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BASICS OF APPLICATION OF UNMANNED AERIAL VEHICLES

Basics of application of unmanned aerial vehicles

- ✈ historical aspects of creation
- ✈ classification, functions, mission
- ✈ composition of unmanned complexes
- ✈ factors of influence
- ✈ an experience of combat use
- ✈ an experience of civil application
- ✈ resistance
- ✈ the current condition
- ✈ the development perspective

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The monograph reveals the power of creation, the formation and combat using of unmanned aircraft in military conflicts of the 20th and 21st centuries, as well as a further development of combat drones beyond the reach of foreign countries and Ukraine.

Proceedings has been prepared by a team of authors consisting of Doctor A.M. Jawad, Doctor N.H. Qasim, Doctor H.M. Jawad, Doctor M.J. Abu-Alshaeer, Doctor of technical science, Professor Y. Khlaponin, Doctor of technical science, Professor O. Sieliukov, PhD, DSc, Ing. Associate Professor Marek Aleksander.

The text of the monograph was prepared using materials of the open press on the experience of foreign countries and Ukraine. For professionals involved in the development, creation and operation of unmanned aerial vehicles, it can also be recommended to graduate students and undergraduates.

Edited by the winner of the State Prize of Ukraine in the area of science and technology, Doctor of Technical Sciences, Professor O. Sieliukov.

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INTRODUCTORY WORD

The rapid development of unmanned aerial vehicles in modern conditions has raised a number of problematic issues regarding its conceptual, theoretical, methodological and terminological support that need to be addressed promptly and qualitatively. Now it is not even a question of an unmanned aerial vehicle capable of conducting air reconnaissance and transmitting data in real time. The unmanned aerial vehicle is now becoming an element of a single information field.

Currently, hundreds of UAVs have been created in different countries, differing in both design and tactical capabilities. They can be used to address a wide range of military tasks, from the strategic and operational to the tactical level, including flying for the benefit of individual servicemen.

In recent decades, unmanned aerial vehicles have confidently taken a leading position in the arsenal of many armies and law enforcement agencies around the world. Military experts believe that in today's combat environment, especially in hybrid warfare, at the present stage of development of martial arts, unmanned aerial vehicles in contrast with manned aircraft can to more efficiently and quickly than manned aircraft, to solve problems of air reconnaissance, electronic warfare, retransmission, targeting and fare adjustment, combat management and, meteorological, radiation, chemical, biological intelligence and others without risk to personnel in the interests of the command of various levels of the armed forces. It significantly reduces the time of bringing the received intelligence to the appropriate level of management. Combat drones can operate both in the immediate vicinity of the front edge of the combat area and over enemy territory.

Modern unmanned aerial vehicles are not the result of enlightenment or a revolution in military affairs. Several generations of scientists, technicians and testers in different countries have been working on them for decades. Designers have implemented in unmanned weapons systems world experience in this field and the latest advances in science, technology and engineering. The best military analysts thought about the combat use of projectiles and cruise missiles. The experience of operating the first, imperfect generations of unmanned weapons was comprehended. And only after a certain scientific-technical and military-theoretical reserve has been accumulated, the implementation of which involved achievements in related fields of science and technology (e.g, space, information technology, materials science), the paradigm of development of weapons changed.

Weapons development has long ceased to be a state or corporate secret. New models of military equipment and weapons are demonstrated at exhibitions, new weapons developments are covered in the open press, new directions and trends in the field of armaments are discussed at international symposia and conferences. It is quite reasonable to talk about the prospects for the development of unmanned aerial vehicles (UAVs). For single-use UAVs it is to increase the accuracy of hitting the target, increase range, achieve hypersonic speeds, ensure a high probability of overcoming air defense and missile defense in the theater of operations, create conventional combat units with high impact, expand the range of targets, the ability to adjust the flight task during the flight and the concomitant use of disposable UAVs for reconnaissance. For reusable UAVs, it is high reliability and survivability, long flight duration and range, high flight technical and economic performance, the ability to conduct comprehensive reconnaissance with real-time data transmission and more.

