated radio pulse is used, which simultaneously allows to increase the range and Doppler resolution.

IMPROVING THE QUALITY OF DETECTION AND TRACKING BY RADAR OPERATORS OF STRIKE UNMANNED AERIAL VEHICLES OF THE "SHAHED" TYPE AND ITS ANALOGUES BASED ON THE EXPERIENCE OF COMBAT OPERATIONS

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Analysis of statistical data for the period from January 2024 to April 2025 showed a significant increase in the intensity of the enemy's use of strike Unmanned Aerial Vehicles (UAVs) of the "Shahed"/"Geran-2" type and decoy drones "Gerber" and "Parody".

Here are the main problematic issues:

RCS(Radar Cross Section). Small effective scattering area (ESA): Due to their relatively small size and the use of composite materials (carbon fiber, fiberglass). Altitude. These vehicles fly at extremely low and low altitudes, sometimes in the terrain-contouring mode – for the purpose of covert flight to the strike object – low-altitude flight hides the drone in interference from the reflective surface, although they can reach flight altitudes of up to 4000 m in order to avoid possible damage from mobile fire groups.

Cruising speed. The cruising speed is approximately 180 km/h, which corresponds to the class of low-speed air objects.

Massive attacks. Launching drones in large groups or waves is aimed at overloading and saturating air defense systems.

Difficulty in identification. Use of false targets with a Luneberg lens to increase its RCS to the level of the Shahed UAV.

The purpose of our work is to provide the radar operator with methodological recommendations for the timely detection, stable tracking and correct identification of air targets of the "Shahed" type, providing a detailed explanation of the physical processes affecting detection, its possible maneuvers in the radar detection zone, and for the correct adjustment of the radar by the operator.

PROPOSALS FOR INCREASING THE EFFICIENCY OF RADAR SURVEILLANCE THROUGH MODERNIZATION AND UNION OF EXISTING RADAR STATIONS IN THE CONDITIONS OF THE RUSSIAN-UKRAINIAN WAR

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Based on combat experience of the russian-Ukrainian war, it is clearer that the enemy's use of air attack means – cruise missiles, UAVs (in particular, the Shahed-136 type), as well as aircraft bombs and operational-tactical aviation is significantly increasing, and the methods of their use are also dynamically changing. This creates a high level of threats to strategic and military facilities and infrastructure.

Modern challenges for radar means – small values of the radar cross section, low visibility and maneuverability of modern air attack means, which reduce the effectiveness of traditional radars. Insufficient level of equipment renewal and slow adaptation to new types of threats reduce the effectiveness of air defense response.

Obviously, radar modernization is necessary to increase sensitivity to objects with a small radar cross section, especially UAVs. Introduction of digital phased array antennas (DFAR) – for quick reconfiguration and multitasking. But radio engineering units are armed mainly with domestic radar means. The production of fundamentally new models requires a fairly long period of time and resources. Instead, the network approach to radar – combining reconnaissance tools into a single information and analytical system could significantly improve the quality of radar reconnaissance even now. This became possible thanks to the Modernization of computing power for instant data analysis and real-time decision support. In addition, digital signal synthesizers allow you to experiment with the choice of a probing signal to optimize radar parameters for better detection and more accurate determination of the coordinates of certain classes of air objects.

PROPOSALS FOR THE CONSTRUCTION OF AN L-BAND SURVEY RADAR

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At present, the growing number of unmanned aerial vehicle (UAV) flights, the rapid development of their functional capabilities, the deep integration of drones with army units' firepower, and the uncontrolled use of strike UAVs pose a threat to Ukraine. There is a need for high-quality detection of various UAVs and their guaranteed tracking in the airspace of Ukraine at extremely low and low altitudes.

In order to improve the quality of detection and tracking of low-altitude targets, it is advisable to develop a promising radar with a phased array of L-band waves with high resolution in range and angle, which will take measures to reduce the intensity of the signal reflected from the underlying surface.

Using radar signals L-band radar signals have a number of advantages in detecting small aerial objects, which include UAVs. This is due to the fact that these objects have dimensions commensurate with the wavelength of L-band sensing.

Modern methods for measuring the range and angular coordinates of airborne targets are analyzed. The parameters of a broadband multifrequency sensing signal are selected.

A structural diagram and algorithm for the operation of the digital range measurement channel of the advanced L-band survey radar are proposed.

PROPOSALS FOR ENHANCING TARGET CLASS IDENTIFICATION IN RADAR SYSTEMS

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Pattern recognition devices are currently an integral part of technical decision-making systems. Most modern radar systems incorporate recognition devices or their components. The constant complication of the airborne jamming environment and the expansion of the range of observed objects necessitate improving the efficiency of the classification process.

When using active radar, information about the class of the observed object is contained in the echo signal. One of the current directions in the theory and practice of automatic target recognition is the analysis of radar signatures or range profiles. In radar recognition tasks, signal and trajectory features of observed objects are most commonly used. To increase classification efficiency, these features must fully characterize the object’s image and be both stable and informative.

The author proposes enhancing existing methods for air target recognition based on range profiles and echo signals by applying the nonparametric BDS statistic. The BDS statistic values are proportional to the size and complexity of the target's shape, which is reflected in the structure of the echo signal under conditions of high range resolution. The key distinction from existing methods is that it does not compare reference range profiles or frequency spectra of echo signals, which vary depending on the target's aspect angle. Instead, it determines the range of BDS statistic values for a specific aerial object, accounting for changes in aspect.

The results of this work can be applied in the development of target classification algorithms for radar systems that use wideband signals.

RECOMMENDATIONS ON USING MICRO-DOPPLER SPECTRA FOR RADAR IDENTIFICATION OF AIR OBJECTS

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The moving elements of the air objects (propellers, turbines blades) cause amplitude modulation of the raflected signals. Characteristics of rotor (turbine) modulation, or micro-Doppler characteristics as referred to in English literature, can be used as reliable features for non-cooperative identification of the air object class (type). The characteristics primarily include the width of the modulation spectrum and the interval between the frequency components of the lined modulation spectrum. By separating (assessing) the specified parameters based on the results of the reception of reflected signal, it is possible to carry out target non-cooperative identification. The implementation of radar non-cooperative identification allows for more effective target distribution among the surface-to-air missile systems and aviation. Sdentification enables the assignment of fire assets primarily to eliminate the most important and dangerous targets.

The use of micro-Doppler parameters of the amplitude modulation spectra is justified as a stable feature for their radar identification. Mathematical modeling of the spectra of the blade modulation of helicopters was carried out using a known numerical calculation method. The results of the modeling of the blade modulation spectra of two helicopter models in the UHF and SHF band are demonstrated. An analysis of the influence of various parameters on the micro-Doppler characteristics is conducted, and the possibility of their use for robust radar identification of air objects is justified. The proposed system is narrowband, allowing for a sufficiently simple practical implementation without the expansion of the probing signal spectrum used in the radar.

СЕКЦІЯ 6

РОЗВИТОК ОЗБРОЄННЯ, ІНФОРМАЦІЙНОГО ЗАБЕЗПЕЧЕННЯ ТА СПОСОБІВ ЗАСТОСУВАННЯ ВІЙСЬК ПРОТИПОВІТРЯНОЇ ОБОРОНИ СУХОПУТНИХ ВІЙСЬК ЗБРОЙНИХ СИЛ УКРАЇНИ. ПРОТИПОВІТРЯНА ОБОРОНА ВІЙСЬК В УМОВАХ ПОВНОМАСШТАБНОЇ АГРЕСІЇ РОСІЙСЬКОЇ ФЕДЕРАЦІЇ

Керівники секції: к.т.н. доц. пр. ЗС України Станіслав ПІСКУНОВ
Секретар секції: солдат Роман ЯРОЩУК

METHOD OF SUBSTANTIATION REQUIREMENTS FOR MOBILE ARMAMENT OF THE GROUND FORCES

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The report analyzes the state and trends in the development of modern weapons systems of the world's leading countries.

The results of the analysis show that one of the main directions of development of modern weapons systems is the integration of technical means of intelligence, automated control systems (automated control systems) and means of destruction into a single functional system. Such a system should detect and destroy enemy objects (ground and air targets) in real time during hostilities (local conflicts).

When creating new mobile weapons of the Land Forces, for example, combat vehicles (CV) of mobile weapon systems (MWS), the task arises to formulate and justify the requirements for the movement parameters and mobility index of CV of MWS, and to assess the probability of performing a combat mission.

Thus, ensuring the ability of the CV to conduct operations of movement and use of weapons in the basing area, taking into account changes in the conditions of use, is an urgent scientific task. The solution of which will reduce the probability of defeat of the CV and increase the effectiveness of the combat use of MWS.

It is noted, that the survivability of a CV depends on the parameters of its movement and the overall mobility index during the performance of a combat mission, which affect the time spent by the CV in a particular state. The parameters of CV mobility include the following: the minimum permissible speed of CV movement, the permissible time for preparing and conducting weapons use operations, the permissible time for CV to fold and leave the firing position after the use of weapons.

DEVELOPMENT OF AN OPTIMAL METHOD AND ALGORITHM FOR SEARCHING FOR AIR TARGET BY A MULTIFUNCTIONAL RADAR STATION WITH A PHASED ANTENNA ARRAY OF A SHORT-RANGE ANTI-AIR MISSILES COMPLEX

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The paper considers the problem of improving the algorithms for surveying the working area for a multifunctional radar with a PAR in the air target search mode. To solve the problem, an approach is proposed that is related to the discretization of the survey process, both in time and in state. The area in which the targets move is divided into cells, each of which is identified with a certain position of the target. To solve the problems of optimal control of the distribution of energy resources when surveying the area in the search mode, it is advisable to use a mathematical apparatus based on the Pontryagin maximum principle in discrete form. The optimality criterion is chosen to maximize the average Shannon amount of information in observations. Based on the developed method of optimal survey control for the MF radar with a PAR in the air target search mode, an algorithm for optimal control of the search for an unknown number of moving targets is synthesized. A mathematical simulation of the operation of the surveillance radar, which implements the developed algorithm of controlled inspection, was carried out. For comparison, an algorithm with a uniform distribution of search efforts across the cells of the inspection zone and their sequential (in time) inspection was used. Analysis of the results of mathematical simulation shows that when using the algorithm of optimal inspection control in the search mode, the target search time is reduced by 20-50%, the radar throughput increases by an average of 15-20% and the quality of target service does not deteriorate.

DEVELOPMENT OF AN OPERATIONAL ALGORITHM FOR A PROMISING MEANS OF FUNCTIONAL DEFEAT OF UAVS

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Due to the extensive use of UAVs of various types by the enemy, the issue of neutralizing or suppressing aerial attack systems through alternative (advanced) methods has become increasingly relevant. These include technical means originally used in everyday civilian life as well as electronic warfare systems.

This study proposes the use of new physical principle weapons for countering UAVs, specifically functional disruption and suppression means (hereafter referred to as FDSM).

The research focuses on exploring the use of advanced weaponry capable of effectively exerting destructive influence on aerial attack systems. To achieve this goal, the application of advanced functional disruption means targeting the electronic equipment of aerial threats is suggested. The necessity of using FDSM to inflict destructive impact on enemy UAVs is substantiated.

RESULTS OF THE ANALYSIS OF THE USE OF THERMAL IMAGING BINOCULARS AS A MEANS OF AIMING IN NIGHT CONDITIONS ON BM 9A34M2

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The intensive use of unmanned aerial vehicles (UAVs) and strike UAVs by the Russian Federation in the course of the aggressive war against our country requires the search for quick and effective solutions to combat targets of this class both in daylight and at night. At the same time, open expert assessments indicate that the intensity of aerial reconnaissance and adjustment of fire strikes on ground targets at night by the enemy does not decrease, so an essential solution to combat enemy UAVs at night is the use of thermal imaging devices as means of guiding anti-aircraft guided missiles (AGM) 9M37, 9M333 at night. Therefore, the use of thermal imaging devices for targeting may be appropriate and needs to be analysed. The report describes the use of a combined optoelectronic device designed to inspect the terrain and observe the objects of interest to the user in any light conditions, under conditions of limited vision, to actively measure the distance to the object selected by the user using a built-in laser rangefinder that is safe for the human eye, to record the image on the built-in flash memory at distances of 3000 m ± 15% at ambient temperatures from –30° to +55° with relative humidity of no more than 95% and atmospheric. The device was mounted on the launcher in a protective casing to protect it from various damages during movement, a monitor was attached to the operator's viewing window, which does not interfere with the operator's view, and connected by cables, and the thermal imaging sight was aligned with the combat vehicle's (CV) sight at a remote point at a distance of up to 2 km. With this device, the operator can detect and destroy enemy air targets at night.

THE DEVELOPMENT OF A MATHEMATICAL MODEL OF THE FLIGHT CONTROL SYSTEM FOR A MISSILE FOR ANTI-AIRCRAFT COMPLEXES WITH A THREE-POINT GUIDANCE METHOD

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In the current realities of the Russian-Ukrainian war, the battlefield situation is complicated by the large number of aerial targets.

The experience of using anti-aircraft weapons demonstrates the high effectiveness of surface-to-air missile systems, especially those based on the principle of first-generation remote control, where targeting and automatic tracking of aerial targets do not require the thermal (infrared) signature of the target. This increases the range of targets the system can engage, but a problem arises due to the large number of aerial targets, resulting in a shortage of surface-to-air missiles.

To address this issue, the idea emerged within the armed forces to use aviation missiles, which, due to their tactical, technical, and dimensional parameters, can be adapted to anti-aircraft complexes.

When adapting different types of missiles, real-world experiments were used, which did not always provide the opportunity to assess the missile's compatibility with the control system.

Therefore, creating models, including mathematical ones, to study the "behavior" and compatibility of a missile with the control system in which it is planned to be used is highly relevant. This, in turn, would reduce both time and financial costs associated with experiments to select appropriate parameters for both the missile and the control system of the anti-aircraft complex during the adaptation process.

DEVELOPMENT OF A SOFTWARE SYSTEM FOR THE FUNCTIONING OF 1C91

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Since the beginning of a large-scale armed aggression against Ukraine, the enemy has been using the latest technologies that are not adapted to the training facilities of the Armed Forces of Ukraine (AFU). Our partner countries, including

Poland, France, the United Kingdom, Germany, Czechoslovakia and other countries, are actively helping and training our military. With the transfer of various military equipment for the Air Defence Forces (ADF) of the Land Forces (AF), such as the Gepard self-propelled anti-aircraft gun, Crotale-NG, and the KUB anti-aircraft missile system, which has been withdrawn from service in Ukraine, there is a problem with the availability of simulators for these systems aimed at developing the skills of personnel. Due to the limited number of anti-aircraft systems provided to us by partner countries, it is becoming more difficult to train personnel in training centres and higher military educational institutions. Using modern technologies such as modelling and simulation systems, combat management systems and others, we can improve the training of personnel and adapt to the current course of war.

The aim of the work is to develop and implement a new complex simulator for the maintenance of the 1C91 self-propelled reconnaissance and targeting system (SSTS) in the process of training personnel. The developed software system-simulator allows to improve the quality and efficiency of officer training, save the motor life of equipment without actual use, fuel and lubricants, and assess the correctness of inspections of various systems, which is of great importance in the context of the ongoing Russian aggression against Ukraine.

RESEARCH ON THE PARAMETERS OF THE DETECTION ZONES OF THE 2S6 TARGET DETECTION STATION BASED ON THE CHARACTERISTICS OF THE SECONDARY RADIATION OF THE MI-24P FIRE SUPPORT HELICOPTER

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Throughout the russian-Ukrainian war, the enemy continues to launch missile and air strikes on the territory of Ukraine. The enemy actively uses fire support helicopters (FSH) to ensure the effectiveness of the actions of the Ground Forces (GF). In order to reduce the time of approach and increase the combat radius of helicopters, the enemy deploys airfields near the state border of Ukraine (SBU) and in the occupied territories of Ukraine. Combating FSH is an urgent task for the air defense troops of the Ground Forces of the Armed Forces of Ukraine. The effectiveness of the use of means of combating the air enemy can be significantly increased by solving the tasks of radar detection, recognition, assessment of the functional state of individual targets and planning their actions. As signs of recognizing FSH with propeller engines, the parameters of the propeller modulation spectra, which are caused by the rotating blades of the propellers of the engines, can be used. The model of the surface of the Mi-24 helicopter is shown, which was obtained on the basis of the method of mathematical modeling of the surface of the object of a complex geometric shape.

The radar characteristics of the Mi-24 helicopter model in different frequency ranges were analyzed. The circular average and median values of the effective scattering surface (ESR) of the Mi-24 helicopter were estimated. The main tactical and technical characteristics (TTC) of the target detection station (TTS) of the 2S6 self-propelled anti-aircraft gun (ASG) were analyzed, which affect the detection range.

ANALYSIS OF METHODS FOR MANAGING THE DISTRIBUTION OF ENERGY RESOURCES IN MULTIFUNCTIONAL RADAR STATION DURING AIR TARGET SEARCH AND TRACKING MODES

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As a rule, a multifunctional radar station (MFRS) operates with a fixed control cycle consisting of timing intervals. These intervals represent time segments during which the MFRS performs one of its radar functions: either target search or tracking. The sequence of these functions embedded within the timing intervals remains unchanged throughout the radar's control cycle. Due to the algorithm's fixed structure, it cannot adapt to the evolving air situation. As a result, certain timing intervals may remain unused. These unused segments can potentially be repurposed to enhance the radar functions of the MFRS. Because of the unchanging functional order of the radar algorithm, the full operational time of the radar is not always utilized. In other words, the MFRS does not use its full potential. The remaining time is placed in reserve and remains unutilized, which in turn affects the performance of the station’s operating modes. These modes do not operate at full capacity. Therefore, by modifying the control cycle of the station’s operational modes, the throughput of the MFRS can be increased.

An analysis of existing methods for managing the energy resources of radar systems for detection and tracking reveals that these methods do not allow for full utilization of the radar's informational capabilities or for effective response to rapidly changing external conditions. Current radar management methods in air target detection mode generally assume a uniform distribution of search resources across the area of responsibility. Efficient allocation of energy resources in an air defense MFRS is crucial.

ENHANCING THE EFFECTIVENESS OF MILITARY TRAINING THROUGH SOFTWARE SIMULATION TECHNOLOGIES

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One of the key factors ensuring the alignment of military education with modern standards is the integration of information technologies and digital solutions into the training process. This is especially relevant when preparing personnel to operate military equipment and systems. In the context of the constraints imposed by the ongoing Russia-Ukraine war, the development of simulation models for virtual training in various aspects of combat operations becomes crucial. This approach allows for training military crews and technical staff to operate different types of weaponry and military hardware.

To ensure the effectiveness of training using digital tools, three essential components are required: personnel, material and technical base (including software and digital devices), and instructional materials for conducting lessons. The development of simulation software enables the training of specialists in the operation of the launch system of the 2P25 "Kub" surface-to-air missile system without the need for actual weaponry.

Analyzing the most significant factors that affect training quality demonstrates that the use of digital technologies significantly improves the preparation of personnel even with limited resources and time. This provides several advantages, such as the ability to train larger groups of personnel simultaneously, reduced strain on equipment, effective utilization of pedagogical resources, individualized training, the ability to model various combat scenarios, and the assessment of knowledge retention levels.

FUNCTIONING SOFTWARE SYSTEM DEVELOPMENT OF THE GEPARD SELF-PROPELLED ANTI-AIRCRAFT GUN USING CREW ACTION ALGORITHMS

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One of the most important stages in the process of repelling enemy air strikes in the realities of a full-scale war with the russian federation is the training of combat vehicle crews. The work carried out made it possible to develop software in the form of a simulation model of the main control units of the Gepard self-propelled anti-aircraft gun for remote training and preparation of combat vehicle crews. The availability of a wide range of software simulating the operation of air defense systems and complexes will contribute to more effective personnel training, assisting military personnel in mastering educational material, as well as reducing the burden on material and technical base and avoiding fuel and lubricant expenses.

The concentration of military personnel gathered in one place for training or preparation, especially with modern weaponry, is a priority target for the enemy. Therefore, the availability of software or simulation models of basic types of armament and military equipment of the Army Air Defence units that eliminate the need for concentration of military personnel for training and provide them with the opportunity to undergo certain stages of training independently of their location will also be beneficial as a form of distance learning for avoiding threats to the lives and health of military personnel in the event of enemy missile strikes or drone strikes deep into the territory of Ukraine.

USE OF SOFTWARE SIMULATORS FOR TRAINING IN THE FIELD OF MILITARY EDUCATION

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Information technology is an integral part of the modern world, significantly shaping the future development of humanity. Under these conditions, the education system also requires evolutionary changes. Therefore, it can be said that the issue of implementing the digitalization process is highly relevant in the modern educational environment, as high-quality teaching of disciplines today cannot be carried out without utilizing the tools and opportunities provided by information technology.

Let us consider the advantages of using modern tools and technologies to enhance efficiency and reduce costs in training personnel by integrating advanced tools and technologies, such as computer simulation programs, into the learning process.

The use of computer simulation programs allows military personnel to visualize and effectively understand abstract concepts and processes. They can observe how parameters change and how they influence outcomes. Crew members can conduct experiments and simulations in a safe virtual environment without risking expensive equipment or causing negative consequences.

The global trend of digital transformation signifies a shift from passive observation to simulation-based learning, which is significantly more accessible, effective, and engaging, without increasing training costs. Compared to outdated teaching methods and tools that no longer meet modern requirements for professional skills development, it is a far more effective way to achieve educational and instructional goals.

THE SYSTEMS APPROACH TO THE INTERACTION OF AIR DEFENSE AND ELECTRONIC WARFARE UNITS IN THE CONTEXT OF A CHANGING BATTLEFIELD

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The analysis of the experience of conducting a liberation war against the occupying enemy forces provides a basis for asserting that future air assault and air defense operations will be characterized by spatial expansion, high dynamics of combat actions, significant deterioration of conditions for the use of command and weapon control systems, in the context of the massive deployment of electronic warfare and radio-electronic means.

Merely coordinating fire planning and setting up radio-electronic interference at the tactical level is insufficient. This is due to the fact that electronic suppression is most effective when the delay time of information circulating in control systems is minimal compared to the duration of the control cycle during which this information remains valuable.

Therefore, the specific conditions of combat actions involving the forces and means of the Ground Forces’ air defense and EW units in combat formations, the lack of theoretical research, and practical recommendations in this area prompted the need for further scientific research and experiments. Furthermore, it is necessary to develop a methodology to assess the expected outcomes of joint actions between air defense and EW units and to provide scientifically grounded recommendations for their effective joint combat use in air defense units or in combined mobile groups.

APPLICATION OF MULTIFREQUENCY ANTENNA ARRAYS IN COGNITIVE RADAR SYSTEMS

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Modern radar systems for anti-aircraft weaponry must operate effectively in complex jamming environments and under conditions involving multiple low-altitude and small-sized targets. Cognitive radar systems can meet these requirements. This direction involves enhancing radar capabilities through intelligent adaptation of operating modes and system parameters according to the characteristics of the external environment and newly acquired knowledge during operation.

Multifrequency antenna arrays offer a unique opportunity for application in cognitive radars due to their ability to control the spatial-temporal distribution of radiated energy in space. Such arrays enable the implementation of

MIMO (Multiple-Input-Multiple-Output) mode, where each element transmits a signal with its own central frequency.

For a cognitive MIMO radar with a multifrequency array, a methodology has been proposed for minimizing radiated energy in the target area while maximizing the received signal energy at the receiver. The control algorithm for cognitive radar parameters involves transforming a non-convex second-order optimization problem into a convex one, which is solved using the splitting method and convex optimization techniques. Simulation results are provided, confirming the feasibility of the proposed approach for reducing the probability of detection of cognitive MIMO radars without degrading the quality of received signal detection.

СЕКЦІЯ 7

МЕТРОЛОГІЧНЕ ТА ЕЛЕКТРОЕНЕРГЕТИЧНЕ ЗАБЕЗПЕЧЕННЯ ОЗБРОЄННЯ ТА ВІЙСЬКОВОЇ ТЕХНІКИ З УРАХУВАННЯМ ДОСВІДУ ВЕДЕННЯ БОЙОВИХ ДІЙ

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RESEARCH ON MODERN CALIBRATION APPROACHES FOR HIGH-RESOLUTION DIGITAL MULTIMETERS

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Modern digital multimeters are capable of measuring a broad spectrum of electrical parameters, including AC and DC voltage, current, resistance, as well as frequency, period, capacitance, diode characteristics, and temperature.

A pressing issue in the metrological field is the calibration methodology for 5½- and 6½-digit digital multimeters, as current regulatory frameworks and technical resources fall short of modern calibration demands – especially in terms of the minimal number of reference standards required.

To investigate this, several key documents were examined: Calibration Certificate UA/25/230801/000681, UA/26/230801/000567 of Agilent 34401A, UA 25/230801/000685 of Keysight 34461A (Calibration service of the SE "UKRMETRTESTSTANDART"), the Agilent 34401A Service Guide, Calibration Certificate № 1-5607144213-1 (in accordance with ISO/IEC 17025:2005), Technical Bulletin 9-6625-2315-24 (Calibration Procedure for Hewlett-Packard Multimeter Model 34401A), and the Military Standard VST 01.210.022–2013 (Calibration Procedure for Agilent 34401A under the Metrological Support System).

A comparative analysis of foreign and domestic calibration practices reveals considerable disparities, primarily attributed to constraints in local metrological infrastructure. The integration of modern instrumentation is essential to overcome the reliance on obsolete equipment with expired service life, streamline calibration workflows, improve operational efficiency, and support the implementation of automated calibration systems with integrated data exchange capabilities.

THE IMPORTANCE OF DEPLOYING INFORMATION AND MEASUREMENT SYSTEMS IN METROLOGICAL SERVICES DURING WARTIME CONDITIONS

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Amid the challenges of the Great War, the urgency of reformatting the existing system and transitioning to a more advanced and technologically aligned structure became increasingly evident. A key driver of this evolution was the adoption of Information and Measurement Systems (IMS). Recognized as a crucial element within the technological infrastructure of the Armed Forces of Ukraine, IMS have become instrumental in enhancing the precision of measurements and ensuring reliable quality control across vital operational domains.

Warfare imposes new demands on metrological science and practice, particularly under conditions of limited resources, fluctuating environments, and rapid technological shifts. Contemporary IMS, equipped with automated data collection and processing capabilities, enable real-time information transmission. Significantly, such automation minimizes the need for direct human presence in hazardous or inaccessible zones, allowing remote monitoring and thereby reducing risks to personnel safety and health.

These systems are inherently adaptable, allowing swift configuration for diverse measurement needs – from basic indicators like temperature and pressure to complex metrological parameters. IMS facilitate real-time monitoring of equipment conditions, enhancing situational awareness and operational readiness.

Moreover, integration with broader information and management platforms supports a unified approach to resource oversight, embedding IMS within a comprehensive information-analytical ecosystem. This connectivity promotes seamless data exchange between various units and departments. Designed with high resilience, IMS can function reliably under extreme conditions, maintaining operability even during power outages or when technical parameters fluctuate.

In conclusion, the deployment and utilization of IMS in metrological operations during wartime are not only advisable but essential. Their implementation is critical for sustaining equipment functionality, ensuring operational efficiency, and enabling a strategic leap toward a modernized technological framework.

ANALYSIS OF THE INFORMATION AND MEASURING SYSTEM FOR PROCESSING THE MEASUREMENT RESULTS OF A DIGITAL MULTIMETER

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In the context of repulsing the armed aggression of the Russian Federation, when ensuring the country's defense capability and maintaining critical infrastructure are priority tasks, in-depth analysis and optimization of existing information and measurement systems (IMS) is of particular importance. The use of IMS significantly reduces the time for controlling critical parameters of weapons and military equipment samples, while increasing the reliability of the results obtained. This, in turn, helps speed up decision-making processes regarding their technical condition and further operation. A detailed analysis of the IMS software allows us to evaluate its effectiveness in eliminating manual processing of measurement results, which is a laborious and time-consuming process, as well as to identify potential bottlenecks and opportunities for further modernization. Automation of this process with the help of IMS is a relevant and promising direction that has significant potential for increasing the efficiency, speed and accuracy of measurements, and therefore requires a thorough comprehensive analysis.

The analysis of the IMS shows that it allows to automatically read data from a digital multimeter and promptly transfer it to a computer for further processing and analysis. This significantly reduces the time required for measurements, primary processing and interpretation of the results, which is critical in a time-sensitive environment. Automated data collection and processing minimizes the influence of the human factor and avoids accidental errors associated with manual data entry and processing. The software may include advanced functionality such as visualization of data in the form of visual graphs and charts to facilitate their perception, statistical processing of results to identify patterns and anomalies, automated report generation to document measurement results, and the creation of structured databases for long-term storage and subsequent analysis of the accumulated information. All these aspects are important components for a comprehensive analysis of the capabilities and efficiency of the system under study. Further analysis can be aimed at assessing the metrological characteristics of the system as a whole, its resistance to external influences and the possibilities of integration with other information systems.

TECHNICAL MODERNIZATION OF THE MOBILE MEASUREMENT EQUIPMENT LABORATORY УА2-4/А

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The mobile measurement equipment laboratory УА2-4/А performs a critically important function of calibrating and repairing radio-technical, electrical, and thermo-mechanical measuring instruments directly at their места of use.

The current modernization of this laboratory is a key stage in improving the technical infrastructure of the Armed Forces, aimed at increasing the accuracy, reliability, and efficiency of measurement procedures. The main goal of the upgrade is the implementation of innovative measuring instruments, automated analysis systems, and energy-efficient solutions, which provide a qualitatively new level of diagnostics of the technical condition of military equipment.