According to the assessment of past and present military conflicts, it is safe to say that unmanned aerial vehicles have become an important component of the interdependent reconnaissance triad, along with space reconnaissance and manned aviation. The proliferation of UAVs around the world has allowed experts from the US Defense Information Center to make a statement on the 21st century security strategy: «There are two technologies that open up new possibilities - unmanned aerial vehicles and spacecraft… Unmanned aerial vehicles, originally designed for entertainment and surveillance, are being converted into unmanned aerial vehicles».

Unmanned aerial vehicles are also a promising arms market, which is essentially just emerging. At this time, the main direction of programs to acquire reconnaissance UAVs for developed countries was the desire to equip them as soon as possible with all types of their own armed forces.

Thus, today unmanned aerial vehicles are rapidly developing. Experts predict that by 2025 the world’s leading countries will have up to 80% unmanned combat aircraft. Modern unmanned aerial vehicles are capable of hitting a wide range of targets - armored vehicles, engineering structures, infrastructure and manpower. The problem of gaining an information advantage over the enemy also became especially important. However, the most important thing that unmanned aerial vehicles provide, including reconnaissance and strike drones, is the minimal risk for servicemen in the theater of operations. The range of applications of medium and heavy unmanned aerial vehicles, which are successfully used in unmanned aerial reconnaissance and strike systems to solve both traditional and new combat tasks, has significantly expanded. The integration of reconnaissance and strike weapons in military conflicts has created the conditions for changes in the theory and practice of martial arts, the emergence of new forms of operations. In the future, the scope of the most robotic and autonomous unmanned aerial vehicles in aviation will expand, displacing manned aircraft and helicopters. Naval-based aircraft are also gradually moving to the use of unmanned aerial vehicles for various purposes, for example, to search for and destroy sea mines and conduct search operations. The development of unmanned aerial vehicles is significantly influenced by economic motives, as the creation and even combat losses of unmanned aerial vehicles are much cheaper than manned military aircraft.

Given the active growth of the world community's interest in unmanned aerial vehicles, as well as the actualization of this issue in the world, the author's team tried to highlight the range of history of unmanned aerial vehicles and analyze, first of all, war between Ukraine and russia in 2022, show ways to counter its use and identify opportunities for further development of combat drones in the changing conditions of the armed struggle, considering new advances in scientific and technological progress.

On course, significant factual material will allow readers to better understand the main trends in the development of unmanned aerial vehicles for both military and civilian use and determine its place and role from the standpoint of history and from the standpoint of solving modern problems. The systematization of foreign experience in the creation and use of unmanned aerial vehicles should be considered an important aspect of the work. This approach, in our opinion, can be useful for any state in an environment where the state seeks to take a worthy place in the overall process of creating unmanned aerial vehicles in the national science base and aircraft construction and strengthen the combat potential of its Armed Forces.

The monograph «Basics of application of unmanned aerial vehicles» highlights a number of new essential data on unmanned aerial vehicles in the context of scientific understanding of world experience of both the creation and their use for the benefit of all mankind.

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FOREWORD

Unmanned aerial vehicles are experiencing a real splash. Unmanned aerial vehicles of various purposes and aerodynamic schemes, geometric dimensions and mass data rise into the airspace of various countries.

Recently few people understood what an unmanned aerial vehicle was. However, in a short time the drones came out of the shadows and came into focus of media attention. Today the media are reporting on the increasing use of UAVs in warfare for reconnaissance, air strikes and other operations.

Given the growing interest of the world community in the subject of unmanned aerial vehicles as one of the areas of robotics in aviation, the author's team tried to focus readers' attention on the following important aspects: historical principles of creation of unmanned aerial vehicles, experience of combat use of unmanned aerial vehicles by foreign countries in military conflicts, ways to counter drones, the current state and prospects for further development of unmanned reconnaissance aircraft in the world and in Ukraine, taking into account the changing forms and methods of modern and future armed struggle, as well as achievements of scientific and technological progress without trying to comprehend the immeasurable.

The monograph consists of nine chapters, ten appendixes and a list of sources used.

The first chapter reveals step by step the facts of world history of unmanned aerial vehicles creation. It is noted that the starting point for the emergence and combat use of unmanned aerial vehicles is the period of the First World War. This was due to the need to overcome the powerful air defenses that intensified at the end of the war, as well as the desire to increase the effectiveness of combat operations against mobile and small targets. The main historical events in science, politics and military affairs that contributed to the creation and further development of unmanned aerial vehicles are revealed. The role of scientists from around the world who were at the beginning of the creation of unmanned aerial vehicles, creators and developers of drones is emphasized.

The second chapter presents the classification, systematized functions and tasks of unmanned aerial vehicles in modern conditions of armed struggle.

The third chapter considers the composition of the main components of unmanned aerial vehicles and their terminology.

The fourth chapter covers the main factors, in the authors' opinion, that directly influenced the use and development of unmanned aerial vehicles in the world (the conditions of armed struggle, scientific and technological progress and military-economic factors).

The fifth chapter opens questions about the combat use of unmanned reconnaissance aircraft in military conflicts. The role and place of tactical, operational-tactical and strategic reconnaissance UAVs in the conditions of modern armed struggle are revealed.

The sixth chapter provides with examples of the use of unmanned aerial vehicles in some civil areas that were not previously widely disclosed, including in medicine, scientific of unmanned aerial vehicles in some civil areas that were not previously widely disclosed, including in medicine, scientific measurements and environmental monitoring.

In chapter 7 the world's various approaches to countering unmanned aerial vehicles by directly destroying them by various means of destruction or interception of drone control, as well as by protecting people and objects from the actions of unmanned aerial vehicles are analyzed and examined.

The eighth chapter reveals the current state of unmanned reconnaissance aircraft taking into account the requirements of armed struggle at the current stage of its development. The main advantages of unmanned aerial vehicles over manned aircraft in solving various problems are presented. Information on the main developments in UAVs area in foreign countries and in Ukraine is given. Prospects for future development of UAVs in foreign countries are identified, taking into account the growing demands of the armed struggle for information support of troops (forces) on the battlefield, as well as the Ukrainian aspects of various drones development.

The ninth chapter is describing the prospects for the development of unmanned aerial vehicles in future wars which outlines global trends.

Conclusion systematizes the role and place of unmanned aerial vehicles in our lives.

The appendixes provide data on unmanned aerial vehicles used in military conflicts of the second half of the XX- beginning of the XXI century as well as on some types of modern reconnaissance unmanned aerial vehicles.

1

HISTORICAL ASPECTS OF UNMANNED AIRCRAFT CREATION

Unmanned aerial vehicles are experiencing a real splash. Unmanned aerial vehicles for different purposes, various aerodynamic schemes, geometric dimensions and mass data rise into the airspace of various countries.

The success of their application is associated first of all with the rapid development of microprocessor computing, control systems, navigation, transmission of information and artificial intelligence. Achievements in this area make it possible to fly in automatic mode from takeoff to landing, solve the problems of monitoring the earth's (water) surface, and for military UAVs to provide reconnaissance, searching, selection and destruction of targets at any time and any weather conditions. Therefore, in most industrialized countries, both the aircraft and the power plants for them are being widely developed.

When it comes to the wars of the future, one of their main features is considered to be non-contact. There is no sense to deny. However, it is difficult to agree that the mentioned feature will be peculiar only to the wars of the future, according to opinion of foreign military experts. Indeed, in the wars of the XXI century it is going to be decisive in the fast emergence of new technologies that can be used for weapons producing based on new physical principles. Under these conditions, the role of man in the war is undergoing significant transformation.

However, we must consider that non-contact is an evolving trend that accompanies the entire historical period of weapons development. With the appearance of the first primitive (from today's point of view) kinds of weapons (e.g., sticks, boomerangs, wooden spears, bows, stone axes, maces, daggers) the concept of non-contact was born. The further development of society led to the creation of firearms, by which the distance and scale of enemy forces and enemy resources destruction increased significantly, and the concept of non-contact gained its meaningful meaning.

It is known that the development of weapons, like any other tool, is closely linked to the history of society, its economy and the use of natural forces at this stage of development. From ancient times, when a person's physical strength was decisive both for his existence in the tribe and for obtaining food by hunting animals, the desire to win required the invention of something special, which later became known as weapons. Due to the invention of weapons, a physically weak person who was afraid of a stronger one could successfully defeat it. At the same time, not only a person but also an animal could be physically strong. If in the fight against the lion it was enough for a man to have primitive weapons, then in the fight against the same man it was necessary to show great ingenuity in order to create new weapons for a sure victory.