Within the scope of the modernization, a complete replacement of outdated equipment with modern digital devices is planned – spectrum analyzers, digital oscilloscopes, laser measuring instruments, etc. – which guarantees increased sensitivity and measurement accuracy. Automated data collection and processing systems are also being implemented, which allow for the rapid analysis of results and the generation of real-time reports.

In the future, the development of the УА2-4/А laboratory is associated with integration into unified digital control systems for military equipment, the improvement of algorithms for processing large data arrays, as well as the use of artificial intelligence for in-depth analysis of measurement results. Overall, the modernization of this laboratory significantly increases the combat readiness of units by ensuring high speed, accuracy, and reliability of technical diagnostics.

ANALYSIS OF THE POSSIBILITY OF USING A DIGITAL SIGNAL PROCESSOR IN AN INFORMATION MEASURING SYSTEM FOR MILITARY PURPOSES

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In the context of the ongoing military aggression against Ukraine, the issue of increasing the efficiency and effectiveness of information and measurement systems (IMS) for military purposes is becoming increasingly important. The modern battlefield is characterised by dynamism, intense electronic warfare and the need to make decisions based on promptly processed information. In this regard, an in-depth analysis of potential technological solutions is key to ensuring an advantage on the battlefield.

One of the key areas for optimising the IIS is a thorough analysis of the potential of digital signal processors (DSPs). Their high computing power and ability to process signals in real time is critical for systems that require an instant response to events. Energy efficiency and the ability to implement complex algorithms make them extremely promising. The analysis of DSP performance shows their significant advantage over traditional analogue systems in conditions of complex electromagnetic interference. The use of DSPs makes it possible to achieve high measurement accuracy, reduce the response time of military systems and minimise the impact of interference. Programmability and the ability to update algorithms without the need to replace hardware provide flexibility in integrating DSPs into existing military systems. The analysis shows that this flexibility is critical for adapting to the rapidly changing conditions of modern warfare.

The use of DSP in TDFs used for the needs of the military, namely, the improvement of radar and navigation systems, which in turn will increase the reliability, adaptability and efficiency of systems in the conditions of electronic warfare, as well as ensure the speed and accuracy of measurements.

IMPROVEMENT OF THE METROLOGICAL SERVICE FOR THE S-300PS COMPLEX

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The S-300PS system requires high accuracy in measurements for stable operation. The use of outdated measuring instruments reduces service quality, affecting key components such as radar modules and guidance systems. Many old instruments no longer meet modern accuracy standards, leading to errors in voltage and current measurements, which can result in system malfunctions.

To address this issue, outdated instruments should be replaced with modern, high-precision measuring tools that ensure reliable performance in complex operational conditions. Ensuring accurate measurements is critical for the stable operation of the system.

Improving the metrological service also involves enhancing the qualifications of technical personnel. Specialized courses on modern measuring instruments will reduce errors and increase service efficiency. Updating the equipment and improving personnel qualifications will achieve greater accuracy and reliability for the S-300PS complex, ensuring its optimal performance.

PROPOSAL TO CREATION OF AN ELECTRONIC BASIS FOR MEASURING EQUIPMENT FOR THE NEEDS OF AIR FORCES

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The metrological support system encompasses a wide range of tasks, and optimizing the time required for each of them can greatly enhance the efficiency of subsequent operations. One of the most effective methods to improve the system’s performance is by establishing a unified electronic database for accounting all measuring equipment. Digitally organizing and categorizing this equipment significantly reduces the time needed to assess the current state of metrological support across individual military units (segments) under the jurisdiction of Air Commands.

This report outlines a proposed approach to developing such a centralized electronic database, detailing its structure, core components, and the interrelations between them. It also describes the procedures for populating the system. Examples of implementation demonstrate measurable reductions in the time needed to determine the need for restocking measuring equipment in military units. Moreover, the unified database simplifies the process of organizing an equipment exchange reserve for the Air Forces.

The adoption of a centralized digital register of measuring equipment enables instant assessment of both the technical condition and the availability of equipment across various units. This, in turn, allows for timely intervention to maintain the required level of metrological support for specific military units or segments.

ANALYSING THE PROTETCION OF METROLOGICAL INFORMATION IN THE MILITARY SPHERE: A STUDY OF PREVENTING UNAUTHORISED IMPACT ON KEY FACILITIES

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Metrological information in the defence industry is the basis for the operation of key facilities: from the accuracy of ballistic measurements and weapon calibration to the operation of navigation and communication systems. Any distortion or unauthorised access to this data threatens not only to disrupt combat readiness, but also to risk catastrophic consequences for national security.

The analysis of the specifics of military metrology systems includes the study of the peculiarities of operation in electronic warfare, accuracy requirements in combat conditions and the identification of critical vulnerability points. The analysis of modern threats includes the study of cyber attacks on quality control systems for electronic warfare equipment and risks from supply chains. Analysis of existing protection methods involves assessing the effectiveness of standard solutions, identifying shortcomings in current approaches and studying international experience in this area.

The implementation of the system will increase the resilience of military infrastructure, prevent technological sabotage and ensure the reliability of measurements in combat conditions, which is critical for the successful completion of combat missions.

ENSURING MEASUREMENT ACCURACY IN THE OPERATION OF RADIO TECHNICAL TROOPS' WEAPONRY AND EQUIPMENT

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Precise measurement support is a fundamental component in maintaining the combat readiness of radio technical troops, as measurement accuracy directly influences the reliability of airborne target detection and tracking. In operational conditions, even minor measurement errors may lead to incorrect identification of aerial objects, compromising the timely and effective deployment of air defense systems. A persistent issue is the continued reliance on outdated measuring instruments that fall short of current technical and operational standards. These devices often exhibit limited functionality, degraded measurement stability, and insufficient accuracy, which can hinder the timely detection of deviations in the performance of radar systems. This, in turn, reduces the reliability of diagnostic and calibration procedures. A practical solution involves gradually replacing obsolete equipment with new instruments featuring enhanced measurement precision and stability. Priority should be given to equipping measurement units with advanced signal generators, digital oscilloscopes, spectrum analyzers, and frequency counters that meet the demands of current military tasks. The use of these tools will improve the accuracy of equipment parameter verification, reduce maintenance time, and support the consistent combat effectiveness of radio technical units by ensuring dependable technical control of weapon systems.

OPERATING PRINCIPLES OF METROLOGICAL MAINTENANCE OF THE MOBILE CONTROL STATION 9V866

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Metrological support is an integral component of the technical maintenance system for weapons and military equipment, ensuring their reliability, functional accuracy, and combat readiness. It becomes particularly critical under active combat conditions, where measurement precision directly influences target engagement effectiveness and personnel safety.

The mobile control station 9V866 is designed for the maintenance and technical inspection of man-portable air-defense systems (MANPADS) such as "Igla" and "Igla-1." Mounted on a high-mobility GAZ-3308 chassis and housed within a sealed K3301D van, it offers operational flexibility across various climatic and geographic conditions.

The 9V866 includes the 9F719 control and diagnostic apparatus, which enables comprehensive diagnostics and scheduled maintenance of MANPADS components. This includes verification of parameters related to radio-electronic, navigational, and electrical equipment that impact targeting precision and hit probability.

The operating principle of the 9V866 involves the use of reference signals and high-frequency generators to simulate real-world operating conditions of MANPADS. This allows timely detection and correction of deviations in guidance and control systems performance.

Modernization of the 9V866 involves upgrading its measurement instruments, implementing digital diagnostic methods, and automating control processes. These improvements will enhance maintenance efficiency, reduce time and resource expenditures, and ensure rapid restoration of MANPADS combat readiness in the field.

Thus, the 9V866 mobile control station serves as a critical element in the metrological support system of MANPADS, securing their reliability, precision, and readiness for mission execution. Its continuous improvement and modernization represent essential directions in the technical development of the Armed Forces of Ukraine.

RESEARCH OF APPROACHES TO THE DEVELOPMENT OF SYSTEMS FOR AUTOMATIC ANALYSIS AND DIAGNOSTICS OF MEASUREMENT RESULTS DURING METROLOGICAL SUPPORT OF WEAPONS AND MILITARY EQUIPMENT

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Metrological support is one of the fundamental components in ensuring the functional reliability of weapons and military equipment.

In the context of modern warfare, the speed and accuracy of analyzing measurement results are critically important, directly affecting the combat readiness of military units. Traditional methods of analysis often require human intervention, which increases the probability of errors and reduces overall process efficiency.

Among the promising directions for the development of metrological support systems, the implementation of artificial intelligence (AI) technologies and machine learning methods is particularly noteworthy. These technologies help minimize the influence of the human factor, automate analytical processes, increase processing speed, and enable the prediction of potential failures. Furthermore, intelligent systems are capable of dynamically adjusting maintenance parameters based on the analysis of accumulated results.

The integration of automated diagnostic systems into the metrological support infrastructure for weapons and equipment is a strategically important step toward improving technical management. This approach reduces the risk of technical failures, optimizes maintenance and repair costs, and ensures the stable readiness of military units to perform combat missions. The use of advanced digital technologies enhances diagnostic accuracy and improves the overall reliability of the Armed Forces technical assets.

PRECULIARITIES OF METROLOGICAL SUPPORT FOR HIGH-FREQUENCY GENERATORS UNDER MODERN CONDITIONS

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High-frequency generators of the G4 type are widely used in the fields of radio communication, telecommunications, defense technology, electronic equipment testing, and scientific research, where the measurement objects are parameters of electromagnet-ic signals, including frequency, amplitude, and spectral characteristics. G4 generators are characterized by their ability to generate signals over a wide frequency range with high stability, as well as support frequency modulation modes, programmable control, and provide a low level of phase noise.

In modern conditions of the development of radio engineering systems and communication tools, the requirements for the metrological support of high-frequency generators have significantly increased. This is due to the growing need for accuracy, stability, and predictability of the generated signals, especially when operating in the millimeter and sub-gigahertz frequency ranges. Ensuring the reliability of parameter measurements of such generators is a key factor in the development of modern communication systems, radar, as well as aerospace and medical equipment.

To ensure the metrological reliability of generator calibration, a reference base is used, which includes national primary frequency standards, high-precision frequency counters, and spectrum analyzers with traceability to international standards. One of the current trends is the implementation of digital calibration and self-diagnostics methods, which allow for the automation of generator performance control. Digital calibration systems pro-vide high repeatability of results, reduce human error, and in-crease the overall efficiency of metrological support. The CNT-90 frequency counter provides high accuracy and fast response in frequency measurements, which is essential for real-time performance verification of G4-type generators in mission-critical applications.

JUSTIFICATION FOR CHOOSING A MODERN MULTIMETER TO IMPROVE METROLOGICAL SERVICE OF THE AUTOMATED CONTROL AND VERIFICATION MOBILE STATION 9V91

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Metrological maintenance of the automated testing and verification mobile station 9V91 includes monitoring and adjustment of 15 parameters, of which more than 10 are related to the measurement of DC and AC voltage. The most critical point is Control and adjustment of parameters of the converter PNK-124 of the KS-122 unit. Stage 70, which checks whether the DC voltage is within the following limits within the limits of 4 V ± 3 mV. This operation is performed using a universal voltmeter V7-34, the moral and physical obsolescence of which makes it necessary to look for an alternative among modern digital multimeters (4½-, 5½- or 6½-bit). According to the formulas for the accuracy class, which have two forms of recording, the absolute error of various multimeters was calculated and the relationship between it and the parameter tolerance was established. Thus, the 4½-bit multimeters UNI-T UT71E and Fluke 87V MAX have the corresponding ratios of 1:0.5 and 1:1. For 5½-bit multimeters, namely: Keithley 2110, IDM-8351, Keysight 34450A, Fluke 8808A, the ratios are, respectively: 1:4.4; 1:3; 1:2.7; 1:2.5. As 6½-bit multimeters, we chose Keysight 34461A and Keithley DMM6500, for which the corresponding ratios are 1:12 and 1:17. Based on this, it can be concluded that any 6½-bit multimeter can be used as a replacement for the B7-34 voltmeter, but from an economic point of view, Keithley 2110, IDM-8351 or other multimeters that meet the requirements of the measurement task and are 5½-bit should be considered.

USE OF DIGITAL SIGNAL PROCESSING IN MULTIPARAMETRIC MEASUREMENTS CONDUCTED BY MOBILE METROLOGICAL TEAMS

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The modernization of weapons and military equipment (WME) requires the implementation of advanced measuring instruments (MI) and the improvement of metrological support, which is critical for maintaining their operability and combat readiness. An effective solution is multiparametric measurements using digital signal processing (DSP), which provide high accuracy and reliability in assessing the technical condition of weapon, communication, and navigation systems. This approach takes into account various influencing factors through the application of testing, statistical analysis, and artificial neural networks.

As a result of the armed aggression by the Russian Federation, the number of mobile metrological teams (MMTs) operating in field conditions has increased; however, the existing analog MI do not always meet modern requirements. In these conditions, multiparametric measurements using DSP are especially important for monitoring power supply parameters. In particular, the Fluke 435-II analyzer enables accurate detection of energy losses, harmonic distortions, and other critical parameters. This is especially important for servicing portable counter-battery radar systems such as the AN/TPQ-48, 49, and 50, whose operation depends on stable power supply. Practice shows that malfunctions in these systems are often caused by power parameter instability, so the use of such instruments makes it possible to promptly detect and eliminate critical deviations.

Currently, the integration of DSP with modern MI forms the foundation of reliable metrological support and the effective operation of MMTs.

SUGGESTIONS FOR THE DEVELOPMENT OF A MODEL OF A DIGITAL METHOD FOR MEASURING ELECTRICAL QUANTITIES WITH INTERMEDIATE CONVERSION INTO UNIFIED PARAMETER

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War has the power to both elevate and dismantle regimes and empires. It stimulates scientific and technological advancement and reshapes the socio-political fabric of society. The relationship between war and society is reciprocal: scientific breakthroughs often lead to military applications, while military demands, in turn, drive scientific and technological progress – such as in the cases of nuclear fission and unmanned aerial vehicles (drones) – and influence the evolution of warfare.

One of the most critical factors in the advancement of weapons and military equipment (WME), as well as in ensuring their operational effectiveness, is measurement accuracy. This is particularly relevant for electrical measurements, as fields like physics, radio engineering, and electronics rely heavily on precise measurement technologies. The rise of digital measuring equipment (ME) is largely motivated by the need to address increasingly complex scientific, technical, economic, and military challenges. With the advancement of digital measurement techniques and signal processing algorithms, there is a growing emphasis on developing universal digital measuring instruments (DMIs) capable of evaluating multiple physical quantities. Achieving high efficiency in such DMIs requires solving a set of complex, interconnected problems – foremost among them, the development of digital methods for measuring electrical quantities using intermediate conversion into a unified parameter.

This report presents a proposed model for a digital method of measuring electrical quantities through intermediate conversion into a single standardized parameter: frequency.

The use of frequency as a universal measurement parameter enables a level of accuracy that exceeds that of traditional instruments, thereby enhancing the combat effectiveness and technical reliability of WME.

DEVELOPMENT OF A SYSTEM FOR ENSURING THE AVAILABILITY OF MEASURING EQUIPMENT UNDER COMBAT CONDITIONS

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Ensuring the operability of modern weapons and military equipment largely depends on the availability of functional measuring instruments. These tools are essential for monitoring key parameters and making timely decisions regarding the adjustment or repair of corresponding systems.

In the context of ongoing combat operations and constant enemy interference, measuring equipment is often used under extreme and unfavorable conditions, which contradicts standard operational guidelines. High-intensity usage, limited access to maintenance facilities, and logistical constraints significantly increase the risk of system failures, potentially compromising the success of combat missions. Therefore, there is a pressing need to develop an efficient system for supplying and supporting measuring instruments, taking into account peacetime practices of utilizing exchange reserves, but adapted for wartime realities.

This paper presents proposals for the creation of a mobile reserve fund for measuring equipment, including recommendations for its configuration and deployment strategies to enable rapid delivery to active combat areas. These reserves would also be equipped with spare parts and functional modules for the prompt restoration of key systems in military hardware.

Additionally, the development of an automated control system is proposed, enabling real-time tracking of the status and availability of reserve assets, and ensuring timely redistribution of resources to the areas of greatest operational need.

TASKS OF SCIENTIFIC METROLOGY CENTRES

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Scientific metrological centres are determined by the Cabinet of Ministers of Ukraine from among state enterprises, institutions and organisations that belong to the management of the central executive body that implements the state policy in the field of metrology and metrological activities and create, improve, store and apply national measurement standards.

Regulations on scientific metrology centres are approved by the central executive body that implements the state policy in the field of metrology and metrological activities.

The powers of scientific metrology centres in the areas of activity defined by their regulations and regulatory legal acts include:

– carrying out fundamental scientific research in the field of metrology, as well as performing work related to the development and implementation of state programmes on metrology and the concept of development of the metrological system of Ukraine;

– conducting scientific and applied research and performing research works related to the creation, improvement, storage, verification, application of national measurement standards, creation of systems for transferring the dimensions of measurement units;

– participation in the development of draft technical regulations, other regulatory legal acts, as well as normative documents in the field of metrology and metrological activities;

– coordination and scientific and methodological support of work to ensure the uniformity of measurements in the relevant areas of activity;

– conformity assessment of measuring instruments;

– calibration and verification of measuring instruments;

– conducting measurements in the field of legally regulated metrology;

– maintaining an information fund in the areas of its activity;

– international cooperation on issues within their competence.

Under agreements with legal entities and individuals, scientific metrology centres may perform other works (provide other services) related to ensuring the uniformity of measurements.

DEVELOPMENT AND APPLICATION OF INFORMATION-MEASUREMENT TECHNOLOGY IN UKRAINE AND PARTNER COUNTRIES

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In the 2020s, information-measurement technologies (IMT) have experienced a significant technological leap due to the active implementation of artificial intelligence (AI), cloud computing, and cyber-physical systems. In partner countries such as the USA, Germany, and Poland, distributed IMT platforms are actively developing, combining measuring instruments, network infrastructure, and analytical modules into a unified information environment.

Modern innovations include:

edge monitoring – transmission of pre-processed data directly from sensors to servers;

self-calibrating sensors with automatic accuracy adjustment;

digital twins of objects for real-time modeling of technical condition;

predictive analytics systems to foresee failures or malfunctions.

In Ukraine, despite wartime challenges, these approaches are beginning to be integrated into military and critical infrastructure. The creation of a network of digital measuring stations and a national register of IMT devices with an open data exchange interface is being considered.

Thus, the future of IMT lies in the transition from standalone measuring instruments to intelligent ecosystems that adapt, learn, and interact in real time with both humans and machines.

MODERNIZATION OF THE SYSTEM OF METROLOGICAL SUPPORT OF RADAR SURVEILLANCE IN COMBAT USE CONDITIONS

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In modern conditions of warfare, when decisions are made in a short time, and the operational situation changes dynamically, the importance of ensuring the high accuracy of the functioning of radar surveillance means (radar) increases. Metrological support of the radar in such conditions requires deep modernization aimed at improving the reliability, accuracy and efficiency of measurements.

The main problem faced by the Armed Forces of Ukraine in the field of radar metrology is the obsolescence of approaches to calibration and diagnostics of radars in the field. Mobile metrological groups performing these tasks are not always equipped with modern measuring equipment, which leads to a decrease in the reliability of input data and the effectiveness of combat use of equipment.

Modernization of the radar metrological support system should be based on the introduction of digital automated diagnostic systems capable of monitoring the technical condition of the equipment in real time. Another important aspect is the adaptation of the experience of partner countries, in particular NATO members, where remote calibration systems and digital libraries of reference characteristics are actively used to assess the state of the radar.

It is proposed to create on the basis of domestic research centers a single platform for the exchange of metrological data, integrated with combat information systems, which will speed up decision-making on maintenance and reduce the downtime of equipment.

Special attention should be paid to the training of qualified metrologists capable of working in combat conditions with modern digital FTAs. To do this, it is necessary to develop new training programs based on an analysis of the challenges of war and the experience of partner states.

Modernization of metrological support of radar equipment in the Armed Forces of Ukraine is a critical condition for ensuring high combat readiness and effective functioning of air defense systems in the conditions of modern confrontation.

USE OF METROLOGICAL SUPPORT IN THE DEPLOYMENT OF RADIOELECTRONIC WARFARE SYSTEMS

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Modern warfare is increasingly shifting into the domain of information and radioelectronic confrontation.

Radioelectronic warfare (REW) systems can significantly change the course of military operations by disrupting communication, navigation, and command of the enemy. However, the effectiveness of REW directly depends on the accuracy, stability, and reliability of the technical devices, which cannot be ensured without proper metrological control. In this context, the role of metrological support as the foundation for the reliable functioning of REW is growing.

The future of REW systems is closely tied to the development of high-precision technologies, artificial intelligence, and digital signal processing.

In such conditions, metrology must move from classical calibration methods to integrated solutions that allow:

– implementing real-time self-monitoring of parameters;

– using digital twins to model the behavior of systems under operational conditions;

– applying neural networks to detect metrological deviations before they manifest in real-world conditions;

– creating cloud-based metrological monitoring platforms, to which all REW systems will connect, ensuring centralized analysis and coordination.

The metrology of the future must be adaptive, automated, fast, and error-free capable of ensuring technical superiority in real-time.

Metrological support will become an integral part of intelligent REW systems, ensuring their stable, accurate, and predictable operation.

In the future, efforts should be directed toward developing universal metrological modules that will be integrated into REW complexes, providing complete self-diagnostics, remote calibration, and adaptation to environmental changes.

Thus, metrology will move beyond maintenance and become an active element of the combat system.

METROLOGICAL SUPPORT OF MILITARY EQUIPMENT IN THE ARMED FORCES OF UKRAINE (AFU) IN ACCORDANCE WITH NATO STANDARDS

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Metrological support in the Armed Forces of Ukraine in accordance with NATO standards is a key step toward enhancing the effectiveness of military equipment and its interoperability with the systems of NATO member states. For full integration, it is necessary to continue reforms, invest in infrastructure, and train qualified personnel.

Key Aspects of Metrological Support in the AFU According to NATO Standards:

– harmonization of national standards with NATO requirements;

transition to the use of STANAG (Standardization Agreement) and AQAP (Allied Quality Assurance Publications) standards in the field of metrology;

– implementation of calibration and verification systems for measuring equipment (ME);

– in accordance with the NATO Metrology Handbook;

– creation of a unified metrological control system development of metrological infrastructure, including military metrology centers and laboratories accredited under ISO/IEC 17025 standards;

– ensuring traceability of measurements to international standards;

– in particular, through BIPM – the International Bureau of Weights and Measures;

– use of modern calibration and control methods;

– implementation of automated measurement systems using digital technologies (e.g., AI algorithms for error prediction).

– deployment of mobile metrological units to service equipment in field conditions;

– training of specialists according to NATO standards education of military metrologists in accordance with NATO Training Standards;

– joint training with specialists from NATO countries and participation in exchange programs (e.g., NATO Maintenance and Supply Agency – NAMSA);

– quality control and certification of armaments use of First Article Inspection (FAI) procedures to assess new equipment;

– implementation of the Logistics Support Analysis (LSA) system to monitor equipment condition throughout its lifecycle.

Main Challenges for Ukraine. The need to modernize the laboratory base (shortage of modern equipment). Decentralization of metrological services among different branches of the military. Lack of full harmonization with NATO standards due to the historical legacy of the Soviet system.

MODERNIZATION OF CALIBRATION IN THE MILITARY SPHERE: CREATING AN AUTOMATED SELF-MONITORING SYSTEM

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In the current conditions of war, where superiority is gained by those with more accurate and reliable equipment, traditional calibration methods no longer meet the needs of high-tech armies. Today, a new solution is needed that allows weapons and equipment to maintain their accuracy independently, without constant human intervention. That is why the idea arises to create an automated real-time calibration system integrated directly into combat equipment.

To develop a unified self-calibration system that will be built into each sample of weapons or equipment.

This system, using special sensors and detectors, will continuously monitor the main parameters of the devices – for example, targeting accuracy, signal stability, the position of laser sights, etc. If even minimal deviations are detected, the system will independently correct them in real time, without delays and the need for engineers to intervene.

In addition, each such device will be connected to the Technical Control Center via a secure communication network. The center, using artificial intelligence, will collect data from all equipment on the battlefield, analyze it, and timely issue alerts about the need for a deeper technical check, if necessary.

How to implement this idea:

– develop universal sensor modules that can be integrated into various types of military equipment without significant design changes;

– create software that will analyze sensor data in real time and perform automatic calibration or report a problem;

– organize a Technical Control Center where artificial intelligence will process data streams, predict failures, and plan equipment maintenance;

– establish a secure communication network that enables fast data transmission without the risk of interception by the enemy;

– conduct tests to adapt the system to real combat conditions and make it as resistant as possible to interference and enemy influence.

Modernizing calibration through the creation of an automated self-monitoring system will significantly improve the accuracy and reliability of military equipment, reduce maintenance time, minimize the risk of technical failures, and provide a strategic advantage on the battlefield.

METROLOGICAL SUPPORT IN THE HEALTHCARE SECTOR: MEASUREMENT OF BIOMEDICAL PARAMETERS

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Metrological support in the healthcare sector is critically important for the accuracy and reliability of measurements of biomedical parameters, which directly impacts the effectiveness of diagnosis, treatment, and disease prevention. Ensuring that measuring equipment meets international standards, as well as implementing modern calibration and quality control technologies, contributes to enhanced accuracy in biomedical research and the improvement of medical services.

A low level of unification, insufficient periodic verification of medical equipment, limited control over measurement accuracy, and a shortage of qualified metrologists in healthcare institutions lead to unreliable medical data, which can result in diagnostic and treatment errors.

Solutions:

– implementation of modern metrology standards in medical practice$

– expansion of the network of accredited laboratories for the verification and calibration of medical equipment;

– regular training of medical staff on the fundamentals of metrology and the correct use of measuring devices;

– creation of a unified information system for monitoring the technical condition of measuring instruments in healthcare institutions;

– strengthening state control over the metrological reliability of medical measurements;

– development of national metrological standards for biomedical parameters, which will standardize measurements at all levels of medical practice;

– implementation of a system for regular calibration of medical devices and equipment, especially those used for monitoring patients' vital functions;

– improvement of medical personnel’s qualifications regarding metrology and the importance of accurate measurements in clinical practice, which will enhance the quality of medical services;

– use of modern information technologies for the automation of data collection and analysis regarding biomedical measurements, which will reduce the likelihood of errors and increase the objectivity of results.

DEVELOPMENT AND MODERNIZATION OF HIGH-PRECISION INTERFEROMETERS TAKING INTO ACCOUNT THE NEEDS OF THE MILITARY SPHERE

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High-precision interferometers are ultra-sensitive instruments that allow microscopic changes in length, motion, and oscillation to be measured with nanometric precision. Although they are traditionally used in physics laboratories, the prospects for the application of these technologies in the military field are extremely broad.

Modern warfare requires maximum accuracy in weapon guidance, vibration detection, remote sensing, and infrastructure monitoring. Upgraded interferometers can be integrated into:

reconnaissance drones – to detect vibrations of equipment or underground objects;

laser guidance systems – to increase the accuracy of strikes;

electronic warfare means – to determine microchanges in the surface that signal latent activity;

monitoring the technical condition of weapons – to detect microcracks or deformations in gun barrels, rocket launchers, etc.

To adapt interferometers to military conditions, it is necessary to miniaturize them, strengthen protection against vibrations and dust, introduce artificial intelligence to process signals in real time, and create mobile versions for field conditions.

Thus, the upgraded interferometers can become a key element of the latest intelligence, defense and technical control systems, which will provide the Armed Forces with a significant technological advantage.

DEVELOPMENT OF INFORMATION AND MEASUREMENT TECHNOLOGIES IN ENSURING THE ACCURACY OF MODERN WEAPONS SYSTEMS

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Modern weapon systems require high accuracy, which is provided by information and measurement technologies (IMT) through the accurate determination of target coordinates and the state of technical means. One of the key areas of I&M development is integration with digital computing platforms and artificial intelligence to improve the efficiency of real-time measurement processing. Fibre-optic sensors are widely used in combat conditions, as they are characterised by high accuracy, reliability and electromagnetic resistance.

Automated calibration complexes for military equipment allow for operational maintenance of weapons without compromising measurement accuracy. The development of standards for the exchange of measurement information contributes to the unification of equipment and interoperability between units of different countries within the framework of international cooperation.

The development and implementation of modern information and measurement technologies is critical for ensuring the combat effectiveness of weapons. Integration of I&T with intelligent control systems and high-precision sensors contributes to achieving new standards of accuracy and reliability in modern warfare.

DEVELOPMENT AND APPLICATION OF INFORMATION-MEASUREMENT TECHNOLOGY IN MODERN UAVS

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In the 2020s, unmanned aerial vehicles (UAVs) have become a vital platform for implementing modern information-measurement technologies (IMT). Due to the miniaturization of sensors, the advancement of data processing systems, and integration with navigation technologies, UAVs are capable of performing high-precision measurements in real-time, even in complex terrains or above critical infrastructure objects.

Modern innovations include:

– temperature, humidity, and atmospheric pressure sensors with automatic calibration;

– ionizing radiation detectors for radiation background monitoring;

– GNSS modules with differential correction support for centimeter-level coordinate accuracy;

– real-time data transmission modules with secure communication channels;

– onboard analytical systems for preliminary data processing and filtering.

In both military and civilian applications in Ukraine, the implementation of such IMT within UAVs enables environmental monitoring, search and rescue operations, and technical condition assessment of infrastructure. Plans include the creation of a unified data exchange platform for UAV-based measurements and their integration into national situational awareness ecosystems.