However, in both cases, the man aspired to distance himself from the enemy, realizing that the contact fight could end in a physical confrontation where victory will go to a stronger and more agile opponent. Thus arose the sword, spear and bow with arrows have been arise.

It should be noted that the desire to distance themselves and not come into close physical contact with the enemy had one more reason. This reason was the powerful psychological impact of the war on man. No matter how aggressive and cruel a person may be, the war and its results observed by man directly on the battlefield (e.g., bloodshed, the massacre of killed and wounded…) from both sides, have a negative impact on the human psyche and its desire to be on distance from the enemy during battle through the use of powerful weapons that strike at enemy forces at a considerable distance.

Appearance of firearms (first small arms and then artillery) in the 12th – 14th centuries has provided with significant increase in the distance between the warring parties and the possibility of defeating the enemy’s manpower at a considerable distance.

20th century turned out to be a century of new technologies that radically changed the methods of combat due to the emergence of rapid-fire, later automatic weapons: guns, mortars, machine guns.

The period of the First World War is the starting point for the emergence of unmanned aerial vehicles in the form of guided projectiles. Their appearance was due to the need to overcome the power of air defense, which increased by the end of the war, as well as the desire to increase the effectiveness of military equipment against mobile and small targets. Additionally, the flight of guided missiles was usually independent of meteorological conditions, which expanded the scope of their application compared to bomber aircraft.

The creation of unmanned aerial vehicles became possible thanks to the success in science and technology areas such as ballistics, aerodynamics, jet engine theory, radio engineering and automation. Studies in the area of missile design had particular importance.

Among russian and Soviet scientists who had an important role in the development of the jet propulsion theory, we should mention, first of all, I. Meshchersky, who published in 1897 the work ‘Dynamics of the point of variable mass’ which later became a classic, and the greatest russian scientist K. Tsiolkovsky who developed the theory of missile flight. In 1903 K. Tsiolkovsky has published his first work ‘Exploration of the world by jet devices’. Later he has developed a series of design schemes for liquid rocket engines, the theory and schemes of multistage missiles, derived a fundamental formula that links the speed of a missile to its mass, and proposed the use of gas rudders and autopilot to control a missile in airspace.

Among scientists from different countries who worked actively with missile theory and technology are the following: R. Esno-Peltri (France), whose first works appeared in the press in 1913; R. Goddard (USA), who began his work around 1915 and later has created several types of meteorological missiles; G. Obert (Germany) and E. Zenger (Austria) and others.

The beginning of the unmanned era from the military point of view began in 18th century according to some sources. In 1848, the Austrian general and inventor Franz von Uchatius has proposed the use of balloons with a suspended charge of gunpowder against insurgent Venice. To this end, by the summer of 1849, about 200 Montgolfier balloons had been built in Treviso by various sources. Balloons were launched from the windward side of the air current, and at the appointed moment the bombs separated from the shell and fell on the enemy. At least two balloons flew to Venice on July 15th, 1849 and dropped bombs one of which fell on the market and had a striking psychological effect

Of course, the Mongolfiers' flights cannot be called as controlled, but the remote control of the bombings allows to call the modified balloons as the first strike drones.

Work on the creation of aircraft-type UAVs began in the early 20th century almost immediately right after the appearance of the first serial manned airplanes (aircraft). According to N. Vasilin's data, in 1910 a young American military engineer from Ohio Charles Kettering, inspired by the success of the Wright brothers, has proposed the use of non-human aircraft. According to his plan, the clock-controlled device in a special place had to drop its wings and fall like a bomb on the enemy. After receiving funding from the US Army, he built and successfully tested several devices called The Kettering Aerial Torpedo, Kettering Bug or simply Bug, but they were never used in combat.

It is considered that the first world's radio-controlled unmanned aircraft designed by G. Curtis made its first flight in 1916 to the United States. On September 12th, 1916, the first radio-controlled projectile plane 'Hevit-Sperry' has been tested.

An aircraft called 'air torpedo' designed by one of the pioneers of aviation O. Wright, was equipped with from General Motors equipment and has been tested in 1917. During the First World War, on 2nd of March, 1917 the first combat use of remotely controlled equipment took place in the port of Newport city (England), a large part of the berth line was destroyed by a German radio-controlled bomb-boat from the plane.

Work on drones on the European continent began in Britain in 1914. However, the planned effect has not been achieved: one aircraft crashed immediately and another took to the air, flew for a while, and then fell on land because of control losing.

In the autumn 1917 the Germans began developing a strike unmanned aerial vehicle. Unlike the Americans they worked to create a reusable device Fledermaus. To save the unmanned aerial vehicle after its return, it was proposed for the first time to use a rescue parachute.

The first reference of UAVs in russian Empire was available in September 1916, when Staff Captain Jablonski has developed a guided air bomb also called a torpedo helicopter (in modern terminology, ‘torpedo helicopter’). The work was carried out in Petrograd at the Siemens-Schuckert plant. Judging by the fact that the first attempt to transmit a radio signal from an airplane was successfully performed by Colonel-Engineer D.Sokaltsev in russia in 1911 at Gatchina airfield, we can assume the presence of radio control on the developed Jablonski’s device. The tragic death of the author in December 1916 put an end to the work on this project.

Work on the creation of unmanned strike aircraft (torpedo aircraft) continued in the early 1920’s. After testing of several designs of unmanned torpedo aircrafts for attacks on large surface ships in the United States, this area was considered as unpromising and completely closed until 1932.

In the 1920s and 1930s, theoretical and experimental work on jet propulsion was widely developed in the Soviet Union. A significant contribution to solve this problem was made by F.Zander, Y. Kondratyuk and others. In 1930, a jet study group was organized in the USSR to bring together scientists and engineers working in the field. This group has created a number of experimental rocket engines and missiles. The first Soviet missile with a liquid engine has made the flight in August 1933.

Experiments with unmanned aerial vehicles began in the 1920’s and 1930’s in the US Army. In 1936, Lieutenant Commander D. Farney, who headed the secret service in the US Air Force, used the term ‘drone’ (‘drone bee’) to distinguish American aircraft from similar British ones, called the ‘Queen Bee’ and became the first reusable UAV developed in 1933. Such an unmanned vehicle is a radio-controlled target aircraft based on the seaplane Fairy Queen.

The UAV has passed successful tests in the Mediterranean. As a result, the Royal Navy has ordered 400 specially designed radio-controlled targets because of comprehensive tests of unmanned target aircraft. This radio-controlled unmanned target called DH82a Tiger Moth was used during the period 1934-1943.

In 1940, the US Air Force have ordered 53 radio-controlled mini-aircraft RP-4 (QQ-1) as radio targets from American Radioplane Company, and in 1941 a major order was made for a modification of the RP-5 (QQ-2). The US Navy has also adopted the RP-5 (QQ-2) UAV under the designation TDD (Target Drone Denny – target plane Denny). At the same time, the leadership of the US Navy supported Lieutenant Commander D. Farney, who has proposed the concept of using of low-cost unmanned bombers controlled by radio by fleet in 1936. During World War II a lot of experiments on the creation of unmanned aerial vehicles and missiles ended in both great inventions and unfortunate failures.

The creation of guided unmanned vehicles was also carried out in other countries: France, Germany, Italy, however, work on a wide range of aviation, missile, radio and instrumental subjects in the 1930s had state support only in the USSR and Germany. The greatest success in the development of unmanned aerial vehicles before the Second World War was achieved by Nazi Germany with a significant initial lag compare with many countries in the first half of the 30’s. The post-war German archives revealed that German designers had created an unmanned reconnaissance aircraft that made its first flight at the Roechling Research Center of the German Air Force in 1939.

In the USSR in 1939-1940, aircraft designer Nikitin developed a special-purpose torpedo-carrier glider (‘PSN-1’ and ‘PSN-2’) of the ‘flying wing’ type in two versions: manned training and shooting and unmanned with full automation. A project of an unmanned flying torpedo with a range of 100 km and above was presented by the beginning of 1940. However, these developments were not embodied in real designs.

During the war, Nazi Germany was the first who used automatically guided shells and missiles. The most famous of them were the ‘V-1’ projectile (Vergeltungswaffe Eins) and the ‘V-2’ (Vergeltungswaffe-2) ballistic missile, which were used to shell cities in Great Britain and the Netherlands in 1944 and 1945. From mid-1944 to March 1945 about 8,070 of V-1s were launched in London, almost 23% of them had struck their targets and killed more than 6,000 people. To use modern terminology, the ‘V-1’ had a weak ‘intelligence’ but was equipped with autopilot connection, which allowed it to fly in a straight line at constant altitude.