Thus, the future of IMT in UAVs lies in the development of autonomous intelligent systems capable not only of measurement but also of analyzing and transmitting data in interaction with other components of the information infrastructure.

APPLICATION OF PASSIVE MONITORING TECHNOLOGIES TO INVESTIGATE SOURCES OF ACOUSTIC INTERFERENCE

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Research into the development of new, highly sensitive methods and circuit-technical approaches for constructing primary transducers – utilizing ultra-high-frequency electromagnetic waves, surface magnetostatic waves, optical radiation, and surface acoustic waves – has demonstrated that acoustoelectronic transducers based on surface acoustic wave (SAW) devices and systems often offer several key advantages. These include a short operational wavelength even at relatively low frequencies, and the capability for distributed sensing.

As a result, SAW-based devices are widely employed in the design of both active and passive primary sensors for measuring various physical quantities such as temperature, humidity, force, pressure, gas concentration, displacement, velocity, acceleration, torque, and electric or magnetic field strength.

In wartime conditions, passive acoustic monitoring technology – especially for detecting sources of acoustic disturbances such as cruise missiles in flight – has seen significant advancement. The key benefit of this technology is its covert nature, as it functions passively, allowing for the discreet detection and tracking of specific airborne targets. Data gathered by the acoustic disturbance monitoring system is increasingly used to support air defense units (including mobile firing groups) by enhancing situational awareness of the aerial environment.

To further improve the detection algorithms used in these acoustic systems, particularly through the integration of artificial intelligence, it is essential to train the system to identify and differentiate between various classes of acoustic signals.

ANALYSIS OF PROPOSALS FOR THE SELECTION OF A UNIVERSAL VOLTMETER FOR MEASURING THE PARAMETERS OF ALTERNATING CURRENT VOLTAGE OF A MOBILE DIESEL POWER PLANT 5I57A

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A variety of instruments are employed to achieve precise measurements and assess the performance of AC electrical circuits. Among them, the multimeter stands out as a versatile tool capable of measuring core electrical parameters such as voltage, current, and resistance across a wide range. It is commonly used to diagnose faults, verify circuit integrity, test wiring and fuses, and detect hidden cables.

Specifically, a multimeter allows users to:

– measure current across all electrical consumers after installing new wiring;

– verify that current levels remain within acceptable limits when additional loads are connected to an existing circuit;

– monitor current flow through circuit breakers to prevent overloads;

– evaluate the electrical load on appliances, motors, and heating elements;

– test the functionality of outlets, lighting systems, starters, and lamp sockets using an AC power meter;

– assess electrical characteristics such as capacitance, voltage frequency, current strength, inductance, and perform tests on diodes, transistors, and batteries.

Due to its compact design and broad functionality, the multimeter is convenient and user-friendly. Modern multimeters fall under the category of digital equipment, offering greater accuracy and reliability compared to analog devices. These digital instruments are well-suited for measuring a wide array of electrical variables.

For personnel responsible for maintaining electrical systems in military units, it is essential to have a precise instrument capable of measuring the AC voltage and frequency of the 5I57A diesel mobile power plant. Such a device must handle high-load networks and support the routine monitoring of key electrical parameters – voltage, current, phase angle, and frequency – that power various weapon systems and military equipment. Ensuring proper control of these parameters is vital to the functionality and reliability of military systems, which in turn supports the successful execution of combat missions.

To meet this need, it is recommended to utilize the UNI-T UT89X multifunctional digital multimeter for monitoring the power supply characteristics of the 5I57A diesel power unit.

MAIN TASKS OF MEDICAL SUPPORT OF THE ARMED FORCES OF UKRAINE

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The primary mission of the medical personnel within the Armed Forces of Ukraine is to safeguard the lives and health of service members by delivering prompt, high-quality, and effective medical assistance. This care is essential not only for facilitating the rapid recovery and return to duty of those affected by injuries, illnesses, or trauma, but also for ensuring the medical readiness that underpins the overall combat effectiveness of the military.

The development of a modern military infrastructure, alongside the realities of the ongoing armed conflict, underscores the necessity of enhancing the capabilities of the Armed Forces – particularly their medical service.

To successfully meet its responsibilities in today’s operational environment, the medical service must rely on highly skilled professionals, especially well-trained military doctors. These specialists need to possess a deep understanding of combat-specific conditions, comprehensive knowledge of the characteristics and progression of combat-related injuries, and the ability to apply core principles of medical evacuation, preventive hygiene, and epidemic control under a wide range of conflict scenarios. Strong organizational competencies are also critical.

It is clear that meaningful experience and essential practical skills can only be acquired through service within military units or medical institutions. Therefore, medical officers must diligently study the foundations of military medical science. This includes mastering subjects such as the organization of medical support for armed forces, field surgery, military therapy, epidemiology, hygiene, and other essential disciplines that form the basis of their professional competence.

ANALYSIS OF PHYSICAL PRINCIPLES OF TOMOGRAPHIC MEASUREMENTS OF OBJECTS

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According to the established classification of measurement types, tomographic measurements fall under the category of indirect measurements and exhibit characteristics of both aggregate and combined measurements. This is due to the fact that the target spatial distribution of a measured parameter can be expressed as a weighted sum of known basis functions with unknown coefficients – typical of combined measurements. Furthermore, the initial measurement data reflect the integrated spatial effect of all elements within the environment being analyzed, which is another hallmark of combined measurements.

It is important to emphasize that, unlike traditional measurement approaches, tomographic measurements yield primary results that contain integral (rather than local) information about the spatial distribution of a quantity. Consequently, reconstructing an image from these primary results involves explicit or implicit differentiation operations. This introduces challenges related to the stability of the inverse problem used for image reconstruction.

Tomographic techniques are based on various physical principles, and the selection of a particular principle depends on numerous factors – most notably, the physical characteristics of the object under investigation. In principle, almost any physical phenomenon can be harnessed for tomographic imaging. The choice also depends on the required resolution and accuracy, the complexity of the system design, and other practical considerations.

The most commonly employed physical principles in tomographic measurements include:

– natural radiation from the studied medium: such as thermal or radioactive emissions, and waves of various types (e.g., electromagnetic, optical, acoustic, and ultrasonic);

– interaction between external radiation and the medium: including wave absorption, reflection, diffraction, interference, and propagation delay;

– electrical and magnetic properties of the medium: such as electrical conductivity, dielectric and magnetic permeability, and effects arising from the motion of electrically or magnetically charged particles;

– resonance phenomena: occurring at atomic or nuclear levels.

These principles form the foundation for a wide range of tomographic systems tailored to specific applications and environments.

STUDY OF OPTIONS FOR REPLACING LOW-FREQUENCY GENERATORS THAT ARE PART OF THE MOBILE LABORATORY OF MEASURING EQUIPMENT UA2-4 A/B

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Metrological support for special control and verification equipment (C&V) is provided by mobile metrology teams from regional metrology units at the locations of military formations. To accomplish this, mobile measuring laboratories (MELs) are utilized.

Since the onset of the full-scale aggression by the Russian Federation, the demand for metrological support of C&V equipment has grown considerably. The current fleet of MELs varies significantly, typically consisting of large vehicles such as MAZ, KrAZ, or KAMAZ. Presently, a promising direction in the development of portable metrology systems is the design of compact MELs based on minibus platforms. This necessitates a revision of the measurement and verification equipment set.

Currently, the UA2-4A/B measurement kit includes low-frequency generators like the G3-110 and G3-118. While these are high-precision instruments historically used to provide a stable sinusoidal signal for determining the metrological characteristics of other devices, they are now outdated, no longer in production, and most have been in use for over two decades. Additionally, their bulky size and weight make them impractical for installation in compact MELs. As such, replacing them with modern digital signal generators is increasingly relevant. This replacement requires an evaluation of necessary signal stability, purity, and frequency range – making the task complex and demanding thorough analysis.

Today’s market offers a vast array of signal generators with varying metrological specifications and pricing. Therefore, choosing the most suitable option must be based on a well-founded assessment. It is crucial to remember that the reliability of weapons and military equipment used by the Armed Forces of Ukraine is directly linked to the quality and dependability of measurement parameter control.

ANALYSIS OF THE COMPOSITION OF THE POWER SUPPLY SYSTEM FOR A MOBILE LABORATORY OF MEASURING EQUIPMENT

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The power supply system of a mobile laboratory for measuring equipment is engineered to deliver a dependable and consistent energy source for operating measurement instruments and other laboratory technologies. It consists of several key components. The primary power source may be a rechargeable battery or a diesel generator, supplying electricity to all laboratory systems, including measurement tools, computing devices, lighting, and auxiliary equipment.

An inverter along with a voltage stabilizer converts the direct current (DC) from the batteries into alternating current (AC), which is typically required by the majority of measuring instruments. The stabilizer ensures consistent voltage levels, which is crucial for maintaining measurement accuracy.

The system also incorporates battery charging units to maintain continuous functionality when battery levels are low or when external power sources are used.

A critical element of the system is the energy monitoring and control unit, which enables operators to track battery charge status, generator output, and other essential performance indicators.

This power system is designed to support autonomous laboratory operation for extended periods, particularly in remote or field environments without access to external electricity sources.

With this setup, the laboratory can perform measurements reliably even in areas with limited or no connection to the main power grid.

ANALYSIS OF PROPOSALS FOR IMPROVING MEASUREMENT SYSTEMS FOR MONITORING AND DIAGNOSING THE TECHNICAL CONDITION OF MILITARY EQUIPMENT SAMPLES

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Modern military vehicles demand efficient systems for diagnosing and monitoring their technical condition to maintain reliability and ensure combat readiness. Enhancing measurement systems enables the early identification of faults, improves operational performance, and helps reduce maintenance expenses.

A review of current measurement technologies highlights the use of various diagnostic tools and methods, including analog and digital control instruments, computerized diagnostic platforms, sensor-based technologies, and predictive maintenance systems. However, these systems face challenges such as limited measurement precision and high servicing costs.

Key directions for improving diagnostic and monitoring measurement systems include:

– implementation of advanced sensor technologies for detecting pressure, temperature, and vibration;

– use of optical and ultrasonic sensors for non-destructive testing applications;

– creation of a centralized database for failure analysis and forecasting.

Anticipated outcomes of these improvements include more effective technical condition monitoring, reduced repair and servicing costs, and enhanced reliability of military vehicles.

In conclusion, integrating modern technologies into diagnostic measurement systems will significantly boost the operational efficiency of military equipment. Future research should focus on incorporating artificial intelligence and predictive analytics to advance monitoring capabilities.

THE NEED TO MEASURE GROUND RESISTANCE FOR THE SAFE OPERATION OF WEAPONS AND MILITARY EQUIPMENT

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Measuring ground resistance is a vital procedure for ensuring the operational safety and reliability of military weapons and equipment. Its significance is evident across several key areas.

First and foremost, low ground resistance is essential for personnel safety. It facilitates the efficient dissipation of electrical currents into the earth, reducing the risk of electric shock and preventing static electricity buildup that could lead to sparks and potential explosions.

Grounding also plays a crucial role in protecting systems from overcurrent during lightning strikes or accidental short circuits. This helps prevent damage to electronic and electromechanical components within military systems.

Maintaining consistent and effective grounding is particularly important for safeguarding sensitive electronic elements found in modern military platforms. High ground resistance may lead to system failures, communication disruptions, or signal degradation, which can severely impair fire control, navigation, and communication systems.

Additionally, proper grounding reduces the impact of electromagnetic interference, which can disrupt other systems and increase the likelihood of operational failure. This is especially relevant for military assets operating in environments where electronic warfare is prevalent.

Routine ground resistance measurements are a fundamental aspect of safety compliance. Given that military equipment is frequently exposed to challenging environmental conditions – such as moisture, sand, and snow – regular assessments and adjustments to grounding systems are necessary to maintain performance in the field.

In summary, measuring and maintaining proper ground resistance is a critical component of military equipment servicing. It ensures the safety of personnel, supports reliable equipment operation, and helps prevent potentially dangerous malfunctions in combat or field conditions.

PROPOSALS ON THE NEED TO ORGANIZE AUTOMATED ACCOUNTING OF THE TECHNICAL CONDITION OF MEASURING EQUIPMENT IN MILITARY UNITS

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Ensuring efficient tracking of the technical condition of measuring devices (MDs) within a military unit is a critical task that directly impacts the precision of both combat and training operations. Automating the accounting process can significantly enhance monitoring efficiency and support more informed maintenance decisions.

At present, most military units maintain records of the technical condition of weapons and equipment either in paper form or using a hybrid approach (paper and electronic). This system limits real-time access to accurate information, increases the potential for human error, and slows down the decision-making process. Key challenges include the absence of a unified, centralized database, a high risk of data entry mistakes, difficulties in forecasting maintenance requirements, and limited coordination with other departments and command structures.

To address these issues, the introduction of a dedicated information system is recommended. This system would support an electronic registry of all MDs, enable automated status monitoring, issue maintenance reminders, and generate comprehensive reports and analytical summaries.

Implementing such an automated accounting system would:

– reduce the time required to track and analyze the technical condition of weapons and equipment;

– improve the accuracy and reliability of inventory data;

– optimize maintenance-related expenditures;

– enhance the quality and speed of managerial decision-making, and strengthen the unit's combat readiness by ensuring timely servicing of critical systems.

In conclusion, the automation of accounting for the technical state of munitions and measuring devices is essential for the efficient management of a military unit's material assets. Adopting these measures will lead to more accurate tracking, better technical oversight, and a reduced likelihood of system failures in critical operational scenarios.

EVALUATING TRANSIENT PARAMETERS IN GENERATOR SYNCHRONIZATION FOR PARALLEL OPERATION

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The synchronization and parallel operation of generators play a pivotal role in ensuring an uninterrupted power supply, particularly in military applications. This necessity arises from several factors: the need to transition weapon and ammunition power sources between state and autonomous networks depending on combat readiness levels, the imperative to enhance power reliability during military operations, and the requirement to withdraw certain units for maintenance or repairs without disrupting the power system.

Military power systems typically consist of multiple synchronous generators functioning either independently or in tandem. Synchronization is a crucial precursor to parallel operation, and while it is a brief process, its significance cannot be understated – any misalignment may lead to operational disruptions and potential equipment failures.

In combat scenarios, units of the Armed Forces of Ukraine frequently require the simultaneous activation of multiple power sources. Poor synchronization during parallel activation of synchronous generators can result in voltage drops and current surges, jeopardizing the functionality of military equipment and weapon systems.

There are three primary methods for switching generators into parallel operation:

– self-synchronization;
– coarse synchronization;
– fine synchronization.

In military power systems, automatic precise synchronization devices are commonly employed. These systems initiate generator engagement using predetermined parameters such as a fixed advance angle, constant advance time, or a calculated phase shift angle within acceptable slip frequency ranges. The angular slip velocity serves as a key factor in determining synchronization accuracy. When designing synchronizers with a fixed advance angle, engineers must account for the expected angular slip velocity ω. If this velocity exceeds the permissible threshold for the given generator types, synchronization via this method becomes infeasible. Furthermore, when selecting generator parameters such as supertransient reactances and inertial steels, it is critical to calculate the maximum angular slip velocity (ω max) – as excessive slip velocity could pose risks during rotation and hinder smooth parallel operation. Ensuring reliable generator synchronization remains a fundamental aspect of maintaining stable and efficient power supply systems in military applications.

DEVELOPMENT OF PROPOSALS FOR IMPROVING METHODS AND MEANS OF ENSURING POWER QUALITY IN THE ELECTRICAL SUPPLY SYSTEMS OF STATIONARY MILITARY AIRPORTS UNDER POST-EMERGENCY CONDITIONS

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Reliable, high-quality, economical, and secure power supply is a cornerstone of maintaining the combat readiness of weaponry, military equipment, and other defense infrastructure, both in stationary bases and field operations.

Modern warfare demands enhanced power reliability and reduced dependency on external energy sources. The adoption of non-traditional energy sources can significantly diminish reliance on both state energy grids and fuel supplies, thereby boosting autonomy and operational security. Open-source reports indicate that military power plants and energy units within the U.S. Rapid Response Forces remain the largest consumers of battlefield fuel. Consequently, improving energy security, reducing overall energy consumption, and integrating renewable and alternative energy sources are now key objectives in military energy system development.

One potential strategy for increasing the reliability and longevity of autonomous military power systems is the use of alternative electricity sources. Analysis of their feasibility within the Joint Forces Operation (JFO) zone suggests that, despite the higher cost of solar and wind power plants, deploying them in conflict zones could prove advantageous. Factoring in the cost of fuel and lubricants required for conventional diesel and gasoline generators, alongside logistical difficulties in their transportation, strengthens the argument for renewable energy solutions.

However, wind power plants may only be viable at a safe distance from active combat zones due to their high visual exposure risk. Meanwhile, solar power stations, along with solar heating and hot water systems, could effectively support military units at checkpoints and base camps within the JFO zone, provided they are equipped with adequate engineering protection.

These conclusions align with solutions being developed for military forces worldwide. Battlefield experience has consistently demonstrated that only high-reliability electrical networks can guarantee the seamless execution of combat missions assigned to fighters, bombers, reconnaissance aircraft, and transport planes.

Moreover, the protection of power transformers against failures or abnormal operating conditions still relies on obsolete relay protection systems and conventional fuses. Upgrading relay protection to modern component bases would significantly improve power reliability and enhance the combat capabilities of military aviation units.

For robust transformer protection, a comprehensive approach is advisable, integrating:

– maximum current protection or cutoff protection alongside gas protection;

– short-circuit protection to ground;

– overload protection mechanisms.

Given the aging state of legacy relay protection devices, transitioning to modern microprocessor-based relay protection systems should be considered. This shift would substantially enhance the effectiveness of military aviation units in combat.

Strategies for Improving Power Quality in Stationary Military Airport Electrical Systems:

– advanced Diagnostics: Regular monitoring using intelligent diagnostic systems to detect and resolve issues at early stages;

– infrastructure Upgrades: Installing new electrical wiring, transformers, and modernizing existing network components;

– innovative Technologies: Implementing smart energy management systems for optimal power usage and efficiency;

– energy Efficiency Measures: Adopting power-saving technologies, including energy-efficient equipment and optimized consumption strategies;

– personnel Training: Continuous education and skill development for specialists working in electrical power supply systems to ensure effective problem identification and resolution.

By employing these enhancements, military airports can achieve superior power reliability, minimize disruptions, and strengthen operational effectiveness in post-emergency scenarios.

ENHANCING CONTROL SYSTEMS FOR ASYNCHRONOUS MOTORS IN ANTI-AIRCRAFT MISSILE COMPLEXES

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Drawing from real-world combat applications, the S-300PT and S-300PS missile systems are recognized as key components in air defense, playing a critical role in safeguarding strategic industrial and military infrastructure.

Currently, voltage monitoring for power supply consumers within anti-aircraft missile divisions is primarily conducted via visual inspection and basic measurements. However, these methods do not provide a comprehensive evaluation of motor health or enable proactive identification of potential malfunctions. To address these limitations, several advancements in asynchronous motor control have been proposed:

Developing advanced diagnostic techniques by utilizing mathematical modeling to assess the dynamic operating characteristics of asynchronous motors with ferromagnetic rotors. A promising approach involves current and voltage spectrum analysis, ensuring precise identification of technical conditions.

Integrating cutting-edge technologies, including modern computational systems and numerical methods, to enhance the optimization of motor performance.

Upgrading existing control systems with innovative solutions such as neural networks, which can refine motor torque regulation, particularly in field-weakening operational modes.

For electrical engineering teams operating in combat environments, implementing these strategies facilitates condition-based maintenance, effectively minimizing unexpected failures through early defect detection and progressive damage monitoring. These enhancements are designed to improve reliability and operational efficiency in air defense applications. Let me know if you'd like any refinements

ADVANCING STRATEGIES FOR ENHANCING POWER TRANSMISSION LINE PROTECTION AGAINST OVERLOADS AND SHORT CIRCUITS IN MILITARY AIRPORT ELECTRICAL SYSTEMS UNDER COMBAT CONDITIONS

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To enhance the protection of power transmission lines against overloads and short circuits in the electrical supply systems of military airfields under combat conditions, the following measures are proposed:

1. Power Transmission Line Redundancy – Implementing backup power lines to ensure uninterrupted electricity supply in case primary lines are damaged. Given that an airfield's electrical grid is a highly vulnerable component of its power infrastructure, it is crucial to take preventive actions against potential failures caused by natural wear, environmental factors, or hostile attacks.

2. Deployment of Sensor Technologies – Installing sensors that enable rapid monitoring of transmission line conditions and early detection of possible threats.

Analyzing the requirements for relay protection in military airfield electrical networks suggests transitioning from traditional relay protection systems based on electromagnetic relays to modern microprocessor-based relay protection devices.

Recently developed integrated microprocessor-based automatic emergency control devices perform not only protective shutdown functions (RCD) but also automation tasks, including automatic load shedding (ALS), automatic restart (AR), and backup activation (BA). These intelligent control systems feature adaptability to emergency situations, self-testing, self-diagnosis, and even self-improvement through flexible programming.

Based on the analysis, the use of integrated microprocessor-based relay protection and automation systems in military power supply infrastructure is highly advisable. Among the most promising solutions is the universal microprocessor-based relay protection system from ABB, which offers extensive functionality and high reliability – crucial for military facilities operating under combat conditions.

ENHANCING THE EFFICIENCY OF SHORT CIRCUIT AND BREAK DETECTION IN UNDERGROUND CABLE LINES OF MILITARY AIRPORT POWER SUPPLY SYSTEMS UNDER COMBAT CONDITIONS

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Tap-changing devices for power transformers are essential components of electrical supply systems, ensuring stability and reliability in power networks.

Power transformers serve as the backbone of electrical grids, adjusting voltage levels for efficient transmission and distribution. However, electricity is not merely a flow of electrons – it is a dynamic pulse that responds to fluctuations in demand and supply. When network loads shift, voltage levels can vary, potentially causing unwanted consequences for equipment and consumers.

Tap changers help mitigate these effects by adjusting the transformer’s turn ratio, similar to how a musician fine-tunes an instrument to achieve perfect harmony. This allows transformers to compensate for voltage fluctuations and maintain stable levels.

With technological advancements, on-load tap changers (OLTC) have become even more efficient. Modern OLTC devices are equipped with electronic control systems, condition sensors, and integration capabilities with Smart Grid systems. This enables real-time monitoring and rapid response to any deviations in the electrical grid.

Proper utilization of tap-changing devices not only ensures voltage stability but also reduces energy losses in the network, leading to lower energy consumption and decreased greenhouse gas emissions. As a result, these systems play a crucial role in transitioning to more sustainable energy infrastructures.

Today's OLTC devices allow for remote operation, minimizing on-site maintenance needs and improving operational efficiency.

By analyzing performance data from OLTC devices, operators can predict wear and schedule maintenance, preventing unexpected failures.

As the share of renewable energy sources increases in electrical grids, the importance of automated voltage regulation through OLTC technology continues to grow. Wind and solar power plants can introduce additional voltage fluctuations, making effective regulation even more critical for energy stability.

DEVELOPMENT OF PROPOSALS FOR THE USE OF FUEL CELLS AS ALTERNATIVE POWER SOURCES FOR AIR DEFENSE MISSILE SYSTEMS IN COMBAT CONDITIONS

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Fuel cells are devices that directly convert the chemical energy of fuel into electrical energy. Unlike thermal power plants (TPPs), which first convert the chemical energy of fuel into heat producing superheated steam under high pressure and then use this steam to drive turbine rotors for electricity generation, fuel cells convert chemical energy into electrical energy without intermediate transformations. Fuel cell-based power plants are compact and convenient to use.

Fuel cells present a promising alternative power source for air defense missile systems in combat conditions. Several proposals for their application include:

– selection of Fuel Cell Type: Hydrogen fuel cells (PEMFC) and methanol fuel cells (DMFC) are particularly suitable for military applications due to their high efficiency and ability to operate at varying temperatures.

– mobility and Compact Design: Fuel cells can be integrated into mobile power stations, ensuring autonomous power supply for air defense systems in field conditions.

– reduced Emissions: Compared to conventional energy sources, fuel cells significantly lower harmful emissions, which is a crucial factor in combat operations.

– high Reliability: Fuel cells offer long-term, uninterrupted operation, making them ideal for military applications requiring continuous power.

– energy Efficiency: Fuel cells provide excellent energy efficiency, reducing fuel costs and enhancing the effectiveness of air defense systems.

Fuel cells are electrochemical devices where hydrogen serves as the fuel and oxygen acts as the oxidizer. Hydrogen-oxygen fuel cells are widely developed, particularly those utilizing alkaline or solid polymer electrolytes (ion-exchange membranes) with hydrogen fuel oxidized by high-purity oxygen. The efficiency of fuel cells and installations based on them depends on factors such as catalyst properties, electrode structure and porosity, electrochemical reaction overvoltage at the anode and cathode, membrane electrical resistance, and the chemical purity of fuel and oxidizer. To reduce electrochemical reaction overvoltage at the cathode, increase EMF, and enhance specific energy performance, electrodes are coated with electroactive catalysts with high surface area.

ENHANCING THE EFFICIENCY OF SHORT CIRCUIT AND BREAK LOCATION DETECTION IN UNDERGROUND CABLES OF MILITARY AIRPORT POWER SUPPLY SYSTEMS UNDER COMBAT CONDITIONS

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Analysis has identified and summarized key issues in detecting short circuits and breaks in underground cable systems of military airport power supply networks, which is crucial for ensuring reliability and safety. Various methods and devices are used for this purpose, such as cable tracers, signal generators, and other specialized equipment.

Cable tracing involves identifying cable locations, determining their depth, and pinpointing faults within power lines. This process relies on devices that send a tonal signal into the wires, receive, amplify, and reproduce it through headphones or speakers.

Cable tracers, such as the UNI-T UT25CL, are designed for tracing underground low-voltage cables, diagnosing breaks and short circuits, and checking voltage levels. These devices enable effective cable detection and tracing, significantly reducing work time and preventing accidental damage during installation or repairs.

The UNI-T UT25CL is a multifunctional set consisting of a transmitter and receiver. Equipped with advanced sensors, it ensures efficient cable and wire detection, greatly reducing work duration and minimizing the risk of accidental damage during maintenance or installation.

This device is used for locating conductors, identifying break and short circuit locations, tracing underground cables, and detecting fuses and associated equipment. Additionally, it can diagnose short circuits and breaks in heated floor systems, trace metal water and heating pipes, and its receiver can operate with multiple (up to 8) transmitters simultaneously.

TRANSFORMER VOLTAGE REGULATION IN ELECTRICAL NETWORKS

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To maintain the required voltage quality at electrical receivers, transformer-based regulation can be used within power grids. These transformers not only convert voltage but also regulate it. Unlike conventional transformers with a fixed transformation ratio, these specialized units adapt their voltage conversion dynamically to ensure optimal voltage levels at electrical receivers without disrupting automated control and protection mechanisms.

There are several methods for adjusting the transformer's voltage transformation ratio, which directly impact voltage regulation:

– changing the number of windings;

– redistributing the magnetic flux;

– altering the additional electromotive force (EMF);

– adjusting the phase shift between the primary and secondary EMF within the transformer windings;

Transformer voltage regulation systems based on winding adjustments fall into three primary categories:

– purely mechanical regulation systems

– no-load tap changer (NLTC) – voltage regulation performed by disconnecting the transformer from primary and secondary electrical networks during specific intervals of transformation ratio adjustment.

– on-load tap changer (OLTC) – voltage regulation performed under load using contact switching mechanisms that control current and arc suppression during tap transitions.

– hybrid control systems combining thyristor-based and mechanical regulation

–smooth, contactless voltage regulation systems

Transformers come in two major configurations based on regulation design:

– NLTC transformers – where tap changes occur only when disconnected from the grid.

– OLTC transformers – enabling tap changes under load conditions.

Generally, voltage regulation taps are located on the high-voltage side of the transformer to minimize current flow and simplify switching mechanisms.

Modern NLTC transformers typically feature one main tap and four auxiliary taps, allowing voltage adjustments of +5%, +2.5%, –2.5%, and –5% relative to the nominal voltage.

OLTC transformers, equipped with integrated voltage regulation switches, differ from NLTC models due to their specialized switching mechanisms and increased range of tap settings.

A switchgear system within the regulated winding consists of moving contacts, contactors, and reactors. Modern tap changers often replace reactors with active resistors, enhancing dynamic stability. Tap changers allow users to select taps based on peak and low-load conditions to optimize regulation efficiency. However, the presence of switchgear components and current-limiting resistors increases the cost of regulated transformers by 1.5 to 3 times.

Additionally, OLTC mechanisms have a finite switching lifespan, and tap transitions typically require more than 5 seconds for reactivation after soldering.

Recent advancements have led to the adoption of contactless tap changers, eliminating switching limitations by utilizing semiconductor power switches instead of mechanical contacts. These modern transformers perform tap transitions in less than 10 milliseconds, preventing voltage surges and significantly enhancing system stability.

ANALYSIS OF POSSIBLE POWER SUPPLY OPTIONS FOR QUADCOPTERS

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The armed forces of leading nations are experiencing rapid advancements in unmanned aerial technology. Given the significant advantages of electric motors over thermal engines, drones have become an essential asset for various operational tasks. Key challenges include flight range, stealth efficiency, protection against electronic warfare, and payload capacity.

One potential solution to these challenges is the use of tethered power supply systems during UAV operations. This approach offers several benefits:

adrone can remain airborne indefinitely, providing continuous surveillance over a designated area;

the tethered system ensures safe operation with a fully controlled and physically protected power source.

If the power cable incorporates a fiber-optic control channel, the drone becomes resistant to enemy electronic warfare interference while simultaneously reducing electromagnetic emissions, making detection by air defense systems more difficult. Power stations are lightweight, easy to deploy in field conditions, and convenient for transport with rapid activation. A fixed position eliminates the need for the operator to constantly adjust flight parameters manually. Using two or three interconnected drones with a shared tethered power source significantly expands surveillance coverage.

Deploying a swarm of identical drones, where several UAVs receive power from a primary drone while their onboard batteries enable autonomous mission execution after target identification.

There are several power and control configurations for UAV operations:

1. Tethered power with radio signal control.
2. Tethered power and direct electrical cable control.
3. Power transmission through an electrical cable incorporating a fiber-optic core for control.
4. Full fiber-optic power and control – A laser beam transmits energy via optical fiber, where the drone's photovoltaic (PV) system captures and converts it to power its engines.

Laser-based wireless energy transmission through the atmosphere presents several challenges, typically within the infrared spectrum, including signal transparency windows, beam stabilization requirements, and other environmental limitations. Optical fiber technology, however, enables the use of high-energy ultraviolet laser beams, which are unaffected by atmospheric conditions and enhance stealth capabilities.

Another viable power option is direct electrical transmission via cable. Currently, drones rely on 12V or 24V battery systems, which are inefficient for long-term operation. Additionally, electric motors designed for these voltages tend to be compact and lightweight. A proposed solution is high-voltage transmission, delivering up to 1000V through a lightweight cable, with power transmission efficiency increasing quadratically with voltage. The drone itself could utilize high-voltage motors operating at 100–200V, with DC-DC converters facilitating voltage regulation between the tethered cable and onboard propulsion system. Such voltage conversion technology enables broader speed and flight control ranges.

The choice of power transmission method depends on mission requirements and operational conditions. Notably, electrical tethering beyond 100–150 meters becomes impractical due to excessive cable weight and delayed signal transmission. Fiber-optic power and control transmission can extend operational distances beyond 500 meters, though the cost of fiber-optic spooling systems and laser generators is significantly higher than conventional electrical cables.

INDIVIDUAL POWER SUPPLY SYSTEM FOR SOLDIERS

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Modern armed forces face an urgent need to enhance the energy efficiency of soldiers during combat missions. This applies to communication systems, weaponry, rescue operations, and evacuation protocols. While many electronic devices require minimal power, some – such as laser and acoustic weapons – demand substantial energy output. Navigation systems, by contrast, operate on low power but need long-term sustainability.

The increasing use of electronic equipment in soldier gear calls for more powerful portable energy sources. Currently, nearly a quarter of an infantry soldier’s load consists of batteries, some weighing more than 11 kg. To reduce equipment weight, new high-efficiency, lightweight, and user-friendly batteries have been developed. Advanced lithium-acid batteries with an energy density of 300 Wh/kg are 50% more efficient than conventional batteries. Darren Browning, a representative from the UK Ministry of Defense’s Physical Sciences Department, stated at the "Future Soldiers" conference that portable battery capacities could reach 400–600 Wh/kg in the near future.

The global nature of military operations demands an intensified search for alternative energy sources. Current solutions include fuel cells, solar panels, ampoule batteries, flow batteries, and radioisotope thermoelectric generators (RITEG). A new alternative energy program is in development, proposing solar elements integrated into soldiers' uniforms, capable of both generating and storing power.

Military energy experts continue to debate power source integration into soldier equipment. Many believe that a single central power source for all electronic devices would be more efficient than using separate batteries. This system would position the main power unit in a backpack, distributing energy via a conductive strip attached to a soldier's body armor, allowing for adaptability in diverse climates and combat environments.

This study examines existing power sources for military gear. Given Ukraine's latitude, solar panel efficiency in winter drops by 1.5 to 2 times, with November and December having the lowest energy generation potential. Northern regions experience more severe drops in efficiency, making Ukraine's higher latitudes (above 50°) unsuitable for solar deployment. However, combat zones south of this boundary still present viable conditions for solar panel integration under specific circumstances.

The economic feasibility of solar panels remains contingent on masking capabilities, low power consumption needs, and avoiding noisy electromechanical generators. While solar panels can be installed almost anywhere, placement strongly affects efficiency. For instance, north-facing slopes, tree coverage, and coastal fog reduce output, making sunlight intensity surveys crucial for assessing solar viability before installation.

APPLICATION OF ARTIFICIAL INTELLIGENCE FOR EFFICIENT DETECTION OF POWER CABLE FAULTS

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The application of artificial intelligence (AI) in various technological processes is expanding rapidly, including within the energy sector, specifically for detecting faults in power cables. AI-based methods, particularly neural networks, show strong potential in identifying power cable defects in real time and determining their precise locations.

Military airfield cable networks consist of power lines of varying lengths and types, making fault detection, classification, and localization increasingly complex. The dataset (I, U, S, P, Q, W, R_diff, T0) represents continuous data streams collected by multiple sensors, requiring fast and generalized evaluation methods to assess each point's significance at any given moment. By analyzing fault and operational modes, time instances, and load combinations at the moment of failure, AI models can generate highly accurate data labels, useful for training neural networks.

To process real-time data, the LeNET-5 deep learning model was used. This model consists of convolutional layers, pooling layers, and fully connected layers, enabling highly effective diagnostics for cable networks of varying lengths and resistances. By leveraging convolutional neural networks, AI can predict failure locations with greater speed and accuracy than traditional detection methods – even when labeled fault data is limited.

To validate this methodology, seven different datasets were analyzed, covering cable networks of different lengths. Model reliability was evaluated across several technical factors, including voltage fluctuations, fault locations, fault angles, fault resistance, and phase differences between key data points.

Machine learning (ML), a crucial AI-driven predictive maintenance technology, is increasingly relevant in power cable fault detection. ML algorithms can learn from previous cable failure incidents, allowing them to forecast faults based on historical data. In high-voltage power systems, ML algorithms effectively identify operational anomalies that indicate potential faults or malfunctions. As ML models continuously learn and adapt, their accuracy improves over time.

Common ML approaches include:

– supervised learning, where models are trained using labeled datasets containing examples of normal and abnormal operational conditions;

– unsupervised learning, where models identify hidden patterns in unlabeled data to detect unknown faults or anomalies.

Both approaches provide valuable insights into high-voltage cable network conditions, enabling early detection of potential issues.

The future of AI-powered predictive maintenance in high-voltage power systems looks promising as sensor technologies, data processing, and AI algorithms continue to advance. Integrating multiple data streams will enable more comprehensive data collection, leading to higher accuracy in predictions and better fault-prevention strategies. Furthermore, advancements in AI research will unlock new opportunities for enhancing predictive maintenance efficiency. Cutting-edge ML and deep learning algorithms will help identify complex patterns and anomalies with greater precision, allowing maintenance teams to optimize decision-making and improve system reliability.

DEVELOPMENT OF PROPOSALS FOR REDUCING DETECTABLE FACTORS OF MOBILE POWER STATIONS DURING COMBAT OPERATIONS

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Modern mobile power stations, which supply electricity to military units in combat zones, are critical components of operational infrastructure. However, their operation is accompanied by various detectable factors that adversaries could exploit to locate and target military positions. Key signature indicators include acoustic, thermal, electromagnetic, and visual emissions, necessitating technological solutions to minimize their presence.

Implementing innovative camouflage solutions for mobile power stations aims to enhance concealment and battlefield survivability. The most promising areas of improvement include:

– acoustic concealment – using sound-absorbing materials and active noise cancellation systems to suppress engine noise.

– thermal masking – employing advanced thermal insulation coatings and energy dissipation techniques to reduce infrared emissions.

– electromagnetic shielding – integrating electromagnetic wave-blocking devices and reducing electromagnetic radiation levels.

– optical camouflage – utilizing adaptive camouflage systems capable of altering color and texture according to environmental conditions.

Research into these solutions will contribute to the development of a comprehensive concealment system for mobile power stations, significantly enhancing the security of military units and minimizing detection risks during combat operations.

ENHANCEMENT OF OUTPUT VOLTAGE STABILIZATION METHODS FOR SYNCHRONOUS GENERATORS IN RADAR STATION POWER SUPPLY SYSTEMS

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Radar stations (RLS) play a critical role in national defense and airspace monitoring, and their stable operation depends largely on reliable power supply systems. Due to stringent power quality requirements, there is a need to improve output voltage stabilization methods for synchronous generators powering radar stations.

Factors Affecting Voltage Stability

Load fluctuations, variations in generator rotation frequency, and external influences (temperature changes, electromagnetic interference) can cause voltage instability, negatively impacting sensitive radar electronics and reducing equipment lifespan.

Key Areas for Improvement:

– implementation of modern automatic regulation systems (ARS)

– application of digital voltage regulators utilizing adaptive control algorithms

– deployment of PID regulators with self-tuning capabilities for improved dynamic system response

– optimization of stabilization circuit designs

– use of inverter technology to maintain a stable sinusoidal voltage waveform

– integration of active smoothing filters to minimize harmonic distortion and voltage fluctuations

– implementation of advanced energy-saving components

– integration of supercapacitors for short-term load compensation

– use of lithium-ion buffer batteries for voltage stabilization during brief outages

– protection against external influences and overheating

– development of thermal management systems incorporating active cooling for regulatory devices

– application of electromagnetic shielding to minimize interference affecting generator control systems

The proposed enhancements will ensure high stability of output voltage, improve radar power system performance, and reduce the risk of operational failures. Implementing innovative regulation methods will lower energy losses, enhance generator efficiency, and extend the lifespan of power supply systems.

Future research may focus on integrating AI-driven management systems into synchronous generator control, enabling full automation of voltage regulation processes and further advancing radar power supply reliability.

– vector control implementation, improving AM dynamic characteristics and enabling precise torque regulation while minimizing energy losses;

– adaptive control algorithms, utilizing predictive control systems based on mathematical models to optimize motor performance under variable load and grid parameters;

– deployment of digital regulators, using microprocessor controllers for adaptive management, automatic fault detection, and operational optimization;

– energy efficiency enhancements, incorporating AI-driven regulators and modern IGBT inverters to reduce energy losses, enhance AM performance, and lower overall power consumption.

The proposed advancements will ensure high-speed response, operational stability, and energy savings while increasing the overall efficiency of AAMC control systems. Integrating adaptive algorithms and intelligent monitoring will extend equipment lifespan and minimize maintenance costs.

Future research may focus on AI-driven fault prediction technologies and automatic adaptation of motor operation to changing environmental conditions.

DEVELOPMENT OF PROPOSALS FOR THE APPLICATION OF DIGITAL RELAY PROTECTION DEVICES IN POWER TRANSMISSION LINES TO ENSURE RELIABLE POWER SUPPLY FOR MILITARY AIRFIELDS

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The reliability of power supply for military airfields is critical to the effective operation of aviation units. Any power disruptions can negatively impact navigation systems, communications, maintenance facilities, and security infrastructure. One of the key aspects of ensuring continuous power delivery is the enhancement of relay protection for transmission lines. Traditional electromechanical relays are becoming obsolete due to limited response speed, low configuration flexibility, and frequent maintenance requirements. For military airfields, digital relay protection devices (DRPDs) are necessary, providing advanced functionality, high precision, fast response times, and integration into modern monitoring systems.

Key Areas for Enhancing Relay Protection:

– Implementation of intelligent protection algorithms;

– Utilization of adaptive algorithms for automatic parameter adjustments based on operational conditions;

– Integration of artificial intelligence (AI) to predict potential failure scenarios;

– Optimization of protection component selection;

– Use of microprocessor-based relays, offering multi-functionality, rapid response, and self-diagnosis;

– Incorporation of automatic reclosing systems (ARS) to minimize downtime following temporary faults;

– Improvement of resistance to electromagnetic interference;

– Development of shielded devices to reduce the risk of relay malfunction due to electromagnetic emissions;

– Application of secured communication channels for transmitting power network status information;

– Integration into unified automated control systems;

– Implementation of SCADA technology for remote monitoring and relay management;

Utilization of IoT-based systems to collect and analyze real-time power grid data. The proposed improvements will significantly enhance the stability of military airfield power supply. Deploying digital relay protection devices will reduce failure risks, lower maintenance costs, and improve response times to operational abnormalities. Future research in this domain could focus on developing self-learning protection systems based on big data analytics and the implementation of autonomous energy solutions for critical aviation infrastructure.

DEVELOPMENT OF RECOMMENDATIONS FOR ASSESSING THE TECHNICAL CONDITION OF POWER CABLE LINES IN MILITARY AIRFIELD POWER SYSTEMS UNDER COMBAT CONDITIONS

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Ensuring the reliability of power cable lines in military airfields is critical for the effective operation of power supply systems under combat conditions. Risks associated with physical damage, extreme loads, and environmental influences highlight the need for technical assessment and modernization strategies.

Develop scientifically grounded recommendations for evaluating the condition of military airfield power cable lines and establish criteria for diagnostics, damage forecasting, and maintenance strategies.

Existing Research Areas:

– smart monitoring technologies for high-voltage cables, assessing electrical, thermal, and mechanical parameters, including partial discharge detection.

– power distribution network health monitoring, identifying structural defects in lines and substations.

– cable testing methods for damage localization and diagnostic accuracy improvements.

These research efforts help advance diagnostic techniques and predictive maintenance strategies, particularly under combat-related stressors.

Key Diagnostic Technologies

– partial discharge analysis;

– thermal monitoring;

– impulse reflectometry;

– modeling extreme conditions such as impact forces, vibrations, and electromagnetic pulses.

Develop decision-making algorithms for repair, replacement, or reinforcement of damaged cable segments. Generate real-time fault assessment recommendations and establish degradation evaluation criteria for combat environments. Create protection and restoration strategies to ensure continuous power supply for military airfields.

The integration of modern diagnostic technologies and adaptive maintenance strategies will significantly improve power cable reliability and ensure stable operation of military airfield power systems under combat conditions.

СЕКЦІЯ 8

АВІАЦІЙНА ТЕХНІКА, ТЕХНОЛОГІЇ ТА СИСТЕМИ

Керівники секції: д.т.н. проф. пр. ЗС України Юрій ШЕВЯКОВ
Секретар секції: студент Сергій КОНОВАЛЕНКО

PROBLEMS AND PROGRAMMES TO ENSURE ENVIRONMENTAL SAFETY OF INTERNATIONAL CIVIL AVIATION

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As one of the components of aviation safety, environmental safety is a state of the environment that ensures the prevention of environmental degradation and the emergence of a danger to human health. This concept is legally enshrined in the national regulatory framework in the form of relevant articles of the Constitution of Ukraine, the Laws of Ukraine "On the Fundamentals of National Security of Ukraine" and "On Environmental Protection", as well as at the international level, in relation to aviation activities, in Annex 16 to the Convention on International Civil Aviation, Doc. ICAO 9501, 9829 and some other documents that form the regulatory framework for environmental protection from the harmful effects of the aviation industry.

In the report, the author, as part of the analysis of ICAO's objectives to ensure the environmental safety of civil aviation, covers in detail the issues related to the protection of people and the environment from the harmful effects of aviation noise and emissions of harmful substances and greenhouse gases. It describes current and prospective operational measures aimed at reducing the impact of these harmful factors, both locally and globally. The report provides a detailed look at the programmes initiated by ICAO: CO_2 Offsets and Reductions for International Aviation (CORSIA); assessments of the achievability and impact of the Long Term Global Ambitious Goal (LTAG) for international civil aviation to reduce CO_2 emissions; and local CO_2 offset programmes implemented by the world's leading airlines.

HATE SPEECH IN THE CONTEXT OF THE RUSSO-UKRAINIAN WAR

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The full-scale war of Russia against Ukraine has created a new communicative environment in which language not only reflects reality but also actively shapes it. One of the key elements of this discourse is hate speech – a controversial yet functional phenomenon that serves as a means of symbolic resistance, mobilization, and emotional response.

In a military context, hate speech acquires specific features: it not only condemns the enemy but also defines moral boundaries, where hatred becomes a tool of ethical differentiation. This is particularly evident in the Russian information space, where hate speech takes on a systemic, propagandistic character. The dehumanization of Ukrainians through terms such as "Nazis" or "failed statehood" serves as ideological justification for aggression and contradicts the norms of international humanitarian law.

In contrast, Ukrainian military discourse – particularly the communication of the Air Force of the Armed Forces of Ukraine – combines official tone with emotional intensity, irony, and rhetorical contrast. This language functions not only as a tool of information but also as a means of moral support and survival under the conditions of war.

In light of this study, there arises an urgent need to reflect on and preserve linguistic ethics: despite the justified sharpness of statements, the Ukrainian military should strive to avoid dehumanizing the enemy, refraining from mirroring the aggressor's rhetoric. While the legitimacy of strong expressions is recognized, attention to linguistic ethics remains critically important. Avoiding dehumanization even in wartime is a testament to moral superiority, which should become the foundation of the rhetoric of just resistance.

RESEARCH IN AUTOMATED FAULT DIAGNOSIS

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The traditional means of achieving automated diagnosis is by establishing a library of faults, based on field experience and manufacturer data, and using this knowledge to build an expert system to identify the potential failure sources.

There are commercially available software packages that are implemented to achieve this task on aircraft.

The reliability of such packages depends greatly upon the accuracy of faults identified by experts.

Years of accumulation of knowledge is typically necessary to establish all the necessary rules for engine diagnostics. Even when a good knowledge basis is established, new engines still need to be tested based on these rules, as variations between engines can cause different fault signatures.

Many of the research efforts focus on establishing reliable and thorough sets of fault libraries to assure correct diagnosis.

However, the main efforts in the research community concentrate on improving diagnosis reliability by either combining the rulebased diagnosis method with other AI techniques, such as neural networks and fuzzy logic, to "learn" the necessary rules, or combining the rules and test data with theoretical knowledge, based on models of engine performance.

MAINTENANCE DECISION

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Aircraft maintenance work includes pre-flight checks, post-flight inspection and scheduled maintenance. According to statistics, only 60% of the aircraft total failure can be found with ground inspection, while 40% of the fault is exposed during flight. It is obvious that the integrity of the aircraft with a high rate is difficult to guarantee only with the ground inspection, but due to bad maintenance such as frequent power-on check or ineffective removal of equipment will cause the equipment to reduce the inherent reliability and waste the human and financial resources. Although key components of the type of aircraft are of the condition monitoring, but only in the post-flight maintenance technicians can download the monitoring data and carry out the corrective maintenance, namely the condition monitoring information of the aircraft has not been timely and effective use.

Once the future health of the device estimated effectively applying probability forecasting model, the equipment failure rate at a certain time, reliability function, or residual life distribution function has been obtained. A maintenance decision model can be established in accordance with the economy, equipment availability, risk and other criteria, and the optimal strategy.

In decision-making process, based on the fault information provided by the diagnosis and prediction program, the decision is made according to if the faulty equipment is needed to be repaired and when to be repaired, and analysis accounting about maintenance costs and repair working time calculation.

NEURAL NETWORKS-BASED DIAGNOSIS

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Neural network-based diagnosis is another means of complementing rule-based diagnosis.

Neural network models can be used instead of traditional models as a means of providing a nonlinear modeling technique.

ural network models can also provide a general tool for classifying test data for comparison to theoretical data from other models.

The main advantage of neural networks is their ability to learn the faulty and normal operating signatures from actual test data and help with the reliable classification of faults in engines, without requiring detailed system models.

However, a thorough neural-based diagnostic tool requires the collection of extensive training data, including all possible fault signatures, to develop the model.

One possible source of training data is from flight tests, as in the study on helicopter rotor loads.

A new method proposed for training neural nets is the fuzzy learning rate steepest descent (FSD) method, which makes the training process more efficient.

Other examples of using neural networks for gas turbine engines and for the SSME are found in Hans R. DePold and E Douglas Gass. The application of expert systems and neural networks to gas turbine prognostics and diagnostics. ASME Journal of Engineering for Gas Turbines and Power and V.C. Patel, V. Kadirkamanathan, and H.A. Thompson. A novel self-learning fault detection system for gas turbine.

RESEARCH IN ENGINE PARAMETER MONITORING

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Monitoring systems collect large amounts of data that are usually analyzed offline.

Well-established statistical methods are still the norm.

The implementation of these methods has grown in sophistication and speed with increases in computational power.

For typical engine parameters such as temperatures, pressures, and speeds, exceedances and trends are monitored using commercially available software packages.

If a predefined limit is exceeded, a cockpit caution is activated, and performance data are recorded for further investigation on-ground.

Alerts based on exceedances and trend reporting have provided improved diagnostic capabilities in commercial and military aircraft.

For vibrational diagnostics, health indicators are established by means of signal averaging, by generating component-specific vibration signatures.

The idea is to use a variety of indicators from time-domain (synchronously time-averaged) and frequencydomain signals, specific to engine components, as well as amplitude and phase modulation signatures.

Alerts are generated when changes in indicator trends exceed the set thresholds.

ANALYSIS OF MOBILE PHONE SOFTWARE TESTING TOOLS

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Today, mobile applications are an important part of the digital environment, as they cover a wide range of areas – from communication to finance, education and entertainment. In this regard, the quality of software products for mobile phones is becoming particularly relevant. One of the key stages in development is testing, which allows you to ensure the reliability, stability and security of the application on different devices and versions of operating systems.

The report examines modern mobile application testing tools that help developers detect errors at the development stage and provide a positive user experience. Particular attention is paid to such popular tools as Appium, Espresso, XCUITest, TestComplete and Firebase Test Lab.

Appium is a cross-platform tool for automated testing of mobile applications on Android and iOS. It supports various programming languages and allows you to conduct functional testing without the need to change the application code. Espresso and XCUITest are frameworks, respectively for Android and iOS, which provide high test speed and integration with official development environments. Firebase Test Lab allows you to run tests on real devices in the cloud, which significantly improves test coverage.

An important aspect of mobile testing is to take into account device fragmentation – differences in screen sizes, OS versions, technical characteristics and network conditions.

Thus, the use of modern testing tools allows you to effectively ensure the quality of mobile software, minimize post-release risks and increase user satisfaction.

RESEARCH INTO MODERN MEANS OF CREATING LOW-POLYGON GAME MODELS

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Nowadays, game development requires a combination of high visual quality and efficient use of resources. This is especially true for mobile games, where performance is a critical factor. As a result, there is an increasing demand for the use of low-polygon 3D models, which allow for the creation of visually appealing content with minimal system load. At the same time, there is a need for modern software tools that provide efficient modeling, texturing, and optimization of such models.

This report examines current software tools for creating low-poly models that are widely used in the video game industry. Particular attention is given to programs such as Blender, Autodesk 3ds Max, Maya, and ZBrush.

Blender is a modeling tool that enables the creation of full-fledged low-poly scenes thanks to its wide range of tools for mesh editing, texturing, and UV unwrapping. 3ds Max and Maya are used in professional studios to create both high-polygon and optimized models for further implementation in game engines such as Unity or Unreal Engine. Automatic simplification algorithms, bake tools, and normal tools are actively used to optimize models.

Thus, modern tools for creating low-polygon models offer flexibility and high efficiency in 3D content development. Their use significantly reduces the production time of game assets and allows them to be adapted to the technical limitations of target platforms.

ANALYSIS OF INFORMATION PROTECTION METHODS AGAINST ERRORS IN COMPUTER NETWORKS

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Computer networks are the backbone of modern communication and information exchange. However, they are inherently susceptible to errors that can compromise data integrity, availability, and confidentiality. These errors, ranging from bit flips to packet loss, can arise from various sources, including noise in transmission channels, hardware faults, and software bugs. Ensuring reliable and secure communication requires robust information protection methods to detect, correct, and mitigate the impact of these errors. This paper provides an analysis of key information protection methods employed in computer networks, evaluating their effectiveness and trade-offs.

The primary objective of this paper is to analyze the effectiveness of different information protection methods in mitigating errors within computer networks. The analysis will focus on identifying the strengths and weaknesses of various techniques, considering their impact on network performance, overhead, and the level of protection provided. The goal is to provide a comprehensive overview to guide the selection and implementation of appropriate error control strategies in diverse network environments.

This paper provides a comprehensive analysis of information protection methods against errors in computer networks. The findings will contribute to a better understanding of the strengths and weaknesses of different error control techniques, enabling informed decisions in network design and implementation. The analysis highlights the importance of selecting appropriate error control strategies based on the specific requirements of the network, including the error characteristics, performance constraints, and desired level of reliability. Future research will explore adaptive and intelligent error control mechanisms that can dynamically adjust to changing network conditions and optimize overall network performance.

AI-BASED AUTOMATED STUDENT KNOWLEDGE ASSESSMENT SYSTEM

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Traditional methods of student knowledge assessment are often labor-intensive, subjective, and limited in scalability. With the increasing number of students and the diversity of learning materials, there is a need for automated systems capable of providing objective, efficient, and timely assessment. Artificial intelligence (AI) offers powerful tools to address these challenges, opening up new opportunities to automate the assessment process and improve its quality.

This work presents the development and research of an AI-based automated student knowledge assessment system. The aim of the study is to create a system that can automatically assess student knowledge in various subjects, ensuring objectivity, efficiency, and scalability of the assessment process.

Preliminary results show that the developed system is capable of providing accurate and objective assessment of student knowledge in various subjects. Comparison of grades provided by the system with grades provided by instructors demonstrates a high level of correlation. The system also provides detailed feedback for students, indicating their strengths and weaknesses.

The developed AI-based automated student knowledge assessment system has significant potential to improve the process of student knowledge assessment. The system can help instructors save time and effort, ensure objectivity of assessment, increase its scalability, and provide students with timely and detailed feedback. Further research will focus on expanding the system's capabilities, including support for a greater variety of task types and integration with learning management systems.

DEVELOPMENT OF THE "MARKETPLACE COMPANY" MODULE BASED ON WEB TECHNOLOGIES

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At the current stage of e-commerce development, the demand for universal and scalable solutions that allow to unite suppliers, sellers and buyers on a single platform is rapidly growing. Marketplaces have become a key tool of digital trade, providing a convenient way to place, search, buy and sell goods and services. To build a reliable and productive module "Marketplace Company", it is advisable to use modern web technologies, in particular Java and Spring Framework.

The report examines architectural approaches, means of implementation, and features of the development of the "Marketplace Company" module, which implements the functionality of registering seller companies, managing their products, processing orders, and integrating with the client side.

The Spring Boot framework was chosen to implement the server side, which allows you to quickly create RESTful web services with high scalability. Spring Security modules are also used to implement user authentication and authorization, as well as Spring Data JPA for convenient work with databases.

Overall, the use of Java and Spring ensures modularity, security, and high performance of the solution. The Marketplace Company module can be easily extended or adapted to specific business requirements.

AUTOMATED INFORMATION SYSTEM OF A MILITARY EQUIPMENT REPAIR ENTERPRISE

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In modern conditions, military operations and defense resource management are impossible without the effective use of databases and data warehouses that provide centralized storage of large amounts of information. Military databases contain important data on personnel, equipment, ammunition, logistics chains, intelligence, cybersecurity, and decisive combat operations. They allow you to automate decision-making processes, increase forecasting accuracy, and reduce response time to threats. Data warehouses, which operate on the basis of modern Big Data and artificial intelligence technologies, make it possible to analyze and find patterns in large amounts of information, which is important for intelligence, countering cyber threats, optimizing the process of conducting combat operations, and managing resources in real time. The use of cloud and distributed databases increases the reliability and security of information systems, ensuring data availability even in difficult combat conditions. Integration of databases with automated command and control systems of troops and weapons allows to increase the efficiency of operations (combat operations), reduce the risk of errors and accelerate the exchange of information between units (subunits).

Purpose: The main goal is to develop and implement an automated information system (AIS) that increases the efficiency, accuracy, and speed of military equipment maintenance and repair processes.

Key Functions of the AIS: digital registration of incoming equipment for diagnostics and repair; real-time monitoring of the repair process; inventory management and control of spare parts; scheduling and workload optimization for repair crews; generation of reports and technical documentation.

Benefits and advantages: increased repair quality and reduced downtime; enhanced traceability of repair operations and technical inspections; integration with military logistics and documentation systems; minimized human error through automation; improved decision-making via data analysis and visualization.

EFFECTIVENESS ANALYSIS OF DEEP LEARNING ALGORITHMS FOR IMAGE GENERATION

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The field of image generation has been revolutionized by deep learning, with various algorithms demonstrating remarkable capabilities in creating synthetic images. This paper presents a comprehensive analysis of the effectiveness of several prominent deep learning algorithms for image generation.

The analysis considers key aspects such as image quality (measured using metrics like Inception Score and Fréchet Inception Distance), training stability, computational efficiency, and the ability to generate diverse and realistic images.

We investigate the strengths and weaknesses of each algorithm, highlighting their suitability for different applications. GANs, known for their ability to produce high-resolution, sharp images, are evaluated for mode collapse and training instability issues. VAEs, which excel at generating smooth and interpolative images, are assessed for their tendency to produce blurry outputs. Diffusion Models, a more recent development, are analyzed for their superior image quality and training stability but also their higher computational cost.

The findings of this research provide valuable insights into the selection and application of deep learning algorithms for image generation. By quantifying and comparing the effectiveness of these algorithms, we offer practical guidance for researchers and practitioners seeking to leverage AI for creative content generation, data augmentation, and other image synthesis applications. The analysis concludes with a discussion of future research directions, including the development of hybrid models and improved evaluation techniques to further advance the field of deep learning-based image generation.

A REVIEW OF THE 802.11 WIRELESS NETWORK STANDARDS FAMILY AND THEIR INFORMATION SECURITY MEASURES

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This abstacts provides a brief overview of the main wireless local area network standards belonging to the IEEE 802.11 family. The technical characteristics of the 802.11a, 802.11b, 802.11g, 802.11n, 802.11ac, and 802.11ax standards are examined, including frequen-cyranges, data transmission rates, modulation types, and multi-channel transmission features. Special attention is paid to the Wi-Fi 6 (802.11ax) standard as the most advanced solution for improving network efficiency in high-density environments. Key development directions of wireless technologies are analyzed, including their importance for the evolution of the Internet of Things, next-generation mobile networks, and the creation of modern smart infrastructures.

A separate section is devoted to information security tools in wireless networks based on the 802.11 standard. The evolution of authentication and encryption mechanisms is analyzed – from basic WEP to the modern WPA3. Vulnerabilities of outdated security methods are highlighted, such as weak keys in WEP and KRACK attacks in WPA2. The advantages of WPA3 are outlined, including individualized encryption of each session, protection against dictionary attacks, and improved key exchange mechanisms. The necessity of adhering to up-to-date security standards is emphasized in order to ensure effective protection of information in the face of increasing cyber thre-ats.

AN ARTIFICIAL NEURAL NETWORK-BASED INFORMATION SYSTEM FOR PREDICTING METEOROLOGICAL MODELS

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Accurate and timely weather forecasting is crucial for various sectors, including agriculture, transportation, disaster management, and energy production. Traditional numerical weather prediction (NWP) models, while powerful, can be computationally expensive and may struggle with capturing complex, non-linear atmospheric dynamics. Artificial neural networks (ANNs) offer a promising alternative or complementary approach due to their ability to learn intricate patterns from data and provide rapid predictions. This paper presents the development and evaluation of an ANN-based information system for predicting meteorological models, aiming to enhance forecast accuracy and efficiency.

Preliminary results demonstrate the potential of the ANN-based information system to provide accurate meteorological predictions. The ANN models exhibit comparable or superior performance to certain NWP models, particularly in short-term forecasting scenarios where computational efficiency is critical. The system's ability to capture non-linear relationships in weather data leads to improved prediction of extreme events. Furthermore, the system's modular architecture allows for flexible adaptation to different geographical regions and weather patterns.

The development of an ANN-based information system for predicting meteorological models offers a promising avenue for enhancing weather forecasting capabilities. The system's ability to learn from data, provide rapid predictions, and complement traditional NWP models makes it a valuable tool for various applications. Future work will focus on expanding the system's capabilities by incorporating more sophisticated ANN architectures, integrating ensemble forecasting techniques, and developing adaptive error correction mechanisms. The ultimate goal is to create a robust and reliable weather forecasting system that can contribute to improved decision-making and societal resilience.

ANALYSIS OF CONTROL SCHEMES FOR DIRECT CURRENT ELECTRIC DRIVES

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In recent years, Ukraine has been experiencing a severe energy crisis caused by the accelerated development of energy-intensive industries of the economic complex, the free and wasteful use of energy sources, and backward technologies.

Electric motors that power systems in homes and factories consume over 60% of the energy produced. This is where the most significant energy savings are possible.

Most electric motors operate in an uncontrolled mode, and therefore with low efficiency. Due to shortcomings in the design and operation of the electric drive, the load factor of many machines does not exceed 50%, which dictates the need to reduce the installed power of the motors.

However, recent advances in the semiconductor industry, especially in power electronics and microcontrollers, have made variable speed drives more practical and significantly cheaper. Today, variable speed drives are needed not only in highly professional and powerful industrial applications, but increasingly in household appliances, such as washing machines, compressors, small pumps, air conditioners, and more.

The speed of DC motors depends on the electromotive force (EMF) of the current and the supply voltage. By changing these parameters, both the speed of the motor and the direction of rotation of its rotor can be controlled.

Therefore, at present, methods of managing energy-efficient means of industrial electric drives are also of great importance, since on the one hand, the problem of saving electricity has become acute, and on the other hand, there is a real possibility of its effective solution for the main consumer – the electric drive.

ANALYSIS OF THE USE OF OIL SWITCHES AT AC TRACTION SUBSTATIONS

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Oil circuit breakers are switching devices designed to turn on and off circuits with voltages above 1 kV in normal mode and to turn off circuits during overloads and short circuits (SC).

In installations with a voltage of 35; 110 kV, multi-volume circuit breakers are used. In these circuit breakers, transformer oil serves as an arc extinguishing and insulating medium.

Low-oil circuit breakers are used in indoor and outdoor switchgear of all voltages. The oil in such circuit breakers serves mainly as an arc extinguishing medium and only partially as insulation between the various contacts. The insulation of the current-carrying parts from each other and from grounded structures is made of porcelain or other solid insulating materials.

The analysis revealed that oil-immersed high-voltage circuit breakers remain the main high-voltage circuit breakers in AC traction substations, despite the widespread use of SF6 and vacuum circuit breakers.

This is due to the simplicity of the design and, as a consequence, ease of operation. In addition, many years of operation of oil circuit breakers have led to the perfection of maintenance and repair technology, which ultimately leads to increased operational reliability.

The main disadvantage of oil circuit breakers is the explosion and fire hazard due to the use of transformer oil. This disadvantage is partially eliminated by using low-oil circuit breakers for all voltage levels (up to and including 220 kV).

During switching of vacuum circuit breakers, overvoltages occur, which increase the rated voltage by two times or more. Therefore, it is necessary to use surge arresters, which complicates the design of circuit breakers, especially at voltages of 110-220 kV.

ANALYSIS OF THE APPLICATION OF CONVERTER UNITS AT DIRECT CURRENT TRACTION SUBSTATIONS

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The main equipment of converting units is traction (converting) transformers and rectifiers. The basis of rectifiers is power semiconductor devices. Two main types of power semiconductor devices are used – diodes and thyristors.

The rectifier consists of a set of valves placed in cabinets, a cooling system, control, protection, signaling and monitoring devices, devices for powering its own needs and equalizing current and voltage between valves, and measuring instruments.

In further developments of rectifiers, the number of diodes was reduced by increasing their class and using avalanche diodes VL – 200. Rectifiers with natural air cooling were most widely used at traction substations due to their ease of maintenance and high technical and economic performance.

Increasing the efficiency of converter units of traction substations of DC railways can be achieved in two ways:

– using converters with adjustable output voltage, which allows to compensate for the influence of voltage fluctuations in the power supply network and voltage drop from the load current in the contact network;

– implementation of circuit solutions that ensure the transfer of converters to inverter mode for energy recovery from the contact network to the power grid.

Today, it seems advisable to use hybrid solutions based on a series connection of low-voltage converters with pulse-width modulation (PWM). The voltage-reversible PWM converter can provide voltage regulation within the range of ± (20-30) %.

FEATURES OF THE CLASSIFICATION OF AVIATION TERMS OF THE UKRAINIAN LANGUAGE

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Among the significant problems of standardization and classification of Ukrainian aviation terminology are: existence of a period of formation of Ukrainian and Russian aviation terminology; due to the previous problem, it is possible to replace the Russian derivative tokens with the actual Ukrainian ones and the possible image losses associated with this process; Ukrainian aviation terminology is systematically interconnected with the rapid development of the aviation sphere and is therefore constantly evolving and updating; Ukrainian aviation terminology is under pressure from English-speaking aviation, since English is the language of international communication; the unformed of the Ukrainian aviation vocabulary makes it possible to manipulate the specified terminology, to use different variants of linguistic arrangements of the same concepts; the safety factor systematically influences and frankly slows down the process of saturation of Ukrainian aviation terminology with the actual Ukrainian regulatory vocabulary.

The classification of Ukrainian aviation terminology is a serious scientific and methodological problem, which has not been completely solved so far for a number of reasons.

AIRCRAFT ELECTRICAL EQUIPMENT DEVICES

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The aircraft electrical equipment includes a complex of power supply systems and electricity consumers. The power supply system consists of the main power supply system and additional (secondary) systems.

The main power supply system produces three-phase alternating current with a voltage of 200 V at a frequency of 400 Hz and is designed to power electrical systems and individual consumers, as well as provide secondary systems with electricity.

Secondary systems are necessary on the aircraft for the consumption of electricity by devices that require alternating current of other voltages, as well as direct current.

Secondary systems: a three-phase alternating current system with a voltage of 36 V at a frequency of 400 Hz, a three-phase alternating current system with a voltage of 27 V at a frequency of 400 Hz, a single-phase alternating current system with a voltage of 115 V at a frequency of 400 Hz and a direct current system with a voltage of 27 V.

The electricity consumers on the aircraft are: the aircraft control system, the hydraulic system, the fuel system, the engine starting system, the pressurized cabin air conditioning system, the anti-icing system, the radio navigation, location, communication, household and other equipment of the aircraft.

The electricity sources of the main power supply system are four alternating current generators. The total rated power of the main generators allows to provide all the main consumers with electricity in the event of failure of one of the engines (generators). In the event of failure of two engines at the same time, the remaining power of the main generator is sufficient to power all consumers, except for the slat de-icers and household equipment.

AIRCRAFT AUTOMATIC CONTROL AND AUTOPILOT SYSTEM INSTRUMENTS

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The automatic control system (ACS) is designed to control the flight of an aircraft by automatically deflecting the ailerons, elevator and rudder. In the process of control, two main tasks are solved: the first is to stabilize the aircraft relative to the center of mass at the angles of roll γ, pitch γ and heading ψ; the second task is to move the center of mass of the aircraft along a given flight path: in the horizontal plane along a given route, in the vertical plane from takeoff and climb to landing and taxiing to the parking lot.

Automation of aircraft flight should contribute to the achievement of the following goals:

– increasing flight safety, which is due to the fact that the automatic system, when operated correctly, controls the aircraft better: more accurately, reacts faster and compensates for external disturbances, is able to optimize the movement of the aircraft and, unlike a person, can perform several control actions simultaneously;

– improving the flight performance of the aircraft: increasing the aerodynamic quality of the aircraft, maneuverability, controllability, reducing fuel consumption and, thus, efficiency during its operation;

– relieving the pilot from monotonous, fatiguing tasks, such as maintaining straight and level flight with zero bank angle in manual control mode for an extended period of time.

IMPROVING THE DESIGN OF THE AIRCRAFT HYDRAULIC SYSTEM

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The hydraulic system of an aircraft is designed for:

– retracting and extending the landing gear;
– extending and retracting the flaps;
– braking the wheels of the main landing gear;
– steering the nose gear wheels;
– sliding (rolling) and raising (lowering) the cargo ramp (if available);
– controlling the crew emergency hatch;

– actuating the windshield wipers;
– emergency feathering of the propellers.

The hydraulic system consists of the main system, emergency system and a hand pump system.

The main system ensures the operation of all consumers. The source of pressure in the main system is two pumps with constant performance.

The emergency system provides emergency release of flaps and wheel braking, emergency control of the sliding (rolling) of the cargo ramp and opening of the emergency crew hatch in the event of a failure of the main system, and can also be used to power all consumers of the main system through the ring valve in the event of a failure of the main pumps. The source of pressure in the emergency system is an emergency electric pump station.

Using the hand pump system, it is possible to refill the hydraulic tank with hydraulic fluid, as well as to activate all consumers operating from the hydraulic system.

LANDING GEAR MAINTENANCE PROGRAMME DEVELOPMENT

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The aviation industry is highly complex, and delivering safe, dependable, and high-quality transportation has become a key objective for airlines striving to satisfy customer expectations and stay competitive on a global scale.

Given the intricate nature of modern air transport systems and the pressure of intense market rivalry, poor service reliability can lead to serious consequences – including increased operational costs, reduced efficiency, safety incidents, and even potential accidents.

Therefore, ensuring the consistent operability of aircraft is regarded as a fundamental priority by airlines.

One such system is the aircraft landing gear (L/G). The need for its maintenance is determined over time by the operational conditions of its individual components.

The final project explores current strategies for technical operations in today’s aviation industry, highlighting their key strengths and weaknesses. It reviews a standard maintenance programme and presents a proposed maintenance plan specifically for the L/G, along with a developed task card for an individual maintenance operation.

Additionally, the project includes a preliminary calculation of a business jet’s take-off weight using a zero-approximation method.

AVIATION SAFETY AND SAFETY ASSURANCE MEASURES

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The terms "flight safety", "aviation safety", "environmental safety", "economic safety" and "information security" defined in the Air Code of Ukraine are components of aviation safety, the consideration of which provides an understanding of the global directions of practical actions to improve its level. Achieving high indicators for all these components will ensure a high level of aviation safety, and improving the national air navigation system for all these components contributes to achieving, among other things, the global strategic goals of the International Civil Aviation Organization (ICAO), set out in the strategic plan for 2026-2050. This is the relevance and value of the safety measures that are being developed and implemented in the practice of civil and state aviation.

The global instruments for the ongoing enhancement of aviation safety are presently being implemented through strategic planning at the industry level, in alignment with the strategic objectives established by ICAO.

Analyzing these goals, ICAO researchers have identified 11 main areas of activity in the relevant categories that will fully meet the expectations of aviation service consumers.

The effectiveness of the proposed improvements can be assessed using a checklist for cost-benefit analysis of infrastructure investment projects, which is provided on the Global Air Navigation Plan portal. This is a type of universal checklist that represents a standard SWOT analysis of the project, which can be performed independently as part of the implementation of national projects.

AIRCRAFT POWER PLANT SYSTEMS DESIGN

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There are many Mid Passenger aircraft.

This aircraft is designed as base of family of mid Range passenger aircraft with 2 turbofan engines with high degree of design and technology and operational portability.

The designed aircraft shall provide:

– wide range of functional capabilities – range, speed, seating capacity, convenience, independence and airfield network;

– variety of versions according to application types (regional aircraft, airliner, middle and long range, executive airplane) and equipment types (domestic or foreign avionics and equipment);

– modern maintenance and operational perfection;

– conformity with the modern flight safety requirements (АП-25, FAR-25, JAR 25), quality standards and advanced ecological standards;

– competitiveness with other prototypes.

This aircraft is designed for transportation of passengers, baggage, mail and cargoes on local routes with high passenger traffic, and on some international lines providing the possibility of operation on prepared runways.

In order to extend the range of aircraft operation, we calculated the main aerodynamic characteristics: – lift to drag dependence and polar, available and required thrust, change of speed of horizontal steady flight.

IMPLEMENTATION PRINCIPLES OF VESTIGIAL SINGLE SIDE-BAND MODULATION

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Wireless communications is one of the big engineering success stories of the last 25 years – not only from a scientific point of view, where the progress has been phenomenal but also in terms of market size and impact on society. Companies that were completely unknown 25 years ago are now household names all over the world, due to their wireless products, and in several countries the wireless industry is dominating the whole economy. Working habits, and even more generally the ways we all communicate, have been changed by the possibility of talking "anywhere, anytime".

The sheer scope of development that took place can't be even imagined. But from the engineering standpoint, there are some basic concepts without which it is impossible to even begin to comprehend the signal processing techniques that saw the light of the day in recent decades. One of such basic concepts is the analytic signal, which dated back to the beginning of the 20s century.

The use of single-sideband modulation techniques allows to squeeze more information into the assigned frequency range by means of eliminating the so called spectrum redundancy. This redundancy is caused by the spectrum symmetry around its carrier frequency. Technically that means that signals are subjected to some sophisticated manipulations that are based on Hilbert transform of radio signals.

The work considers basic concepts of computational techniques that involve generation of signals with single-sideband modulation and provides MATLAB examples of vestigial single-sideband modulated signals.

OPTIMIZING AIRCRAFT MAINTENANCE: THE CASE OF THE DASH 8-Q400 PROGRAM

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The Dash 8-Q400 requires a comprehensive maintenance program to ensure operational safety and airworthiness. Regulatory authorities like the FAA mandate strict adherence to maintenance schedules through Continuous Airworthiness Maintenance Programs.

Maintenance Check Overview:

Line Checks: Conducted daily or after 25–50 flight hours. Focus on basic checks like oil levels, brakes, and exterior damage.

A Checks: Performed every 450–550 flight hours. Include detailed inspections of systems, filters, and corrosion.

C Checks: Scheduled every 12–24 months. Involve in-depth component testing and can take up to two weeks.

D Checks: The most extensive, done every 6–10 years. Require full disassembly to assess structural integrity.

Modern maintenance utilizes predictive technologies like Health and Usage Monitoring Systems (HUMS) to optimize scheduling. These systems analyze real-time data to identify potential issues before they occur, shifting from time-based to condition-based maintenance.

Regulatory updates have extended some inspection intervals based on operational data, improving efficiency while maintaining safety standards. The program's flexibility allows operators to customize schedules while ensuring compliance with aviation regulations.

This balanced approach combines rigorous inspections with advanced technology to keep the Dash 8-Q400 airworthy throughout its service life.

WAYS TO MODERNIZE THE AIRCRAFT CONDITION MONITORING SYSTEM

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At this time, aviation is used in almost all sectors of the national economy.

The need to repair machines arose as long ago as mechanical engineering itself.

As a result of the repair, the causes that can lead to more serious malfunctions are eliminated.

The experience of some foreign companies has shown that the transition to maintenance of aviation equipment according to condition is an effective means of reducing the volume of work related to the operation and repair of aviation equipment. The labor intensity of such work has decreased by 25...30%.

The greatest effect of the transition to operation in terms of technical condition is achieved in cases where the aircraft design has good operational manufacturability.

When switching to maintenance according to the technical condition of aircraft equipment, determining the technical condition becomes one of the main stages of operation and repair.

However, the transition to the system of maintenance and repair of JSC in terms of technical condition is associated with overcoming certain difficulties — it takes a long time to implement the issues of controllability of systems. These are questions such as:

1. Commissioning of automated control systems.
2. Ensuring the ability to connect a sufficient number of sensors to measure the monitored parameters.
3. Ensuring good approaches to controlled objects.
4. Reduction of the number of objects of control.
5. Introduction of modular structures.
6. Suitability of structures for the use of non-destructive testing methods.

TECHNICAL MEANS AND MEASURES OF AVIATION SECURITY ASSURANCE

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According to ICAO SARPs (Annex 17, ICAO Doc 8973), aviation security (AS) is defined as the protection of civil aviation against acts of unlawful interference (AUI), achieved through a comprehensive set of measures involving both human and material resources. This comprehensive set of measures includes the establishment and maintenance of effective aviation security services (ASS), the protection of airports, aircraft, and civil aviation infrastructure, screening of flight crew members, personnel, passengers, cabin baggage, checked baggage, mail, cargo, and in-flight supplies, as well as the prevention and deterrence of attempts to hijack or unlawfully seize aircraft.

A major role in the effective implementation of most of these measures is attributed to the technical systems and procedures that support AS, which are utilized by airport ASS units and airline personnel.

The report emphasizes the following key aspects:

a) The airport is the principal component in the civil ASS, and therefore, its protection against AUI must always remain a primary focus;

b) Currently, there are no universal security assurance methodologies. Everything depends on the specific threat landscape, geographic region, the number of domestic and international flights, the frequency of high-risk operations, and other relevant factors;

c) The varying levels of threat to airport aviation security (or to the operator/airline) depend on its exposure and vulnerability to AUI.

Guided by these considerations, the authors present a detailed analysis of modern technical means and procedures employed at various international airports. Emphasis is placed on the specific characteristics of their application and their capabilities in detecting threats to AS.

FLIGHT SAFETY AND THE HUMAN FACTOR ISSUE: CORRELATION AND CONSEQUENCES

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In modern aviation, flight safety remains a top priority and requires a comprehensive analysis of all variables that can affect the stable operation of the aviation system. One of the most critical among these is the human factor – a combination of physiological, psychological, emotional, and cognitive characteristics of individuals involved in flight operations.

According to international aviation safety statistics, over 70% of incidents and accidents are directly or indirectly attributed to human error. These may involve pilot mistakes, inadequate coordination with air traffic controllers, maintenance errors, or poor risk management by airline management.

The human factor manifests through fatigue, stress, excessive workload, insufficient training, or communication failures. For instance, delayed decision-making by the flight crew in a critical phase or misinterpretation of cockpit information can lead to catastrophic outcomes. Conversely, timely and coordinated actions by flight and ground personnel can save hundreds of lives.

Thus, the human factor is deeply intertwined with the level of aviation safety. Addressing this issue requires a systemic approach – including advanced crew training programs, integration of innovative technologies, psychological support systems, and the cultivation of an organizational culture where the safety and lives of passengers and aviation professionals are held as the highest value.

CHALLENGES IN DEVELOPING A SAFETY CULTURE IN CIVIL AVIATION SERVICE PROVIDER ORGANIZATIONS

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Safety culture in the aviation industry is a complex and multifaceted phenomenon that encompasses a set of shared values, beliefs, norms, and practices among all members of an organization at every level. It is not merely a collection of rules and instructions, but a mindset and behavioral model in which safety is placed at the forefront of every decision and action. This culture is key to preventing aviation accidents, incidents, and errors in a high-risk operational environment.

The human factor plays a crucial role in the establishment and maintenance of a strong safety culture.

An analysis of the current state of safety culture in civil aviation organizations revealed a range of challenges that hinder the development of an effective safety culture. These challenges include the complexity of regulatory frameworks, issues with ensuring personnel competence, communication barriers, limited resources, the need to balance safety and operational performance, resistance to change from both management and operational staff, inability to adapt to emerging technologies, bureaucratic constraints, and lack of trust in leadership. Understanding these issues is essential for developing effective strategies to enhance safety within the aviation sector.

The report emphasizes that preventing the negative consequences of a weak safety culture requires a comprehensive, multi-level approach involving all stakeholders– from senior management to frontline personnel. The analysis of real-world aviation incidents supports these conclusions. Strengthening safety culture not only reduces the likelihood of aviation occurrences but also positively impacts operational efficiency, system reliability, and overall organizational productivity.

IMPLEMENTATION OF MODERN ALTERNATIVE ENERGY SOURCES IN AVIATION TRANSPORT

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Aviation, as one of the most energy-intensive modes of transport, faces significant challenges in the context of global warming and energy security. Increasing pressure from EU environmental regulations, ICAO, and the United Nations is pushing the aviation sector toward innovative solutions. By 2050, the industry aims to achieve carbon neutrality, with the implementation of alternative energy sources being a key component of this transition.

This shift includes both the modernization of conventional aircraft engines and the integration of advanced technologies, such as the use of Sustainable Aviation Fuel (SAF), electric and hybrid propulsion systems, and the development of hydrogen-powered aircraft. Leading aerospace companies – including Airbus, Boeing, Rolls-Royce, and others – are already investing billions of dollars in research and development in this area.

However, the large-scale adoption of alternative energy sources in aviation faces a number of technical, economic, and infrastructural challenges. Major investments are required in scientific research, airport modernization, and the creation of safe storage and handling systems for new types of aviation fuel.

PROBLEMS AND MEASURES TO ENSURE CIVIL AVIATION SECURITY AT THE STATE LEVEL

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Civil aviation security issues are extremely complex and require a comprehensive impact on all its components. The role of the state in this process is particularly important, as it possesses the administrative resources that are critically needed to launch effective transformations to improve the situation in the areas of flight safety, aviation security, environmental protection, economic security and information security. In addition, the state is the ultimate beneficiary of such improvements and therefore has a direct interest in them.

However, such improvements cannot be made spontaneously, but must be part of a higher-level strategy. This is the ICAO strategy for international civil aviation security, which is presented on the organisation's website in the form of clearly defined strategic goals. The technologies for achieving them are set out in the Global Air Navigation Plan (GANP) (Doc.ICAO 9750) and prioritised by four levels: global strategic and technical, regional and national.

The report focuses on the problematic issues of security and the measures that must be implemented at the national level in accordance with the relevant national plans and programmes. Relevant examples are provided and conclusions are drawn regarding the neglect of security issues at the national level. It is noted that the national level is the responsibility of the state. The security programmes, plans and measures developed by the state must take into account the interests of national airlines and be consistent with higher-level plans (regional and global).

DEVELOPMENT AND RESEARCH OF ALGORITHMS FOR OPTIMIZATION OF THE STRUCTURE OF DISTRIBUTED DATABASES

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Existing On-Line Transaction Processing (OLTP) systems, in particular billing systems (BS), specialize in the operational processing of small transactions that arrive in large quantities. Therefore, the issue of minimizing the system response time to meet client requirements becomes important. At the same time, an important condition is to ensure data exchange with the OLTP tool in real time with minimal delay. Such parameters directly depend on the mathematical algorithms and architectural solutions used in OLTP systems.

The task of optimal data placement in billing OLTP systems is critical for the effective functioning and processing of transactions in real time. The main essence of the task is to find optimal data placement strategies in the database (DB) to ensure the required transaction processing speed, minimize data access time, and maximize system performance.

The relevance of the highlighted problem is due to the growth of data volume, high transaction intensity and the need for reliable operation of BSs used in telecommunications, finance and other industries. Ensuring effective data management allows you to increase the speed of customer service, reduce system response time and increase the overall reliability and productivity of OLTP systems.

The purpose of the research is to increase the efficiency of the optimal data placement solution in billing OLTP systems based on the application of evolutionary genetic programming to solving the integer linear programming problem with dummy variables.

The report considers the results of the development of algorithms for optimal data placement in billing OLTP systems based on evolutionary programming.

СЕКЦІЯ 9

МАТЕМАТИЧНІ МЕТОДИ У ВІЙСЬКОВО-ПРИКЛАДНИХ ЗАДАЧАХ

Керівники секції: к.п.н. доц. пр. ЗС України Галина БОБРИЦЬКА
Секретар секції: працівник ЗС України Вікторія БІЛЕЦЬКА

DYNAMIC PROGRAMMING. THE BACKPACK PROBLEM.

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The dynamic programming (DP) method is one of the most effective mathematical approaches for solving multistage optimal control problems. The core idea behind dynamic programming lies in step-by-step optimization, where each stage involves decision-making with consideration of its future consequences.

Essential concepts of DP include an operation composed of *m* steps, and an additive criterion (gain *W*), which sums the outcomes from individual stages. It's incorrect to assume that each step should independently maximize its efficiency; rather, the true goal is to achieve maximum overall gain for the entire process. Therefore, DP optimization is executed in two phases: initially, from the end to the beginning, conditionally optimal solutions are determined for the remaining stages; then, from beginning to end, the definitive optimal control decisions are established. The DP method has broad applications in engineering, economics, biology, household, and numerous other fields that involve optimization challenges. A prominent example is the "knapsack problem," which involves selecting items to load into a backpack or vehicle with a maximum total weight and value. Dynamic programming significantly reduces computational complexity, quickly delivering optimal solutions without unnecessary exploration of all possible combinations, particularly beneficial when facing extensive datasets.

TARGET ALLOCATION PROBLEM

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Target allocation distributes combat assets (guns, missiles, aircraft, etc.) among multiple targets to maximize force effectiveness. It plays a critical role in defensive and offensive operations, where decision-making time is limited and the number of allocation options surpasses human analytical capacity. Efficiency criteria and target prioritization are essential.

Mathematically, target allocation is an optimization problem, effectively solved using dynamic programming, which ensures each stage contributes to an overall optimal solution by working backward from the final step.

Example: Optimizing Missile Distribution

A practical case involves allocating 8 missiles across 4 targets, where engagement probabilities depend on the number of missiles assigned. The distribution considers all possible combinations, comparing probabilities to identify the optimal allocation for maximum overall effectiveness.

One such optimal configuration is:

– 4 missiles for the first target;
– 1 missile for the second;
– 1 missile for the third;
– 2 missiles for the fourth.

This setup yields the highest probability of hitting all targets – about 0.4.

Automated allocation adapts quickly to dynamic battle conditions, crucial for modern battle management. Rational resource distribution avoids unnecessary expenditures, protects strategic assets, and reduces vulnerability risks.

The developed algorithm supports both defensive and offensive operations, making it an indispensable tool for military analysts and planners.

STRENGTH CALCULATION OF THE WING OF MIG-29 AIRCRAFT

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In modern aircraft construction, special attention is paid to ensuring the strength of the bearing elements of aircraft. The wing of a MiG-29 fighter jet is subjected to significant loads during manoeuvres, so its strength calculation is critical to ensure flight safety.

In this paper the analytical calculation of the strength of the Mig-29 wing is carried out, taking into account the main loads and material characteristics, as well as to determine the most stressed areas of the structure.

The calculations were carried out taking into account aerodynamic pressure, distributed load, bending and torsional moments. The influence of the skin material and internal reinforcing elements was also considered.

It was found that the wing of the MiG-29 aircraft meets the strength conditions under normal load.

APPLICATION OF LINEAR PROGRAMMING TO THE LOGISTICS PROBLEM OF TRANSPORTATION OF CADETS TO THE INTERNSHIP LOCATIONS

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The use of logistics tasks is becoming very relevant in today’s conditions. The optimization of logistical processes plays an important role in ensuring the effective operation of both businesses and transport companies, as well as in everyday life. In this paper we consider the problem of transportation of cadets to their internship locations. The problem is solved using actual ticket prices and the number of cadets of the second faculty of the Ivan Kozhedub Kharkiv National Air Force University.

The task is to determine the optimal cost of tickets for the transportation of cadets who are sent from selected military educational institutions to military units for internships. At the same time, the capabilities of military units to receive, accommodate and provide cadets during the internship were taken into account.

A mathematical model of the problem was developed, a reference plan was drawn up using the minimum cost method and tested for optimality using the classical method of potentials. We improved the reference plan by using the cycle rollover method.

We were able to reduce the cost of railway flowers and thus increase the efficiency of our faculty's logistics processes. Improving logistics not only contributes to the rational use of funds and time resources but also contributes to the optimal use of human resources. The developed model ensured optimal resource allocation and can be applied to enhance planning in military educational logistics.

THE PROBLEM OF FUZZY LINEAR PROGRAMMING

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In the formulation of organizational control problems – particularly those involving the allocation of military resources – it is quite common to encounter situations where the available information is incomplete or subjective. When such information is expressed in natural language, it often contains a high degree of vagueness, using terms like "more or less", "approximately", "few" or "many," which lack direct counterparts in the language of mathematics. Clearly, attempting to describe such information using traditional mathematical tools would significantly narrow the scope and adequacy of the resulting model. Therefore, it becomes necessary to employ a mathematical framework capable of formally representing the vague or imprecise concepts people naturally use when describing their understanding of a system.

One such framework is fuzzy set theory, developed by L. Zadeh in 1965.

In modeling real-world mathematical programming problems, fuzziness manifests itself in the form of vague descriptions of both the objective function and the constraint functions, as well as the parameters on which they depend. Since there are various ways to model this fuzziness, different classes of fuzzy mathematical programming problems exist.

In our work, we have solved a fuzzy linear programming problem in which the coefficients of the objective function, as well as those of the linear constraint functions, are represented as fuzzy numbers. We reduced this problem to a parametric programming problem, which can be solved using wellknown methods such as the simplex method.

LINEAR PROGRAMMING PROBLEMS OF MILITARY ORIENTATION

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Linear programming problems are a special class of optimization problems, and in the military sphere they are a very important tool for optimizing resources, logistics, planning operations, etc.

The aim of the work was to learn how to build and solve mathematical models of optimization problems close to real military and economic conditions using various methods. The task was to determine the optimal number of reconnaissance and attack drones that should be produced to maximize combat effectiveness under conditions of limited access to fuel, electronic components, and equipment operating time. The problem was solved using the geometric method, which demonstrated that even with basic knowledge of higher mathematics – drawing lines, working with graphs, understanding the gradient – it is possible to solve applied problems. The

Solver add-in of MS Excel was also used to solve the problem, which made it possible to automate the process of finding the maximum of the objective function under the given constraints. The analysis of the reports allowed us to draw deeper conclusions about the role of each resource in the task and identify which ones critically affect the optimal solution. Thus, Excel has become not only a solution tool but also a modeling tool.

The use of both geometric and programmatic methods allowed us to see the problem from different angles. The geometric method allows you to better understand the structure of the problem, visualize the decision-making process, and Excel opens up the possibility of solving more complex models with more variables and sensitivity analysis. This approach promotes the development of critical thinking, data analysis skills, and digital literacy.

HOW FRACTIONS CAME ABOUT: HISTORY AND METHODS OF WRITING COMMON AND DECIMAL FRACTIONS

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The need to divide whole objects was the root cause of the concept of fraction. The process of developing and improving fraction writing lasted for 4 thousand years. It included contributions from various civilizations, such as ancient Egyptian, Babylonian, Greek, Chinese, Indian, and Arabic.

The Egyptians were among the first to regularly use fractions to measure and allocate resources. The uniqueness of their approach was the use of aliquot fractions (the numerator was equal to 1). The Babylonians used the hexadecimal system, where fractions had denominators that were powers of 60. Greek mathematicians, in particular the Pythagoreans with their numerical ratios and Euclid with the foundations of number theory and proportions, made a significant contribution to the theoretical understanding of fractions.

Common fractions are divided into regular and irregular fractions (can be represented as mixed numbers). The basic mathematical operations with them are addition, subtraction (requiring a common denominator), multiplication (numerator by numerator, denominator by denominator), and division (multiplication by the inverse fraction).

The idea of decimals came later. They were first used in China, which laid the foundation for understanding decimals. Later, Arab mathematicians contributed to their spread. Simon Stevin made a significant contribution to the popularization of fractions in the 16th century.

Today, fractions are an indispensable tool in science and everyday life for precise measurements and calculations.

UNSOLVED SECRETS OF MATHEMATICS

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One of the unsolved problems in mathematics is the question of the relationship between the P and NP classes of problems. The P class includes problems whose solution time increases moderately with the size of the input data. For example, sorting elements, finding the shortest path in a graph, etc. In contrast, the NP class includes problems for which we can quickly check the correctness of the solution if it has already been found, but it can be extremely difficult to find this solution on large amounts of data. Among the most famous NP-hard problems are the backpack problem, graph coloring, etc.

In this paper, we consider the backpack problem, in which you need to choose the optimal subset of items with given weights and values to fill the backpack as much as possible without exceeding the permissible weight. Such a problem has many applications in the military domain, where you need to optimally select a limited number of resources from a set of possible ones to maximize efficiency. For example, loading a UAV or the optimal choice of munitions for a limited carrier. Two ways of solving such a problem with a certain number of items were considered: searching all combinations manually and reducing it to an integer linear programming problem. To solve the LP problem, the Solver add-in of MS Excel was used.

Using the brute-force method is useful for training, analyzing all options, and checking for correctness. Excel is a practical tool for quickly finding the optimal solution in problems of medium complexity close to real-world applications. The use of both methods in combination increases the understanding of the structure of the problem, promotes the development of skills in mathematical modeling and analysis of optimization problems.

THE NUMBER PHI AND THE THEORY OF THE GOLDEN RATIO IN THE UNIVERSE

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The golden section $\left(\varphi = \frac{1+\sqrt{5}}{2} \approx 1.618\right)$ a unique mathematical constant that arises as the positive root of a solution to a quadratic equation $\varphi^2 - \varphi - 1 = 0$.

The number Phi is associated with the Fibonacci sequence, in which $\left(a_{n+2} = a_n + a_{n+1}\right)$ each subsequent number is equal to the sum of the previous two. The ratio of each number in the sequence to the previous one tends to a constant number $\varphi = a_{n+1} : a_n$. If we divide any number in the sequence by the next number, we get the inverse of 1.618 $\left(\frac{1}{\varphi} \approx 0.618 = a_n : a_{n+1} = -\psi\right)$.

Binet's formula $\left(a_n = \frac{\varphi^2 - \psi^2}{\sqrt{5}}\right)$ establishes a direct link between Fibonacci numbers and the golden ratio $\varphi > 0$ and its conjugate meaning $\left(\psi = \frac{1-\sqrt{5}}{2} = 1 - \varphi \approx -0.618 < 0\right)$.

The mathematical harmony inherent in the number Phi encourages us to look for its fundamental role in the organization of the universe, in the arrangement of planets and other celestial bodies. Spiral galaxies, such as our Milky Way, have a structure that resembles the golden ratio.

In space exploration, the golden ratio can be used to design spacecraft and their orbits, which can help optimize flight paths and increase the efficiency of space missions.

MODERN ENCRYPTION METHODS

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In today's digital era, encryption is a vital tool for protecting data from cyber threats. Technological advancements demand continual improvement in cryptographic methods to ensure confidentiality, integrity, and accessibility.

There are two main types:

Symmetric encryption, where the same key is used for encryption and decryption.

Asymmetric encryption, which employs a public-private key pair.

Each approach has advantages: symmetric algorithms offer high speed, while asymmetric algorithms enhance security in key exchanges.

Key encryption algorithms include AES, RSA, ECC, Blowfish, Twofish, and ElGamal. AES is the global standard, RSA secures internet communications, and ECC is efficient for low-resource devices.

Special attention should be given to data protection methods, such as hardware, software, and hybrid encryption. Network security relies on SSL/TLS, IPSec, and end-to-end encryption (E2EE), alongside database protection.

Additionally, quantum-resistant algorithms like CRYSTALS-Kyber and CRYSTALS-Dilithium are being developed to counter future threats. Secure key management practices, including key rotation and storage in hardware security modules (HSMs), are crucial for maintaining encryption integrity. Multi-factor authentication (MFA) and zero-trust architecture further enhance security by minimizing unauthorized access risks. Continuous monitoring and regular security audits help identify vulnerabilities and ensure compliance with evolving cybersecurity standards.

Hash functions like SHA, MD5, and Bcrypt support password storage, data verification, and digital signatures.

Modern cryptography is evolving to meet future challenges, including quantum-resistant algorithms and AI-driven security. Encryption remains a cornerstone of cybersecurity in a rapidly advancing digital landscape.

WAVELET TRANSFORM AND ITS APPLICATIONS

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A wavelet is a set of functions used to analyze the frequency characteristics of signals.

The most well-known wavelets include: Haar wavelet, Daubechies wavelets, Gaussian wavelets, Meyer wavelet, Morlet wavelet, Paul wavelet, MHat ("Mexican hat") wavelet, Coifman wavelets (coif lets), and Shannon wavelet.

Wavelet transforms are widely applied in various fields, such as image processing, blood pressure analysis, pulse and ECG analysis, DNA examination, protein studies, climate research, general signal processing, speech recognition, computer graphics, and multifractal analysis. This transformation is also used for signal encoding, signal analysis in engineering and computer science, and scientific studies of physical processes.

The Study Covers:

– History of wavelet development;
– Examples of wavelets;
– Wavelet classification;
– Concept of wavelet transform (integral and discrete);
– Examples of signal decomposition using wavelets;
– Sequence reconstruction using selected coefficients;
– Noise reduction in signals;
– Applications of wavelet transforms;
– Conclusions.

USING COMPUTER ALGEBRA SYSTEMS FOR SOLVING DIFFICALT MATHEMATICAL MODELS

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Modern Computer Algebra Systems (CAS) are powerful tools for researching and solving complex mathematical models, particularly in combat modelling.

This study compares the characteristics of Maple, Wolfram Mathematica, and Mathcad, based on their ability to solve a battlefield model described by a system of two differential equations.

The Necessity of CAS. Analytical solutions for such equation systems are often impossible or highly complex, making CAS essential for obtaining numerical solutions, graphical visualizations, and model behaviour analysis.

Research Results. Demonstration of solving a system of differential equations describing the battlefield model in each of the three CAS. Comparison of results (analytical and numerical solutions, graphs, and model behaviour analysis). Assessment of accuracy of obtained results.

The choice of CAS depends on specific needs and model complexity:

– Maple and Mathematica are more powerful tools for solving complex mathematical models.

– Mathcad is better suited for simple engineering calculations.

For solving battlefield models, Maple and Wolfram Mathematica are the best options due to their advanced differential equation-solving functionalities.

APPLICATION OF MATHEMATICAL PACKAGES FOR SOLVING DIFFERENTIAL EQUATIONS

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The development of mathematical software packages has significantly simplified the solution of differential equations (DEs), which are widely used in natural sciences and engineering. Computational tools enable the automation of complex calculations and facilitate numerical and analytical analysis.

Mathematical packages such as MATLAB and Maple provide powerful tools for solving both ordinary and partial differential equations. They support numerical methods (e.g., the Runge-Kutta method) and symbolic computation, ensuring a result accuracy of 95–98%.

Key advantages include high-speed data processing, visualization of solutions, and dynamic system modeling, which optimize scientific research and practical applications in physics, engineering, and economics.

Beyond conventional solutions, mathematical packages play a crucial role in predictive modeling, control system analysis, and AI-driven simulations, enabling real-time optimization in technical fields. Their integration into education enhances interactive learning and problem-solving methodologies, making complex mathematical concepts more accessible.

The continuous improvement of computational tools offers new perspectives for analyzing complex models, fostering the integration of theoretical knowledge with cutting-edge educational technologies.

PSEUDORANDOM SEQUENCE GENERATION

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Pseudorandom sequences are widely used across various fields, including mathematics, computer science, biology, and cryptography. As information security requirements grow, the need for reliable generation methods also increases.

The goal is to explore main pseudorandom sequence generation methods, evaluating their practical applications, strengths, and weaknesses.

Mathematical approaches use recursive formulas, such as the Fibonacci sequence. Popular algorithms include the linear congruential method, Mersenne Twister, and Xorshift. However, these methods have a limited period and are dependent on initial seed values.

Physical methods rely on natural random processes such as electrical noise, light fluctuations, and nuclear decay. These approaches ensure high entropy and extended periods but require complex hardware and significant costs.

A striking example is Cloudflare's use of lava lamps as an entropy source for generating secure cryptographic keys. Capturing their light variations produces unique and unpredictable values.

Our study examined a wide range of generation approaches, revealing that the choice of method depends entirely on task specificity and available resources.

In security-critical applications, algorithms with long periods and high unpredictability are the most suitable, ensuring robust protection against potential threats.

THE BATTLE DYNAMICS PROBLEM WITH REINFORCEMENT

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In 1906, F. Lanchester published a study proposing attrition-based combat models. Today, Lanchester’s models remain widely studied, expanded upon, and used to verify historical battles. These models are relatively simple, making them suitable for military education as examples of applied combat scenarios.

This paper examines a highly organized combat simulation based on Lanchester's approach, incorporating the following factors:

– Initial numbers of combat units for both sides, assuming homogeneity within each force.

– Hit probability for each unit per shot.

– Rate of fire for combat units on both sides.

– Reinforcement rate – number of additional combat units entering the battle per unit of time.

Results:

– Development of a mathematical combat model.

– Solutions to a system of two linear inhomogeneous differential equations with initial conditions, calculating the number of surviving combat units over time t.

– Graphical representation of solutions.

– Estimation of battle duration.

– Determination of the winning side.

– Calculation of remaining combat units for the victorious side.

– Conclusions based on numerical and analytical findings.

MAGIC OF PIXELS

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Satellite images play a crucial role in military, scientific, and civilian applications. Their automated analysis is possible due to their representation as numerical matrices, enabling object recognition, mine detection, landscape monitoring, and terrain change analysis.

Any image can be transformed into a brightness matrix (for grayscale images) or a three-dimensional array (for RGB-format images). In grayscale images, each pixel carries an intensity value, allowing precise data processing and feature extraction.

$I(x, y) \in [0, 255]$, where 0 is black and 255 is white.

Digital image matrices enable object extraction, contour detection, and anomaly identification in satellite imagery.

Object extraction method based on brightness levels:

$$I_{bin}(x, y) = \begin{cases} 1, & I(x, y) < T \\ 0, & I(x, y) \geq T \end{cases}$$

where T is a bound which determines whether a pixel belongs to an object.

Military approaches:

Detection of mines and explosive devices, in particular, analysis of shape, color, and texture.

Recognition of military objects, by using neural networks to identify equipment.

Monitoring terrain changes comparing images from different time periods.

Presenting images as numerical matrices allows the application of mathematical methods for their analysis. This opens possibilities for automatic object recognition and classification, which is extremely important for military research.

USING BAR CODES IN MILITARY OPERATIONS AND LOGISTICS

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Barcodes play a critical role in military operations and logistics, ensuring quick and accurate accounting of identification data. They help minimize errors in data entry, which can have serious consequences in military conditions.

Barcodes represent a set of 13 digits – the European Article Number (EAN), designed for optical reading. They consist of black and white stripes of different widths, where each digit of the code is represented by a set of 7 modules. The barcode contains information about the country of registration of the company, the manufacturing company, the product itself, and a control digit intended to detect errors during reading. The control digit is determined in such a way that the sum of all the digits along with it is a multiple of 10. This helps to detect entry errors, such as the transposition of two adjacent digits.

Military applications of barcodes:

– Identification and tracking of military objects
– Inventory management
– Access control to confidential information

Barcodes are an essential tool in military research and operations. They contribute to accurate data entry and processing, which enhances efficiency and reduces the likelihood of errors. The use of barcodes demonstrates how mathematics can be applied to solve practical problems in the military field.

IMPROVEMENT OF THE CAESAR CIPHER

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Cryptography is one of the key sciences in the field of information security. Its main goal is to transform information into a form that is inaccessible for understanding by unauthorized persons, ensuring its confidentiality, integrity, and authenticity.

Modern technological development, including the widespread exchange of data through open communication channels, creates serious threats to information security. The increase in the number of cyberattacks, unauthorized access to data, as well as the risks of their theft or falsification, make cryptography an indispensable tool for protecting the digital infrastructure.

Encryption of information has been actively used by humanity for a long time. One of the earliest known methods is the Caesar cipher, which involves shifting each letter of the alphabet by a certain number of positions. However, this algorithm is quite simple, which reduces its effectiveness.

To improve classical methods, we propose a new approach to text message encryption – adding not a constant number to the code of each character, but members of the Fibonacci sequence. At the same time, an initial key is set, which determines from which member of the sequence the encryption will begin.

The main feature of our method is that the encrypted characters and the original letters do not have a one-to-one correspondence, which significantly complicates the decryption process.

For the implementation of this method, a Windows Forms application has been developed that encrypts and decrypts text files using a modified Caesar cipher. The use of the Fibonacci sequence for dynamic key shifting makes the encryption more robust.

The program code implements the main components that provide interaction with the file, encryption and decryption of text, as well as verification of the correctness of the entered key.

СЕКЦІЯ 10

РОЗВИТОК ВІЙСЬКОВО-ПРИКЛАДНОГО СПОРТУ В УКРАЇНІ ТА В ПРОВІДНИХ КРАЇНАХ НАТО

Керівники секції: к.н.ф.в. і с. підполковник Андрій ПОЛТАВЕЦЬ
Секретар секції: майор Дмитро КМЕТЮК

DEVELOPMENT OF MILITARY APPLIED SPORTS IN UKRAINE AND LEADING NATO COUNTRIES

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In Ukraine, the focus on military-applied sports has intensified, particularly in light of the ongoing conflict. Disciplines such as combat sambo, military all-around, and shooting have gained prominence as they directly contribute to combat effectiveness and survival skills. There's a growing emphasis on incorporating these elements into the physical education of youth to enhance national defense preparedness from an early age.

Leading NATO countries, while also valuing the physical and tactical benefits of military-applied sports, often exhibit a broader range of developed disciplines. These may include orienteering, parachuting, naval pentathlon, and various forms of marksmanship, reflecting the diverse operational environments and specialized roles within their armed forces. Resource allocation in these nations often allows for more sophisticated training facilities and participation in international military sports competitions organized by bodies like the International Military Sports Council (CISM).

Despite these differences, the underlying objective remains consistent: to cultivate physically robust, mentally agile, and tactically proficient individuals who are prepared to defend their nations. The development of military-applied sports serves as a vital link between physical culture, military training, and the overall security and resilience of both Ukraine and its NATO allies.

ANALYSIS OF THE TRAINING PROCESS OF CADET ATHLETES DURING PREPARATION FOR MILITARY AVIATION PENTATHLON COMPETITIONS

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Military aviation pentathlon consists of air and sports competitions. Air competition is a special type. It is known that the components of a sports competition are shooting and swimming, fencing, basketball, obstacle course and orienteering, competitions in which are held every subsequent day from the start of the starts. Each men team consists of four participants. Each of the components of a sports competition contributes to the overall quality of the result, but the last day of the competition deserves special attention – passing the obstacle course and orienteering.

Considering the specifics of the VAP sports competition (analysis of literary sources and questionnaires of current members of the national team), the leading criterion that determines the final result of the competition is the ability to perform sports tasks with a minimum number of errors at maximum physical exertion. Since the functioning of the sensorimotor area of the cerebral cortex and the ability of higher nervous activity functions to adequately process information directly depend on adaptation to hypoxia, which occurs when aerobic load transitions to anaerobic, it is important to achieve the best results in a VAP sports competition, primarily when overcoming an obstacle course and sports orienteering, to introduce interval loads – changes in aerobic and anaerobic motor activity within one workout (CrossFit).

THE HISTORY OF AERONAUTICAL PENTATHLON IN UKRAINE

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The history of aeronautical pentathlon in Ukraine dates back to 2016, when representatives of the command of the Armed Forces of Ukraine were invited as observers to the competition in Tikkakoski (Finland). At these competitions, the delegation of the Ukrainian studied in detail all sports of competitions, rules and material base for competitions and training. After arrival, the national team in this sport was honored, which began its preparation for the first competition

The first competitions for the Ukrainian national team were Lithuanian Open Military Aeronautical Pentathlon Championship, 2017, Kaunas.

The next important competition for the Ukrainian national team was the regional championship, which was held in 2018 in the city of Uppsala, Sweden.

In 2019, the national team of Ukraine took part in competitions in Lithuania. It was at this competition that two men's teams performed for the first time.

In 2021, the national team of Ukraine took part for the first time in the World Aeronautical Pentathlon Championships, which was held in Las Palmas de Gran Canaria, Spain.

Despite the large-scale war, in 2022 the national team took part in the World Aeronautical Pentathlon Championships in the city of Tikkakoski (Finland). The national team of Ukraine went to these competitions as one of the favorites of the competition.

The next important competition for the national team of Ukraine was the regional championship, which took place in 2024 in the city of Tikkakoski, Finland.

Today the team is preparing for the next championship.

IMPROVING COMBAT READINESS OF SERVICEMEN THROUGH PSYCHOLOGICAL TRAINING BASED ON HAND-TO-HAND COMBAT

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The combat readiness of military personnel depends not only on their physical fitness but also on their psychological resilience under extreme combat conditions. In response to the challenges faced by the Armed Forces of Ukraine in modern warfare, a specialized training program was developed and tested. This program uses hand-to-hand combat techniques as a means of improving psychological stability and decision-making skills under stress.

The study was conducted at the National Army Academy (Lviv) and involved 60 cadets specializing in the management of mechanized unit operations. The participants were divided into an experimental group (EG) and a control group (CG). Over the course of three days, both groups performed a series of exercises simulating combat tasks: disembarkation from vehicles, tactical movements, 3-km forced marches, hand-to-hand combat techniques, and firing or tactical standards under physical and psychological stress.

Results showed a 37.94% improvement in task completion rates in the EG compared to baseline data, while the CG demonstrated minimal progress or negative dynamics. The EG also showed better endurance, group cohesion, and the ability to make decisions under stress, with zero dropouts during the exercises.

The findings prove the effectiveness of the program in improving combat readiness by integrating realistic physical activity and psychological training through hand-to-hand combat.

ANALYSIS OF NATO STANDARD EXERCISES AND EXERCISES THAT DEVELOP SPECIAL PHYSICAL QUALITIES AND FORM TASK-SPECIFIC SKILLS AMONG PERSONNEL OF THE AIR DEFENSE MISSILE TROOPS OF THE ARMED FORCES OF UKRAINE

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The generalization of the training and educational experience of the air defense missile troops demonstrates a close correlation between the indicators of special physical fitness of military personnel and the level of their professional skills and competencies.

The article presents a comparative analysis of exercises based on NATO Standards and the structure and content of current military-applied exercises (PTI-2021) in the context of their use for the development of professionally important psychophysical qualities and the formation of applied skills of servicemen in the Air Defense Missile Troops of the Air Force of Ukraine. The paper also includes conclusions and proposals for the development of new, necessary exercises and complexes to be included in the combat training program.

As a result of the theoretical analysis, a certain inconsistency was identified between the current list of military-applied exercises (PTI-2021) and the special tasks of servicemen of the specialties under consideration.

Further research should be aimed at optimizing the exercises, taking into account the specific training needs of Air Defense Missile Troop specialists in preparation for and conduct of combat operations.

СЕКЦІЯ 11

СУЧАСНІ НАПРЯМКИ РОЗВИТКУ ФІЗИКИ ТА РАДІОЕЛЕКТРОНІКИ

Керівники секції: к.т.н. с.н.с. пр. ЗС України Микола БАРХУДАРЯН
Секретар секції: солдат Ігор ТРОФИМЕНКО

PHYSICAL PECULIARITIES FOR MOVING TARGET DETECTION UNDER INTERFERENCE

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The analysis of Ukraine's experience in the war against Russian aggression confirms the relevance of detecting moving targets under artificial interference. Therefore, when designing radar systems for moving target detection, it is very important to clearly define the physical characteristics that give rise to criteria for distinguishing features and structures in the signals reflected from both moving and stationary targets. These differences in criteria form the physical basis for detecting moving targets under passive artificial and natural interference. To determine the physical criteria for moving target detection, the spectral analysis of signals reflected from moving targets fling a wide speed range and the spectral analysis of signals reflected from artificial interferences have been analyzed in the research.

It is proposed that the measurement of the Doppler phase shift over the pulse repetition period can be carried out in various ways, using a phase detector or another type of phase meter device. The average value of the cosine of the phase shift can then be used to adjust the local oscillator frequency to compensate for the motion of passive interference, or to control an electronic phase shifter method is discussed in the presentation. The spectral shift of the received signal frequency from the carrier frequency is called the Doppler frequency and is used to detect signals from moving targets against the background of signals reflected from stationary objects in a moving target indication (MTI) system. Thus, the spectral characteristics of signals reflected from stationary and flying targets have been considered to determine the detection criteria.

THE PHYSICAL METHODS OF ANTENNA RADIATIONAL PATTERN SCANNING IN F-16 FIGHTERS

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The physical methods of antenna radiational pattern scanning in F-16 fighters refer to how the radar antenna onboard the F-16 physically moves or stays stationary to direct its beams across space to detect, track, and engage with the targets.

The antenna radiation pattern scanning refers to how the radar "looks around" in different directions to detect objects (like enemy aircraft, cruise missiles, guided bombs, and drones). The radiation pattern is the shape and direction in which the radar emits and receives energy of electromagnetic waves. The physical method refers specifically to the mechanical movement of the antenna. In early or conventional radar systems, this would mean the antenna physically rotates or tilts using motors to change its direction of view. Thus, the radar antenna is fixed in shape but can be physically tilted both up/down and left/right, using servo motors. This physical movement allows the radar beam to sweep across the sky systematically, and scanning helps the radar detect and track multiple targets within a wide field of view.

Moreover, the modern fighters equipped with AESA (Active Electronically Scanned Array) radars like the AN/APG-83 SABR no longer rely on physical movement. These use electronic beam steering, meaning the beam is redirected by changing the signal phase electronically, much faster and without moving parts. There is no mechanical movement of the antenna in the AN/APG-83. The beam is scanned using phase shifting of signals across thousands of tiny transmit/receive modules. In conclusion, the radiation antenna pattern’s scanning is done electronically, using an AESA radar, which changes the direction of the radar beam without moving the antenna–feeder system mechanically.

NUCLEAR ENERGY IN AVIATION AND ROCKET TECHNOLOGY

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The energy effects of nuclear fission and fusion processes are millions of times greater than the energy of chemical combustion and explosion reactions, which are the source of energy for the vast majority of engines of all types of modern military equipment and for the striking effect of shells and missiles.

In nuclear charges (warheads of missiles, torpedoes, bombs, artillery shells, etc.), the explosion occurs due to the release of a large amount of energy in rapid chain reactions of fission of heavy nuclei, and in thermonuclear weapons it initiates thermonuclear reactions of fusion of light nuclei. Aviation nuclear propulsions (ANPs) are capable of saving a huge amount of aviation kerosene. They generate thermal energy in a nuclear reactor and transfer it to the aviation gas turbine engine (GTE) in an open or closed way.

In ramjet engines, air is heated by a nuclear reactor and enters a nozzle apparatus, where the potential energy of the gas is converted into the kinetic energy of a jet stream. Long-range, precision-guided ballistic missiles and cheap mid-air refueling technologies have made the idea of a large bomber with ANPs obsolete.

The relevant developments were not completed, since the main problems were not solved: the creation of a compact, lightweight nuclear reactor and reliable biological protection for the crew, as well as the safety of the nuclear-powered aircraft in flight.

Based on field tests of rockets with nuclear stage showed that nuclear engine is suitable for use in space technologies, its specific impulse is twice as high as in a thermal chemical system. The engine can be considered suitable for a manned flight to Mars.

LASER WEAPONS TODAY

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The vast majority of engines of all types of modern military equipment, as well as the implementation of the striking effect of projectiles and rockets, use chemical reactions of combustion and explosion as a source of energy. Heated to a high temperature, the gaseous products of the reactions expand very quickly, performing the mechanical work of moving projectiles and vehicles or destroying and moving the environment. Due to the limited abilities of gunpowder and fuel components, the modernization of artillery and missile technology requires fundamentally new sources of energy. Laser weapons are at the stage of testing and practical application.

Laser ("Light Amplification by Stimulated Emission of Radiation") is an optical quantum generator that creates powerful coherent monochromatic electromagnetic waves by forced emission of light through an active medium. Its beam spreads over long distances and can destroy materials and electronic systems.

Laser systems operate at the speed of light, allowing instant impression of targets. Today, laser weapons are undergoing field tests and are already being used in the air defense system to destroy missiles, artillery shells, aircraft, UAVs, destroy enemy manpower and equipment, and protect ships, aircraft and ground objects without significant side effects – explosions or debris. Laser weapons are also being researched in the direction of space defense. Despite high energy costs, the toxicity of chemical laser reagents requiring special safety measures, and the impact of the environment (rain, fog and dust can scatter or absorb laser radiation, reducing the effectiveness of weapons), development in this promising field of military affairs continues in many countries. New Israel laser system "Iron Beam" that shot down UAVs, missiles, mortar shells, and anti-tank missiles is planned to be used as an addition to "Iron Dome". By now Ukraine has got its own laser system "Tryzub" ("Trident") able to knock down UAVs and planes.

THE PHYSICAL PRINCIPLES OF RING LASER GYROSCOPES

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Ring laser gyroscopes (RLG) are the result of over 100 years of research, development, and experimentation in navigation technology. They are essential to flight safety, combat applications, and accuracy in both manned and unmanned aerial vehicles. Nonetheless, gyroscopes are devices utilized for measuring and maintaining the orientation of an object in inertial space, at any given time. Before RLG technology, mechanical gyroscopes were the norm. A mechanical gyroscope is based on the principle of conservation of angular momentum, which states that if no external torque acts on a system, the total angular momentum of the system remains constant. It operates on the principle of the Sagnac effect, which shifts the nulls of the internal standing wave pattern in response to angular rotation. Interference between the counter-propagating beams, observed externally, results in motion of the standing wave pattern, and thus indicates rotation. The Sagnac effect manifests itself in an experimental setup called ring interferometry.

The ring interferometry means that a beam of light is split, and the two beams are made to follow in opposite directions a trajectory that constitutes a ring. To act as a ring, the trajectory must enclose an area. The light that exits the ring is guided in such a way that an interference pattern is obtained. The position of the interference fringes is dependent on the angular velocity of the setup. This arrangement is also called a Sagnac interferometer.

When a ring laser is rotating, the detector will detect a frequency that is consistent with the laser process generating two frequencies of laser light. Thus, Ring laser gyroscopes are lightweight, compact, and self-contained, which allows for effective combat applications. This is a major benefit, especially for inertial navigation systems.

DEVELOPMENT HISTORY AND SIGNS OF METAMATERIAL CLASSIFICATION

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Metamaterials are artificially and specifically engineered media that exhibit electromagnetic properties that are technologically challenging to achieve or do not exist in nature.

Metamaterials can be designed with various electrical properties. Their classification is based on the values of relative permittivity and relative magnetic permeability.

A key feature of metamaterial design is an artificially created periodic structure.

The anomalous properties of metamaterials arise due to:

– the periodicity of the internal structure of the dielectric filler;

– resonance phenomena within the cellular structure, enabling control over the amplitudes of surface and/or evanescent (authentic) waves;

– the correct selection of coating layer parameters (thickness, electrical characteristics of material layers, number of layers, and their sequential arrangement).

An analysis of research directions in metamaterial theory allows us to predict the emergence of antenna designs based on active and nonlinear metastructures, the theory and technology of which have yet to be developed. It is highly likely that this process will also involve so-called chiral meta-environments, materials with artificial magnetic and quadrupole responses, and metamaterials with strong spatial dispersion, which are already being used to create optical devices with resolutions exceeding the diffraction limit. Given the successful beginning of the metamaterial era in antenna technology, accompanied by the discovery of a range of remarkable effects, there is reason to believe that its continuation will be equally impressive.

TO THE ISSUE OF USE THE POLYGONAL MEASUREMENT AND COMPUTING COMPLEX MEANS IN CONDUCTING MILITARY EXERCISES

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The effective use of the Polygonal Measurement and Computing Complex (PMCC) in the process of combat firing remains an unresolved task.

Polygon equipment must ensure:

– the safety of combat training activities within the polygon area;

– reliable control over the actions of crews and units, as well as clear management of crews, units, and military formations;

– monitoring and processing of the results of combat applications of weaponry, electronic warfare (EW), and the actions of crews during firing exercises, as well as timely communication of these results to military units;

– assessment of the effectiveness of combat applications and the combat capabilities of military and technical equipment (MTE) during firing exercises.

A distinctive feature of PMCC usage in this period is the simultaneous utilization of both measurement tools and objective control means for firing units, along with the measurement and computing tools of the polygon. This approach enables the acquisition of more reliable information for monitoring troop actions, improving the efficiency and accuracy of analysis and evaluation of military operations at specific stages.

The issue of PMCC methodology and its application at all stages of exercises, the rational interaction between PMCC and firing unit tools, as well as the establishment of requirements for the tactical and technical characteristics of PMCC and its components, requires further research.

ADAPTIVE AIR MANEUVERING SYSTEM FOR DRONES

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Modern drones and robots are equipped with automatic systems that ensure their autonomy, accuracy and adaptability to the environment. Such systems use a variety of sensors, data processing algorithms, and controls, combining analog and digital approaches. The main automatic systems include navigation and orientation systems, stabilization systems, pattern recognition and decision-making systems, energy management systems and adaptive control systems.

The report discusses an adaptive air maneuvering system for drones. It is shown that when creating an adaptive dynamic maneuvering system, it will use variable hull geometry and intelligent control algorithms. The drone will have movable wing modules (blades) that will change their shape depending on flight conditions (similar to the wing control system in birds). Built-in sensors (pressure, wind speed, tilt) will read environmental parameters, and a machine learning algorithm will adapt the shape of the hull to reduce aerodynamic drag and improve maneuverability.

The main advantages of the considered adaptive air maneuvering system for drones are also analyzed - more efficient use of the battery due to reduced resistance, adaptation to gusts of wind and unexpected changes in conditions, as well as the possibility of use in conditions of different pressures (for example, at high altitudes).

HYBRID ANALOG-TO-DIGITAL SYSTEMS FOR ADAPTIVE FILTERS

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Hybrid circuits combine analog and digital approaches to signal processing. This allows you to take advantage of each technology. At the same time, the analog part provides high accuracy, minimal delay and natural screening of high-frequency noise, while the digital part adds flexibility, programmability, adaptability and the ability to implement complex processing algorithms. The main hybrid circuits include analog prefilters followed by digital processing, hybrid control systems, and digitally controlled analog neuromorphic processors.

Hybrid analog-to-digital approaches optimize energy consumption, reduce delays in signal processing, and increase measurement accuracy.

The report makes an analysis of a hybrid analog-digital system for adaptive filters. It is shown that when developing such filters, they will change their parameters depending on the signal. At the same time, the analog part performs coarse filtering to protect against high-frequency noise, and the digital controller analyzes the output signal and adjusts the parameters of analog elements (for example, changes the Q-factor or frequency of the filter cut). It is noted that this can be useful for: adaptive processing of communication signals in radio engineering; dynamic adjustment of ECG filters in biomedical devices, as well as flexible noise cancellation in autonomous drone and robot systems.

RESEARCH ON THE INFLUENCE OF REAL CONDITIONS OF RADIO WAVE PROPAGATION ON THE EFFICIENCY OF MULTI-CHANNEL RADIO COMMUNICATION AND RADIOLOCATION SYSTEMS WITH PHASED ANTENNA ARRAYS

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Multi-channel radio communication and radar systems perform their intended tasks in real conditions of radio wave propagation, that is, under the influence of tropospheric inhomogeneities and reflection of radio waves (RW) from the earth's surface with a complex terrain or a rough sea surface.

These conditions cause fluctuations in the phase front of RW, which can significantly reduce the efficiency of these multi-channel systems with phased antenna arrays (PAA). The reduction in this efficiency is due to the fact that the presence of fluctuations in the phase front of RW causes a decrease in the accuracy of determining the angular direction of their arrival.

In addition, when the radio systems (RS) is exposed to active masking interference, the distortion of the phase front of its wave can lead to a significant decrease in the effectiveness of the use of appropriate interference protection devices. Thus, the analysis of the effectiveness of the use of devices that provide spatial measurements and adaptation to the external interference environment in real conditions of performing RS with PAA tasks for their intended purpose is an urgent practical task.

A numerical assessment of the influence of fluctuations in the phase front of a RW on the reduction in the accuracy of determining the angle of its arrival in RS with PAA was carried out, and the possibilities of ensuring the interference immunity of these systems in real conditions of RW propagation were analyzed.

SKIN EFFECT AND ITS APPLICATION IN ELECTRONICS AND ELECTRICAL ENGINEERING

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The skin effect is an electrophysical phenomenon in which a high-frequency alternating current is concentrated in the surface layers of a conductor. Its occurrence is due to eddy currents induced by an alternating magnetic field in the conductor according to Maxwell's equations.

The paper investigates the physical nature of the skin effect and its impact on the design and operation of electrical systems. It is shown that as the frequency increases, the depth of current penetration decreases, which increases the resistance of the conductor and heat losses.

The applied significance of the skin effect in such industries as electromagnetic shielding, induction heating, high-frequency electronics, telecommunications, energy, and non-destructive testing is considered. Practical solutions are described: the use of litz wires, copper coating of steel conductors, and shielding of printed circuit boards.

Taking into account the skin effect allows for increased energy efficiency of devices, optimized material consumption, and avoidance of signal loss. This is critically important in the design of modern electronics, microprocessors, and communication systems.

DIAGNOSTICS AND TROUBLESHOOTING OF TYPICAL FAULTS OF THE "OSA" ANTI-AIRCRAFT MISSILE SYSTEM

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As part of the planned monthly work for the position of "Head of the Power Plant of the Regulation and Repair Group", during the necessary drying of the equipment after exposure to moisture from condensate by external power, namely a 100-kilowatt mobile power plant (PES-100), a full diagnostics (functional control (FC)) of the combat vehicle was carried out. FC allows to check the following main system parameters: 1) checking the supply voltage, 2) checking cable connections, 3) periodic inspection of radar systems.

Prompt replacement or repair of faulty units – if a problem is detected with any unit, repairs must be carried out immediately to avoid further failures. At the moment, there are many problems with the equipment, since it was released back in the 1980s and is in constant operation. Due to the wear of the housings, especially the external units, there is often a violation of tightness, which leads to the ingress of moisture, dust, oxidation of contacts and short circuits.

The synchronization and stabilization unit (SSU) causes the most problems, which is responsible for the coordinated operation of the radar, missile control and guidance systems, stable operation of computing modules and data correction when tracking the target. Typical malfunctions include loss of synchronization, errors in calculations, system freezes and failure of antenna drive stabilization.

Troubleshooting the SSU involves checking contact groups and modules, updating or replacing outdated electronic components, as well as mandatory calibration and testing before combat use.

PROPOSALS FOR UPGRADING THE AZIMUTHAL RADAR ROTATION SYSTEM

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Equipment for radio detection of air objects and measurement of range and altitude is widely used in the armed forces and in aviation flight control systems. Since the modernization of existing radar systems is the most important task, much attention is paid to the updated version of the radar's azimuth remote control system, called a radio altimeter, and is intended for use in the aircraft altitude measurement system.

An upgraded version of the analog-to-digital electromechanical tracking system is proposed for implementation. It can effectively replace a double-circuit servo mechanism with an induction measuring device – a synchronous drive, remote control of the azimuthal position of the radar antenna.

The use of digital angle sensors allows you to reduce the number and reduce the dimensions of the azimuth rotation system equipment. Encoders (digital rotation angle sensors) are available and maintenance-free, and can operate in extreme environments with high potential load and high rotational speeds. Non-contact optical and absolute magnetic encoders are suitable for replacing obsolete selsyns.

To analyze the efficiency of the electromechanical system of rotation of the radar antenna, it is proposed to use the SIMULINK MATLAB application program. Studies have shown that the 180-degree angle correction time is about 9 seconds, as in the existing system. Thus, the implemented analog-digital azimuth position control system of the radar antenna has quality indicators identical to the indicators of the existing radar antenna rotation system, which are determined by the capabilities of the electromechanical part. At the same time, the amount of necessary equipment is significantly reduced and modernized.

DIFFICULTIES AND PROSPECTS OF IMPLEMENTING CYBERPHYSICAL HOLOGRAPHIC TELEVISION

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Nowadays, research and development of cyberphysical systems is one of the promising areas. For example, cyberphysical holographic television is a system whose purpose is to receive and transmit 3D information about the environment and reproduce the amplitude and phase of the optical signal in such a way that it would be possible to implement the idea of holographic television.

However, the implementation of such a structure is hindered by several significant problems: first, the lack of real holographic screens with appropriate characteristics; second, the lack of algorithms for calculating holograms corresponding to complex scenes from a large number of facets with specified optical properties; third, the high computing capabilities of the corresponding processors.

But overcoming the above obstacles will open the way to revolutionary transformations, such as increasing the transmission speed and quality of three-dimensionality of holographic images, creating ultra-broadband optical communication lines, appropriate systems for modulating and scanning light beams, transmitting a huge amount of information contained in a hologram, developing dynamic image receivers and faster screens with increased resolution, etc. Thus, cyber-physical holographic television remains a promising subject of development. It can be used in various areas of human life, from scientific and applied research (holographic microscopy, holographic interferometry, medical imaging) to technologies for teaching, communication, entertainment, advertising and business.

ADVANCED USE OF THE IONOSPHERE TO DETECT TARGETS, INCLUDING UAVS: OVER-THE-HORIZON RADARS (OTHR)

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The ionosphere is an ionized layer of the atmosphere made up of several sublayers (D, E, F1, F2), which depend on altitude, time of day and solar activity. Its ability to reflect HF waves (3–30 MHz) is due to the presence of free electrons, the concentration of which varies from 50–90 km - D-layer; 90–150 km - E- layer; 150–1,000 km - F- layer. HF waves directed upwards are reflected from these layers and return to Earth, covering distances of up to 4,000 km depending on the angle of incidence and the state of the ionosphere.

The principle of operation of over-the-horizon radars using the ionosphere:

1. Signal transmission: the transmitter emits HF waves (FMCW) in the band 5–33 MHz (JORN) or 5–28 MHz (ROTHR).
2. Reflection from the ionosphere: the signal is reflected from the F2 - layer (or E at night) to the Earth's surface.
3. Interaction with the target: the wave is reflected from the object (aircraft, ship, UAV) back through the ionosphere to the receiver.
4. Processing: digital algorithms analyze weak reflected signals, taking into account the Doppler shift to determine the speed.

The report takes a detailed look at two leading OTHR systems, the Jindalee Operational Radar Network (JORN) in Australia and the Relocatable Over-the-Horizon Radar (ROTHR) in the United States, which are unique systems that use the ionosphere to reflect high-frequency (HF) radio waves, allowing targets to be detected beyond the line of sight.

THE ANALYSIS OF POSSIBLE METHODS FOR REMOTE CONTROL OF SMALL ARMS

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At present, the war introduces new requirements to the tactics of using small arms, especially large-caliber machine guns, and puts forward new requirements and approaches to personnel training. The article analyzes the main disadvantages of existing small arms guidance systems when used to combat ground enemies, defeat air targets, and defend military, industrial, administrative, and other objects. The ways to modernize existing small arms guidance systems and the main scientific and technical problems that arise in the development of such systems are shown.

One of the main directions of such modernization is the introduction of remote control of small arms, which will ensure the secrecy of their positions, increase the accuracy of shooting and preserve the safety of the personnel. All possible methods of remote control of small arms should be developed without significant changes to their design, especially the trigger mechanism.

A comparative analysis of possible means of technical realization of radio electronic equipment and actuating mechanisms of small arms remote control systems is carried out, their disadvantages and advantages are shown.

The report shows the advantages of using microcontrollers in various small arms remote control systems and stepper motors of the same type in the guidance channels. The use of microcontrollers in the azimuth and angle guidance channels allows to increase the accuracy of aiming and memorize the angular coordinates of the shot targets for quick targeting.

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СОЦІАЛЬНО-ГУМАНІТАРНІ ПРОБЛЕМИ НАЦІОНАЛЬНОЇ БЕЗПЕКИ, РЕФОРМУВАННЯ ТА РОЗВИТКУ ЗБРОЙНИХ СИЛ УКРАЇНИ

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STRENGTH AND SACRIFICE: WOMEN’S FOOTPRINT IN THE HISTORY OF THE UKRAINIAN INSURGENT ARMY

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Until recently, the topic of women's participation in the Ukrainian Insurgent Army (UPA) remained on the periphery of historical memory. However, today, in the context of Russia's armed aggression and the active participation of women in the Armed Forces of Ukraine, this topic is being revisited with renewed attention.

For a long time, the history of the UPA was told mainly through the male experience, while the role of women remained either muted or reduced to auxiliary functions. However, research shows that women's contribution to the liberation struggle was extremely important, multifaceted, and often heroic.

Despite all the trials that women in the insurgency faced, Soviet historiography completely neglected their contribution. It was only after Ukraine’s independence that these figures began to gradually return to the public consciousness. Women in the UPA were not just an "auxiliary force" but full-fledged participants in the liberation movement, equal brothers in the struggle for Ukraine's independence.

Their experience is inspiring even today, at a time when a new generation of Ukrainian women is defending the country with arms in their hands. That is why recognizing and studying their contribution is not just an act of historical justice, but a necessity for shaping the modern Ukrainian national and patriotic discourse.

UKRAINIAN SOLDIERS – HEIRS OF THE STRUGGLE FOR INDEPENDENCE

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In November 1919 the remnants of the Ukrainian army found themselves caught in the grip of three forces: The Red, the White and the Polish armies. It seemed that the struggle for the Ukrainian state was lost: The Army of the Ukrainian People's Republic lacked ammunition, medical supplies, food, clothing, and, most critically, its own territory. The core of the force that was to embark on a partisan raid consisted of about 3,000 combat-ready cossacks and officers.

On January 1, 1920 the Kost Hordiyenko Regiment captured Uman. Over the next five months, Ukrainian soldiers continued to seize towns and villages with an almost total absence of ammunition and artillery shells.

On May 6, 1920 in the area of Yampil the Black Zaporozhian Regiment linked up with the Iron Division, which was advancing on the Bolsheviks from the west. This marked the completion of the Winter Campaign. The primary objectives – preserving the army and continuing the struggle for independence behind enemy lines – were successfully achieved.

Drawing a parallel to the present, it is fitting to recall the raid conducted by the 95th Airmobile Brigade. During this operation 470 km were covered, including 170 km through enemy-controlled territory. In the course of fierce battles for Lysychansk, Savur-Mohyla, Stepanivka, and crossings over the Mius River, the Ukrainian raiding group managed to evacuate 3,000 personnel and over 250 units of military equipment.

The similarity of these two military operations allows us to conclude that today's Ukrainian soldiers are the true heirs of the historical struggle for Ukraine's independence.

ACTIVITIES OF THE UKRAINIAN INSURGENT ARMY (UPA) IN THE DNIPROPETROVS'K REGION

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Russia's full-scale aggression against Ukraine has been going on for four years. And while the resistance of our people has come as a surprise to the whole world, and especially to the aggressor, Ukrainians know that the struggle for independence is engraved in our history. One of the glorious pages of the historical past of the Ukrainian people is the UPA, and the study of which is becoming increasingly relevant.

The UPA in the Dnipropetrovs'k region, as well as in Ukraine as a whole, performed the functions of a military and political formation aimed at creating an independent united Ukrainian state that sought to unite Ukrainian ethnic lands. The UPA was characterized by guerrilla tactics, and all its weapons were trophies, that is, obtained in battles with German or Soviet troops, or Hungarian or Austrian, acquired during the First World War.

Two stages can be distinguished in the activities of the UPA in the Dnipropetrovs'k region. The first stage was active during the Second World War, within which two periods can be distinguished: the first: from 1942 to August 1943 during the German occupation, and the second: from August 1943 to 1945 after the liberation of the Dnipropetrovs'k region from the German occupiers.

The second stage was the postwar partisan struggle (1945-1946) against the Soviet regime. This stage was characterized by the distribution of OUN propaganda printed materials by the UPA, as well as mass arrests of Ukrainian underground members.

IMPACT OF INTERNATIONAL MILITARY ASSISTANCE ON THE REFORM OF THE AFU

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The Armed Forces of Ukraine have undergone significant changes after the annexation of the Autonomous Republic of Crimea and the armed aggression in Eastern Ukraine, and with the beginning of a full-scale invasion, Russian aggression has highlighted critical problems and shortcomings in the defense sector, as well as in the Armed Forces of Ukraine as a whole.

International military assistance plays a key role today in the reform of the Armed Forces of Ukraine. In addition to logistical support, international financial assistance for the needs of the Armed Forces of Ukraine, such assistance contributes to the reform of military strategy, improvement of management, and the introduction of advanced NATO technologies.

Thus, international military assistance has a significant impact on the Armed Forces of Ukraine, since it is aimed not only at rapid changes, but also has a prolonged effect, which is visible every year, despite the fact that Ukraine has been in a state of war for almost 11 years. International resources not only helped Ukraine to resist in the first days of the war, but also to resist and fight with dignity on the battlefield to this day.

International military assistance has become a key factor in the reform of the Armed Forces of Ukraine, contributing to the modernization of weapons, improving combat training and adaptation to NATO standards. The continuation of this support is important for ensuring Ukraine's resilience in confronting external threats and developing a modern combat-ready army. In the future, interaction with Western partners should be aimed not only at receiving assistance, but also at full integration into the Euro-Atlantic security system, which will be the key to Ukraine's long-term stability.

THE IMPACT OF WAR ON THE PSYCHO-EMOTIONAL STATE OF UKRAINIAN SOLDIERS

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Ukraine's best sons and daughters stood up to defend their country with arms in hand. Most of them left with the realization that they might not return to their families and friends. However, today we are paying the highest price for the opportunity to live in a free country – the lives of soldiers. Life is the highest priority and the highest value. Ukrainian soldiers often emphasized the importance of realizing these values not only at the moment of tragic loss, but also afterwards, when they have the opportunity to analyze their experience. Therefore, it is important to study an important, yet difficult topic – the impact of war on the psycho-emotional state of Ukrainian soldiers on the battlefields with the russian aggressor.

When Ukrainian soldiers witness the deaths of their own comrades, they often do not have time to properly react, process and analyze the loss they have just experienced. In addition to the painful perception of the death of a comrade-in-arms, Ukrainian soldiers are forced to make important decisions instantly, as such an event is often accompanied by heavy shelling and difficult combat conditions. One of the most difficult decisions is to continue the fight, not to let emotions and impressions of the loss interfere with further combat missions, as the lives of the soldier and his comrades depend on it. Not only psychologists or psychotherapists learn to work with the traumatic experience of war, but first and foremost, the leadership of military units and subdivisions. In the realities of armed confrontation, they deal with such issues as searching for the bodies of fallen soldiers, evacuating them with identification, and transporting them to the families of the victims for further farewell and burial.

THE FORMATION OF AN OFFICER'S SOCIAL RESPONSIBILITY

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Social responsibility is one of the main moral qualities of a modern officer. It manifests itself in going beyond the scope of official duties and reflecting a deep personal commitment to serving the Motherland, society, and fellow soldiers. The formation of this quality of an officer's personality begins during the training as a cadet and continues throughout the officer's career.

Social responsibility is based on moral awareness, developed sense of military duty, patriotism, devotion to the state, and a developed sense of justice.

In the process of military professional activity, officers must not only follow orders, but also understand the social and ethical consequences of their actions. Their decisions must comply with moral principles and maintain public trust in the Armed Forces.

The formation of social responsibility is achieved through a combination of theoretical knowledge, national-historical and military-professional values, practical military experience and consistent demonstration of personal example. Decency, professionalism and sincere care for subordinates are the main qualities that officers must embody daily in their military-professional activities.

Through constant self-improvement and communication with military personnel and civilians, an officer becomes a true moral leader.

Thus, social responsibility is not just an unattainable ideal, but an essential part of an officer's identity. Its presence is a guarantee not only of the effective operation of military structures, but also of moral legitimacy and trust in the Armed Forces. Therefore, modern military education should place significant emphasis on the formation of social responsibility in order to form officers as true leaders and conscious members of society.

FEATURES OF EDUCATION OF CADETS IN LEADING NATO COUNTRIES

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In connection with the rapid transition of the education and training program of cadets in the Ukrainian military universities to the standards of the North Atlantic Alliance countries, it is advisable to consider in general terms the methods and standards of education used in NATO member countries. Future military personnel must skillfully and successfully perform service and combat tasks of any level of complexity, and therefore, knowledge of foreign experience is one of the extremely important elements in the process of building the educational process in the cadet environment, which is preparatory for future service and the performance of assigned tasks.

Classes on educational work with personnel are conducted by junior commanders and are characterized by a variety of forms and methods. The program includes aspects of France's domestic and foreign policy, the international situation, the history of the Armed Forces and their combat traditions.

Having analyzed the main features of the educational environment in the military higher education institutions of the USA and Great Britain, we come to the conclusion that the organization of cadet education in Ukraine has significant differences from the methods of NATO countries only in the military-professional, that is, combat, training of cadets. Our educational program has not yet introduced so many new technologies, which, moreover, were correctly and properly developed for use in military higher education institutions. This is, of course, due to the difference in the material and financial support of military higher education institutions, the historical development of military affairs, the approach of teachers and relevant departments to the organization of the educational process.

INTERNATIONAL SUPPORT FOR UKRAINE IN THE WAR WITH RUSSIA: ALLIES AND PARTNERS

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During the current Russian-Ukrainian war, despite the heroic resistance of the Defense Forces, Ukraine needs effective assistance, primarily military, from the Western democratic world. Ukraine would hardly have been able to withstand the more than three-year large-scale armed invasion of the Russian aggressor on its own and would have been able to preserve national statehood and the Ukrainian nation from genocide and destruction. To wage a protracted defensive war of attrition, Ukraine needs billions of dollars a year, which only Western partners can provide.

International support plays a key role in promoting Ukraine's stability and recovery, and partnerships with international organizations have become an important factor in rebuilding and strengthening the country, contributing to defense capabilities and supporting the economy in the war zone. According to World Bank estimates, over the next decade, to rebuild Ukraine's war-ravaged infrastructure, it will be necessary to attract large sums of money, which will far exceed Ukraine's GDP, so without investments and financial assistance from our partners, it will also not be possible to find these resources in the country.

Today, the International Coalition provides Ukraine with military, political, financial, humanitarian, human rights, and reform support, and also pursues a sanctions policy towards the aggressor country that unleashed the war against Ukraine.

Allied powers rearmed the Ukrainian army and provided shelter to millions of refugees. Diplomatic efforts by both the government and civil society institutions played an important role in ensuring solidarity and support.

RUSSIA’S COLONIAL POLICY: GENOCIDE OF THE UKRAINIAN PEOPLE

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In history, everything repeats itself only in a different dimension and level of development of humanity, and in this modern war nothing new is happening. National pride for many developed countries has always been considered achievements in economic development, science, technology, and the arts. In contrast, the pride of Russia has always been and remains the conquest of foreign lands, accompanied by bloody acts of genocide against the conquered peoples.

The history of Ukraine also contains many examples of genocide by Russia. The methods of the aggressor are not so different then and now. The armed units of the Russian Federation invaded Ukraine in 2014 to kill Ukrainians, destroy critical infrastructure facilities, the disruption of which causes significant damage to vital national interests. The Russian Federation again resorted to genocidal policies in 2022. As in the past, so now, civilians, both men, women, and children, are once again suffering from war crimes committed by the Russian troops, which are waging war using terrorist methods.

Scholars and commentators, including Timothy Snyder, Gregory Stanton, Yevgeny Finkel, and legal scholars such as Otto Luchterhandt and Zakhar Tropin, have argued that Russia is committing an act of genocide in Ukraine. In addition, more than 30 leading legal scholars and experts on genocide, in their report prepared by the New Lines Institute for Strategy and Policy and the Raoul Wallenberg Center for Human Rights, concluded that the Russian Federation is responsible for violating the "Convention on the Prevention and Punishment of the Crime of Genocide" in Ukraine.

VYACHESLAV LIPYNSKYI: ARCHITECT OF UKRAINIAN CONSERVATISM

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Vyacheslav Lypynsky (1882-1931) is a classic of Ukrainian political thought that remains relevant in the context of Ukraine's current struggle for statehood and national unity. Born into a Polish-Ukrainian family in Volyn, Lypynsky formed a unique synthesis of Western European conservatism and Ukrainian national tradition. He was the first to raise the question of the internal causes of Ukraine’s statelessness, emphasizing the need for a strong, organized government and the unity of the national elite.

In 1917, he co-founded the Ukrainian Democratic Farmers’ Party with Mykhnovsky, promoting the idea of a "constitutional hetmanate" as a model of a modern monarchy for Ukraine. His collaboration with Hetman Pavlo Skoropadskyi was an attempt to put these ideas into practice. After the defeat of Ukrainian statehood, Lypynsky continued his work in exile, developing the concept of classocracy, the power of organized social strata. In his writings, Lypynsky demonstrated a brilliant analytical mind. In his Reflections on the Old Ukrainian State, he rejected imperial myths and asserted Ukraine’s right to a separate tradition. In his monograph "Ukraine at the Turn of the Century 1657-1659", he showed the greatness of Khmelnitsky as the creator of the. His work: "Letters to Brothers Farmers has become a political testament. He emphasized: "The state is an organized force. And without this force, there can be neither freedom nor order". V. Lypynsky’s ideas are relevant for Ukraine in the twenty-first century, which is once again at a crossroads and deciding whether to become a strong state or remain "forever divided between East and West". And that is why today his legacy is worth not only studying but also implementing.

PAINTING AS A TESTIMONY TO THE RESISTANCE OF UKRAINIANS IN THE RUSSIAN-UKRAINIAN WAR

A. Nakornieieva; N. Kudriavtseva
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The reflection of the Russian-Ukrainian war in Ukrainian painting has become a powerful means of comprehending tragedy, resistance, and national identity. Artists from all over the country are actively responding to the Russian-Ukrainian war by creating deep, emotional, and symbolic works. Some works, imbued with warmth and caring, give hope; others bring tears to your eyes; others are full of wicked satire; others make you feel horrified.

V. Ralko created a series of paintings full of drama and symbolism during the active fighting in Kyiv. The main theme is the helplessness of a person in the face of war, but also the indomitable spirit. The artist uses red, black, and white colors to convey emotions: fear, pain, and hope. N. Titov is known for his posters, which have become recognizable due to their laconicism and powerful symbolism. The work "Guardian Angel" depicts a Ukrainian warrior with wings guarding the country. His works are used not only as elements of national propaganda, but also have a high artistic value. A. Zamanova painting installation "Children" is made of fragments of a discarded window frame. The window frame, which was once a portal to the outside world, has now become an intimate portal where the stories of children affected by the war unfold. R. Malets has created a series of paintings called "War Through My Eyes", including "Putin's Kaput", "Berehynia", and "Lost Childhood", which reflect the horrors of war and the resilience of the Ukrainian people.

Painting is a powerful weapon in the fight for truth. The works of Ukrainian artists not only document the events of the war, convey the pain of war, but also serve as a powerful tool to draw the world's attention to the tragedy and heroism of the Ukrainian people, help shape national memory and support the spirit of defiance.

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СОЦІАЛЬНО-ГУМАНІТАРНІ АСПЕКТИ ПРОФЕСІЙНОЇ ДІЯЛЬНОСТІ ВІЙСЬКОВОСЛУЖБОВЦІВ ПОВІТРЯНИХ СИЛ ЗБРОЙНИХ СИЛ УКРАЇНИ

Керівники секції: працівниця ЗС України Кристина ЯНДОЛА
Секретар секції: молодший сержант Анна ПАВИЦЬКА

PROBLEMS AND CHALLENGES OF REINTEGRATION OF UKRAINIAN DEFENDERS INTO CIVILIAN LIFE

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Modern military conflicts and hostilities in Ukraine pose complex challenges for veterans returning to civilian life. The reintegration of defenders into peaceful society is often complicated by psychological, socio-economic, and medical problems.

According to the current legislation of Ukraine, the state must ensure proper conditions for the return of veterans to normal life, including access to quality medical, psychological, and social services. However, there are a number of problems that require systematic solutions.

To clarify the problem of reintegration, let's outline the main aspects of this process:

1. Psychological adaptation: veterans often face post-traumatic stress disorders that affect their ability to socialize and self-actualize.
2. Socio-economic barriers: difficulties with employment, insufficient support in acquiring new professional skills.
3. Medical needs: limited access to rehabilitation for wounded servicemen.

Considering the multifaceted challenges inherent in the reintegration process, it becomes paramount to emphasize that the successful return of Ukrainian defenders to civilian life is inextricably linked to comprehensive support extended across all levels of their existence – familial, societal, and governmental.

Therefore, it should be noted that proper attention to the problems of veterans can contribute not only to their successful return to peaceful life but also to increasing trust in the state.

POSITIVE IMPACT ON THE MORAL AND PSYCHOLOGICAL STATE OF PERSONNEL STUDYING WITH VIRTUAL REALITY

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In the modern world, the use of the latest technologies increases the power of personnel, shortens training times, and also maintains a positive moral and psychological state.

Virtual reality is very actively used in our university for the training of future professionals. In this work, we will consider why the use of interactive learning positively affects the moral and psychological state of personnel.

Firstly, the use of VR glasses by cadet pilots allows them to safely master complex scenarios, for example, to practice the ability to react quickly under pressure and maintain emotional stability. This significantly improves psychological resilience and reduces stress from the fear of making mistakes in real conditions.

Secondly, the use of VR as a modern tool sparks the cadet's interest in the learning process, making learning more engaging, which positively affects the cadet's overall motivation.

In addition, training cadets on VR aviation simulators maximally imitates real flight conditions, with the possibility of adjusting external influences. This allows increasing the efficiency of practical training while reducing the costs of physical flights, which will make education more accessible.

The described technologies offer a more effective and safe learning environment, which increases the overall quality of training, making it interesting. The implementation of VR in cadet training helps to build confidence, motivation, and readiness for the performance of complex tasks by future officers.

WAYS TO RESTORE THE PSYCHOLOGICAL RESOURCES OF COMBATANTS

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In our time, servicemen who participate in combat operations face one of the most intense stress factors. Combat operations affect not only their physical but also their psychological state. Combatants constantly encounter consequences such as post-traumatic stress disorder (PTSD), depression, anxiety, and difficulties adapting to peaceful life. Restoring the psychological state of combatants is important not only for improving their mental health but also for their successful return to peaceful life.

One method of restoring a healthy psychological state is cognitive-behavioral therapy (CBT). CBT aims to identify and change destructive thought and behavioral patterns that provoke the onset of PTSD or depression. Group therapy provides an opportunity to exchange experiences with other combatants, where individuals receive support and understanding. Pharmacotherapy is another stage of rehabilitation. This therapy uses medications under the supervision of a qualified doctor, which help reduce symptoms of depression and anxiety and alleviate the condition of patients.

There are also rehabilitation programs for combatants that include: art therapy, sports activities, meditation, etc. Art therapy allows individuals to express emotions through creativity, reducing internal tension and promoting emotional recovery. Physical activity improves physical condition, promotes the production of endorphins, and reduces stress levels.

Therefore, ways to restore the psychological resources of combatants should be implemented, including psychotherapeutic, medical, social, and professional support. Timely assistance contributes to improving the mental state of combatants and their return to peaceful life.

THE IMPACT OF COMBAT OPERATIONS ON THE COGNITIVE FUNCTIONS OF MILITARY PERSONNEL

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Modern military conflicts create conditions that affect the cognitive functions of both combatants and the civilian population. Stress, psychological trauma, and constant exposure to a dangerous environment become significant factors in changes in the functioning of consciousness.

Combatants often experience a decline in the ability to concentrate and remember information. This is due to constant stress and the effects of adrenaline.

Post-traumatic stress disorder is common among military personnel. It is accompanied by anxiety, depression, and sleep problems, which also negatively affect cognitive abilities.

The influence of combat conditions changes the structure and functions of consciousness. In some cases, its plasticity allows adaptation to stressful conditions, but most often it leads to cognitive disorders.

Modern therapeutic methods offer crucial pathways for military personnel to navigate and overcome the profound consequences of traumatic combat experiences. These interventions aim to address the multifaceted impact of trauma, focusing not only on alleviating immediate distress but also on fostering long-term recovery.

Therefore, combat operations leave a deep imprint on human cognitive functions. To preserve the mental health of participants in military conflicts, it is important to implement rehabilitation and psychological assistance programs in a timely manner. This will ensure not only the effectiveness of military units but also the harmonious return of veterans to public life.

PROBLEMS OF FORMING PSYCHOLOGICAL RESILIENCE OF MILITARY PERSONNEL IN WARTIME CONDITIONS

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For the third year already, our country has been in a full-scale war, and every day, military personnel face psychological pressure. Therefore, it is worth analyzing an important problem that is of great importance for the effectiveness of the performance of combat tasks by military personnel, as well as for the preservation of their mental health. This is the problem of forming psychological resilience in wartime conditions.

In the scientific literature, psychological resilience is defined as the ability of an individual to maintain the necessary level of psychological readiness for a specified time under specific conditions and to quickly restore their psycho-emotional state after extreme (crisis) situations. Considering the experience of the Russian-Ukrainian war, it is possible to identify the main problems in the formation of psychological resilience of military personnel. For example, a high level of combat stress, high risks of developing post-traumatic stress disorder (PTSD), as well as the lack of adequate support in critical situations from commanders and command, and untimely detection of psychological disorders.

Taking into account the above-mentioned problems, we will highlight the methods of forming psychological resilience of military personnel: psychological training; individual work with military personnel.

Thus, the formation of skills to ensure the psychological resilience of military personnel is an important component for their successful performance of combat tasks and the preservation of their mental health.

CIVILIZED WAR: CONDITIONS AND POSSIBILITIES FOR HUMANITARIANIZATION OF ARMED CONFLICT

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Warfare has evolved with society. Modern conflict necessitates regulated norms to minimize suffering and protect civilians, the wounded, and POWs. International humanitarian law sets limits, but the Ukraine example shows ineffective enforcement and accountability for aggressors.

Considering the crisis in international humanitarian law (especially the Russia-Ukraine war), prerequisites for more civilized, humane wars exist: developed international relations, strengthened trust/cooperation, globalized social policy, and the evolution of international humanitarian law.

State cooperation, stronger international bodies, and a unified global consciousness respecting humanitarian law and ethics create opportunities for humanitarianizing armed conflicts.

Humanitarianization should be rooted in international humanitarian law, cooperation, and technologies minimizing destructive impact.

Despite progress, true humanitarianization is complex. Key possibilities include: enhanced international cooperation (deterrence, aid), using technology to reduce harm and control its misuse, improved international enforcement, and increased public awareness to influence government military decisions.

Ultimately, humanitarianizing war demands not just legal changes but practical implementation of modern international humanitarian law, effective international organizations, and state reforms enabling armies to act according to international norms. This limits violence, protects civilians, and promotes global peace and stability.

VIRTUAL REALITY AS A TOOL FOR PSYCHOLOGICAL SUPPORT SPECIALISTS OF PERSONNEL

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The integration of virtual reality (VR) technologies into psychological practice opens new opportunities for working with military personnel in crisis and extreme conditions.

The relevance of VR application is due to the need to create a controlled environment for the diagnosis, correction, and rehabilitation of the psycho-emotional state of personnel.

The aim of VR implementation is to increase the effectiveness of psychological assistance through the use of interactive environments for modeling real-life situations.

This allows diagnosing the level of anxiety, adaptive capabilities, and rehabilitating servicemen who have experienced combat operations and received psychological trauma. In the context of psychotherapy, VR provides gradual desensitization to stressors, which is especially important when working with post-traumatic stress disorder (PTSD).

The application of VR technologies is also relevant for training. Virtual simulators model scenarios of high psychological stress, contributing to the development of stress resistance and self-regulation skills. Despite the advantages, the implementation of VR is associated with challenges such as the high cost of equipment, the need for technical training of personnel, and the adaptation of software to specific military tasks.

Thus, the use of VR in psychological support is a promising area that allows improving the quality of diagnostics, the effectiveness of therapy, and adaptability to extreme operating conditions.

GENDER EQUALITY AND DISCRIMINATION IN THE MILITARY ENVIRONMENT

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Modern conflicts and military reforms in many countries, including Ukraine, contribute to the active involvement of women in the Armed Forces. However, the integration of women into the military environment is often hindered by gender stereotypes, discrimination, and inequality.

According to UN Security Council Resolution No. 1325 "Women, Peace, and Security" (adopted on October 31, 2000), states are obliged to ensure equal access for women and men to military service and create conditions for gender equality. To clarify the research problem, let's define gender equality and discrimination: gender equality implies equal rights, opportunities, and responsibilities for all individuals, regardless of their gender. Gender discrimination manifests itself in establishing unequal conditions for men and women, which may include social, economic, and political aspects.

Revealing gender stereotypes in the military environment, it should be noted that traditionally, the army was considered an exclusively “male” environment, where women face difficulties even when trying to join the Armed Forces, as well as during their career development. Consequently, gender stereotypes can limit women in professional opportunities and career advancement.

In conclusion, we note that gender equality can positively impact the effectiveness of military units, as it ensures diversity and access to a wide range of talents of both genders. It contributes to raising morale and mutual respect among military personnel, improves the image of the army, and strengthens the national security of the country at the international level.

"NEWSPEAK" AS A TOOL OF CENSORSHIP AND MANIPULATION IN MODERN MILITARY CONFLICTS

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In modern conditions of military conflicts, "newspeak" has become a powerful tool for information influence, manipulation of public opinion, and restriction of freedom of speech. By "newspeak", we understand a specially created language or modified linguistic constructions aimed at distorting reality, controlling thought, and shaping a predetermined perception of events. This paper will examine the mechanisms of using "newspeak" as a means of censorship and manipulation, as well as propose possible ways to counter its influence.

Regarding the impact of "newspeak" on the information space and public consciousness, the following problems can be identified: distortion of reality – replacing traditional concepts with neutral terms that conceal the real consequences of military actions (for example, replacing the word "war" with "special operation"); disinformation – using "newspeak" to create a false picture of events; limiting critical thinking – introducing terms that reduce the ability to analyze the situation and replace real discussion with propaganda.

To overcome the influence of "newspeak", it is necessary to: implement information literacy and develop critical thinking; monitor linguistic changes and analyze terminology in the media; ensure access to objective information through independent sources.

Thus, the fight against "newspeak" requires increasing the media literacy of citizens, developing independent expert institutions, and transparency in communications, which will strengthen democratic values and societal values in society.

THE INFLUENCE OF SOCIAL NETWORKS ON THE MORALE OF MILITARY PERSONNEL

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In the modern world, it is impossible to do without social networks; they influence both civilians and military personnel. Social networks have a positive and negative impact on the psychological state of various population groups, including military personnel.

Regarding the positive impact, the following aspects can be highlighted: social networks can strengthen the morale of the military, promote patriotism, and enhance the belief in victory; thanks to social networks, military personnel have the opportunity to maintain contact with loved ones and relatives, which helps reduce stress; social networks provide the opportunity to always be aware of the latest news, exchange information, and coordinate actions.

Negative factors of the influence of social networks include: manipulations by the aggressor country through media content aimed at demoralizing the population, weakening morale, and intimidation; the spread of false information and fake news through information and psychological operations (IPSO); excessive consumption of negative information can lead to depression, stress, and unwillingness to perform combat tasks.

To solve the problem of the negative impact of social networks on the military, it is necessary to raise their general educational level, develop critical thinking, and form an information culture. It is very important to provide psychological support, conduct group sessions and training to increase morale and stress resistance of the military, and carry out activities to build support and trust within the team.

Thus, social networks have a significant impact on the morale of military personnel, so it is necessary to use the information space грамотно, acquire knowledge and skills in media literacy to reduce the negative impact and increase the positive one.

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ПІДГОТОВКА, БОЙОВЕ ЗАСТОСУВАННЯ ЧАСТИН І ПІДРОЗДІЛІВ ТА ПЕРСПЕКТИВА РОЗВИТКУ СИЛ ПІДТРИМКИ ПОВІТРЯНИХ СИЛ ЗБРОЙНИХ СИЛ УКРАЇНИ

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ANALYSIS OF THE PERFORMANCE OF THE DECONTAMINATION TASKS OF WEAPONS AND MILITARY EQUIPMENT

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The existing special treatment facilities in service with the radiation, chemical, and biological protection troops of the Armed Forces of Ukraine cannot fully meet the needs for the decontamination of weapons and military equipment resulting from the use of weapons of mass destruction by the enemy.

It is concerning that the insufficient number of technical means for special treatment will lead to a concentration of troops in special treatment areas and untimely implementation of measures to decontaminate weapons and equipment.

In the special literature and scientific publications, insufficient attention is paid to modern technical means for decontamination of various objects, including weapons and military equipment, and to the issues of the order of dispersal and movement of troops in areas of special treatment.

The purpose of the work is to analyze possible options for using modern means of the existing infrastructure of the national economy, with the help of which it is possible to solve the issue of decontamination of weapons and military equipment in the event of their radiation, chemical, or biological contamination.

Self-service complexes for washing and caring for motor vehicles, which are currently deployed in large numbers in our country, as well as a large number of small-sized high-pressure pumping stations that are widely used in everyday life, are considered as means for disinfection.

Analysis of the technical characteristics of the specified means gives grounds to assert their effectiveness, and taking into account the capabilities of the existing infrastructure, to develop proposals for planning and implementing measures to support the actions of troops in matters of radiation, chemical, and biological protection.

VIEWS ON THE USE OF THE INFORMATION AND COMMUNICATION SYSTEM "DELTA"

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The "DELTA" system is designed to support Ukraine’s defense forces, providing commanders at all levels with up-to-date, verified information on the enemy, friendly units, and other important elements of the battlefield situation. It facilitates operational planning and the conduct of combat operations through integrated data collection and analysis. The system's modules, including "DELTA", "MONITOR" and "VEZHA" are aimed at creating combat graphic documents using electronic maps. The use of satellite imagery, intelligence data, and information sharing with adjacent units enables the forecasting of changes in the battlefield situation. The system provides access to topographic maps of necessary areas in any format and coordinate system, with the ability to print them at the required scale.

This capability allows for the creation of detailed combat graphic documents without the need to undergo procedures for obtaining maps through the topographic service. The option to select information layers helps focus attention on critical objects, reducing unnecessary loads on the topographic database.

The functionality for importing and exporting information layers between the "DELTA" system and the tactical-level combat management system "KROPIVIÁ" ensures effective interaction between units and command systems.

One of the current challenges is the partial incompleteness and inaccuracy of information about local objects, which can affect the quality of terrain analysis. Addressing these deficiencies is an important task for improving the timeliness and accuracy of the data within the system.

These points demonstrate the potential of the "DELTA" system in supporting the operational control of combat actions and enhancing the situational awareness of commanders by using a comprehensive approach to collecting, processing, and utilizing data on terrain and the military environment.

CONSTRUCTION OF GEOSPATIAL DATABASES USING AN OBJECT-RELATIONAL MODEL

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Solving the problem of effective processing of domestic geospatial data is proposed by creating an adequate model for its storage. The most functionally suitable method for storing geospatial data in addressing the tasks of topographic and geodetic support for military forces is the object-relational model.

Its main advantages are as follows:

the use of client-server technology;

the possibility of parallel data processing on different servers;

storing the data processing code together with the data itself;

a natural representation of geospatial data in the form of objects;

support for hierarchy and access restrictions;

support for standard relational structures.

In order to define the data for the object-hierarchical database from a set of flat contours, the possible interrelationships between them have been identified.

A mathematical model has been developed, which will subsequently serve as the foundation for the creation of an object-relational database and geospatial operators that implement the functions of their interaction. The model examines the interrelationships between geospatial objects by representing them as an external contour along with a set of internal flat contours and a set of attributes, where spatial arrangement algorithms are embodied by the connections between the objects.

DETERMINATION OF THE DISTRIBUTION OF POINTS FOR THE ELIMINATION OF THE CONSEQUENCES OF RADIOACTIVE CONTAMINATION

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To carry out tasks related to the elimination of the consequences of radioactive contamination of personnel, weapons, and military equipment, a rational distribution of forces and resources of radiation, chemical, and biological protection units is carried out. The maximum element method allows, under resource and time constraints, to rationally distribute the available resources of forces and means and determine the rational composition of their grouping. Its main advantage is that the solution of a problem with a large number of variables is reduced to the sequential solution of many problems with one variable. The use of the maximum element method will improve the quality of decisions made regarding the rational distribution of special treatment points on traffic routes by taking into account the load on the routes of movement of personnel, weapons, and military equipment from areas of possible radiation contamination.

The direction of further research is to assess the effectiveness of special treatment using methods of the theory of mass service, where the number of infected weapons and military equipment is considered in the form of applications, which arrives at service areas at points, special treatment areas and self-service places for washing and caring for motor vehicles, and as service channels – various means of radiation, chemical, biological protection units and modern means of existing infrastructure of the national economy that carry out maintenance activities.

СЕКЦІЯ 15

РОЗВИТОК ТА ЗАСТОСУВАННЯ ПОВІТРЯНИХ СИЛ, ІНШИХ ВИДІВ ЗБРОЙНИХ СИЛ УКРАЇНИ

Керівники секції: к.т.н. підполковник Іван НОС
Секретар секції: к.т.н. с.н.с. підполковник Олег ВОРОБЙОВ

MODERN AUTOMATED MANAGEMENT SYSTEMS IN THE ERA OF ARTIFICIAL INTELLIGENCE: METHODS, MODELS AND DEVELOPMENT PROSPECTS

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The rapid development of artificial intelligence (AI) is significantly transforming automated control systems (ACS), opening new horizons for efficiency and autonomy. AI, encompassing machine and deep learning, computer vision, natural language processing, and expert systems, is finding increasingly widespread practical application. ACS used in defense, industry, public administration, logistics, and cybersecurity demonstrate substantial improvements in speed, accuracy, and flexibility due to AI integration.

Modern AI methods such as neural networks for forecasting, expert systems for decision support, genetic algorithms for optimization, and fuzzy systems for handling uncertain data have become the foundation of ACS intellectualization. Future prospects include the emergence of autonomous self-learning systems, explainable AI technologies, and large-scale implementation driven by the growth of computational power and related technologies.

The integration of AI into ACS architecture occurs at various levels, ensuring a high degree of autonomy. Alongside the advantages, there are challenges related to implementation complexity, cost, and reliability. Ethical and social aspects of automation also require careful consideration.

A vivid example of the effectiveness of AI in ACS is the control of unmanned systems, where intelligence enables autonomous navigation, target recognition, electronic warfare resistance, and coordinated actions.

Thus, the integration of AI is a key stage in the development of ACS, leading to the creation of more efficient, adaptive, and intelligent control systems across various sectors.

MODEL OF THE HELICOPTER'S ONBOARD DEFENSE SYSTEM

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The problem of mine danger is becoming increasingly relevant in the modern world, especially in the context of armed conflicts that lead to significant contamination of territories with explosive ordnance. Traditional demining methods are typically labor-intensive, time-consuming, and carry a high risk for sappers. In this regard, there is an urgent need to develop more effective technologies.

The existing development of unmanned aerial vehicles (UAVs) and artificial intelligence (AI) opens up new possibilities for solving this problem. The use of a swarm of multi-rotor UAVs, equipped with various sensors and intelligent systems, creates conditions for increasing the speed, accuracy, and safety of analyzing mined territories. In the field of demining, UAVs show promise in deploying mine detectors as a payload, as well as in using multispectral and infrared equipment for reconnaissance of the mine situation by detecting temperature differences between mines and the soil.

The integration of cloud computing with UAVs significantly expands their functionality, providing the necessary computing power for processing large volumes of data. Advanced research is aimed at developing UAVs with various combinations of sensors, including thermal imagers, ground-penetrating radar, and optoelectronic sensors, which expands their functional capabilities. An important direction is the optimization of AI, weight, and energy consumption of sensor equipment to ensure efficient and long-lasting operation of UAVs. This is key for their further implementation in the areas of demining, building up-to-date maps of mine threats, and safe routes of movement.

PROBLEMS OF DETERMINING UAV LOCATION WITH MODERN ELINT MEANS

A. Diahovets; A. Panfilets
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The development of the element base, the minimization of its mass and dimensions, the increase in energy efficiency, etc. leads to the increasingly widespread use of electronics in modern life. Military technologies are no exception to this, and on the contrary, for many centuries they have been a kind of "locomotive", the driving force of the technical progress of mankind. That is why the conduct of modern combat operations involves the widespread use of radio-electronic means of the most diverse purposes.

The experience of conducting combat operations proves the increasing prospects and capabilities, the systemic impact on the nature and methods of conducting combat of unmanned complexes (devices) of ground, surface and air bases. The tasks they perform range from reconnaissance, destruction, delivery of cargo, etc. The use of unmanned aerial vehicles (UAVs) on the battlefield, which have radically changed the nature of the actions of units on the front line, proves to be particularly effective. The issue of countering these means is problematic, which is impossible without ensuring their early detection and location.

The vast majority of UAVs have a control and data transmission system (video stream), which is implemented using radio channels, which is their unmasking feature. Therefore, the detection of such means can be ensured by searching by frequency (space) and receiving these emissions. The solution to this problem relies on radio and radio reconnaissance means. On the other hand, the operating frequency range of these means allows for detection only if there is direct visibility between the receiving station and the air target, which, given the low flight altitude of the vast majority of them, from a few to several dozen meters (especially kamikaze UAVs), significantly limits the possibilities for their early detection.

The report analyzes the capabilities of modern radio and radio reconnaissance means for detecting and determining the location of UAVs. The advantages and disadvantages of triangulation and TDOA methods of determining coordinates are given. Attention is drawn to the fact that some modern means of radio reconnaissance, for example, the Vera-NG system, allow detecting and processing continuous radio signals. It is proposed to use the TDOA method more widely when detecting UAVs on the battlefield, which provides better accuracy in determining the location of air targets compared to other passive radar methods.

USE OF ARTIFICIAL INTELLIGENCE FOR DETERMINING THE IMPACT COORDINATES AND DEVIATION ASSESSMENT OF GUIDED AIR BOMBS

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Determining the exact impact coordinates of guided air bombs (GAB) and assessing their deviation is a critically important task for analyzing the effectiveness of aerial weapon use and fire correction. Traditional methods relying on telemetry data or eyewitness reports may be inaccurate or unavailable.

Modern advances in computer vision and artificial intelligence (AI) offer new opportunities to address this issue. The use of AI algorithms for video surveillance processing of GAB impacts allows for automated coordinate determination and quantitative deviation assessment, even when other sources of information are limited. Special attention is paid to the development of AI algorithms and machine learning methods, particularly deep neural networks, to evaluate the deviation of the GAB impact point based on a series of video recordings. Statistical analysis and modeling methods are explored for the quantitative assessment of impact point dispersion and identification of potential error sources. Experimental studies using simulated and real video data are conducted to evaluate the effectiveness of the proposed methods. The results demonstrate a high potential of AI for automated impact coordinate determination and objective deviation assessment through video surveillance.

The proposed approaches can be applied to improve fire control systems, analyze the effectiveness of air strikes, train personnel, and provide warnings about the threat of aerial attacks to troops.

METHODOLOGY FOR MEASURING THE PROTECTIVE RATIOS FOR SHORT-RANGE NAVIGATION RADIO SYSTEMS AGAINST THE INFLUENCE OF TRANSMITTERS OF DIGITAL RADIO COMMUNICATION MEANS

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During the armed aggression of the Russian Federation, the Air Force of the Armed Forces of Ukraine received a large number of new modern vehicles, equipment, and the latest models of radio communications. These digital radio communications are built using modern technologies and are characterized by a modular design. Compact and lightweight transceivers provide high performance, which allows them to be used for operation on aircraft.

The aircraft to be equipped with modern radio communications have old onboard electronic equipment.

The use of new generation digital radio communications equipment at the onboard communication nodes of the air control centers of the Air Force of the Armed Forces of Ukraine may create unintentional radio interference to the onboard electronic equipment, which in turn may complicate the control of the aircraft.

Thus, studies of the electromagnetic compatibility of digital radio communication equipment planned to be installed on the onboard communication units of air control centers of the Air Force of Ukraine with the aircraft electronic equipment have not been previously conducted and are currently relevant.

METHOD FOR OPTIMIZING THE DEPLOYMENT OF INFORMATION PROTECTION TOOLS IN DISTRIBUTED CLOUD COMPUTING SYSTEMS

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In recent years, there has been a noticeable trend of increasing the share of information technology use in various areas of life. Now almost every company is oriented in the production process and management to the use of computing resources. A modern approach to the design of distributed information systems is the direction of cloud computing, which includes a specialized range of information processing technologies, when computing network resources are provided as Internet services depending on the needs of users. The specificity of cloud computing is that cloud resources are maintained dynamically, in which the internal structure remains hidden from users. The high reliability and availability of cloud systems make them a promising option for implementing distributed information systems. Based on this, ensuring information security that meets the required level of quality is one of the primary tasks facing network infrastructure designers. The NIST recommendations describe in detail the architecture, main vulnerabilities and features of cloud systems. These works consider various aspects of information security, but at the moment there is no universal approach capable of providing the optimal option for the placement of information protection tools based on a given network architecture, analysis of information security mechanisms and their effectiveness relative to the existing spectrum of threats.

The report considers the results of the development of a mathematical model of a distributed information system and algorithms for optimizing the placement of information protection tools, which allow forming a complex of means of countering threats to information security in distributed systems implemented on the basis of cloud computing technology.

INFORMATION TECHNOLOGY OF DYNAMIC PLANNING AND MONITORING OF THE DEVELOPMENT PROCESS OF WEB-ORIENTED INFORMATION SYSTEMS

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Nowadays, cloud computing is a new concept that effectively combines many areas of computing. Cloud computing offers users several online services such as storage, processing power, databases, virtual servers with minimal cost and minimal energy consumption. Users can easily access these services from anywhere and anytime via the Internet. Users only pay for the resources they have used. Cloud computing stores data and distributed resources in an open environment and the amount of data storage increases very quickly.

Due to the increase in the number of applications, the load on the cloud also increases. Load balancing is a major problem among cloud networks. The main purpose of load balancing is to use resources efficiently and improve performance. Along with this, it removes nodes that carry a large load as well as nodes that are not working properly or performing small tasks.

The following basic criteria related to increasing the efficiency of cloud load balancing in real time can be distinguished: minimizing resource movement costs and task execution costs, maximizing the speed of transmission and task execution. The quality (efficiency) of balancing in work is understood as an integral criterion that includes essential parameters of the system's operation.

The purpose of the study is to improve the quality of load balancing in cloud systems, accelerate task execution time and reduce processing costs based on the development of mathematical models and algorithms for optimizing resource allocation and scheduling of application tasks in real time.

PROSPECTS FOR UAV DETECTION BY ACOUSTIC RECONNAISSANCE MEANS

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Ivan Kozhedub Kharkiv National Air Force University

The impact of modern electronic warfare on the conduct of military operations is difficult to overestimate. The experience of waging war by our State proves the increasingly widespread use of unmanned technologies on the battlefield, especially unmanned aerial vehicles (UAVs). The use of these technologies has already radically changed the tactics of units on the front line. Counteraction to these means is an urgent and important task that requires an active and purposeful search for ways to solve it.

It is known that counteraction is impossible without detection. Accordingly, detection is carried out using unmasking signs. Usually, early detection is carried out visually and/or using electronic and radar reconnaissance equipment, etc. However, one of the auxiliary unmasking signs is acoustic visibility, which is caused by the generation of acoustic (sound) waves by the engine operation and the rotation of the UAV propellers. It is known that a working internal combustion engine is a more powerful source of acoustic waves. On the other hand, most modern quadcopter-type UAVs use electric motors, so acoustic noise in this case is caused mainly by the rotation of the propellers. Usually their number is at least 4, which also allows generating noise sufficient for their detection and determination of bearing.

The results of the analysis of open publications on the issue of detection and determination of the location of UAVs using sound measurement systems are presented. Empirical data are provided on the range of their detection using modern sound measurement stations and the accuracy of direction finding. Attention is drawn to the relatively short detection range and low accuracy of determining the bearing by sound measurement stations, in addition, the difficulty of their use near the line of combat contact, given the presence of powerful sources of acoustic waves in the battle area. Acoustic reconnaissance means are proposed to be used as an auxiliary means of detection during the protection and defense of stationary objects in the depths of our territory.

АЛФАВІТНИЙ ПОКАЖЧИК

Для нотаток

Для нотаток

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НАУКОВЕ ВИДАННЯ
ДВАДЦЯТЬ ПЕРША НАУКОВА КОНФЕРЕНЦІЯ
КУРСАНТІВ ТА СТУДЕНТІВ
ХАРКІВСЬКОГО НАЦІОНАЛЬНОГО УНІВЕРСИТЕТУ
ПОВІТРЯНИХ СИЛ ІМЕНІ ІВАНА КОЖЕДУБА

Тези доповідей

Відповідальний за випуск *К.С. Васюта*
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