Regarding the more expensive ‘V-2’ missile, it is considered a robotic missile. About 1115 of them fell on British area. The ‘V-2’ marked the beginning of a technical rivalry between missiles and unmanned aerial vehicles that lasted for many decades.

‘V-1’ or ‘flying bomb’ was an unmanned aerial vehicle with a pulsating air-jet engine and autonomous control system. With a fairly simple design, it was quite cheap to manufacture and delivered a powerful warhead to the target. A simplified autopilot was installed on board the ‘V-1’, providing flight at a given altitude, as well as a simple system that controlled the diving mechanism.

There was no navigation system in ‘V-1’ as they were simply launched in the direction of the target. The lack of an autopilot on the ‘V-1’ allowed British Air Force fighters to destroy them in flight, using a close pass across the course with the accompanying jet on the projectile, after this projectile lost control and crashed to the ground.

It’s important to note that the ‘V-1’ projectile was not fully neither an unmanned aerial vehicle nor a guided missile. It should be considered as a precursor to modern UAVs and combat missiles.

‘V-2’ turned out to be an insurmountable weapon. From the very beginning of its application the British military cabinet has decided not to inform the population about the missile strikes because there was no protection against them. One of the creators of ‘V-2’ was a famous German engineer Werner von Braun who moved to the United States after the war.

The strikes performed by ‘V-1’ and ‘V-2’ did not meet the expectations placed on them by the leadership of Nazi Germany, however the damage inflicted on Britain was hard. It should be noted that the new weapons were not cheap for the Germans themselves. The ‘V-2’ missile was five times more expensive than the ‘V-1’ flying bomb.

A new option for solving this task was the creation in Nazi Germany of the Mistel aviation radio-controlled strike complex under the ‘Beethoven’ program. During the war German scientists also developed several radio-controlled types of weapons including guided bombs Henschel Hs 293 and Fritz X, Enzian missile. Despite the incompleteness of the ‘Hs 293’ and ‘Fritz X’ projects they were used in the Mediterranean against armored warships.

The Americans also worked in this direction. The US Navy tried to use manned deck-based systems remotely based on the ‘B-17’ aircraft to strike at German submarine bases.

Considering the psychological impact of the use of projectiles, that resulted from the use of aircraft shells, combat use of various types of unmanned aerial vehicles and their purposes during World War II showed quite modest results, as the level of technology did not provide the necessary flight and technical characteristics, targeting accuracy, reliability of drone complex, the possibility of accumulating or return of intelligence information, etc.

During the postwar period creation of various unmanned aerial vehicles was widely deployed in all industrialized countries, especially in the USSR and the United States. By the end of the 1950s guided projectiles became the main weapon of the armies of many countries around the world. Missiles have been widely used to explore near-Earth space and outer space.

Development of perspective equipment samples of technology, especially for military purposes, in industrialized countries took place at the same time. Often the ‘commonality’ of solutions in products of different countries could be explained by the success of reconnaissance, but first of all the main focus was on the tasks set for the developers, the level of industrial development, the culture of design and production, the degree of international integration in the creation of relevant projects.

Based on historical experience, in several cases the leadership in the development and creation of many models of technology, including many types of drones, belonged to Soviet designers.

Experience in the creation and use of unmanned combat vehicles, numerous experimental developments allowed to begin to create unmanned reconnaissance vehicles in the middle of the 20th century. The situation has changed due to progress in the instrumentation area. After the appearance of combat drones and targets, the development of reconnaissance UAVs has been started.

At the end of 1950s and early 1960s in the United States and France and in the number of other countries later some models of drones previously used as targets were upgraded into reconnaissance vehicles used for many years as part of unmanned aerial vehicles of reconnaissance.

In conditions as close as possible to combat, according to a few sources, the first use of reconnaissance UAVs took place in 1949 during the testing of Soviet nuclear equipment at the Semipalatinsk training grounds. To measure the level of radiation in the nuclear ‘mushroom’, they used specially converted double-piston fighters ‘Yak-9’ equipped with a radio command control system and radiation monitoring devices located on the upper plane of the wing. The flight of the UAV was controlled from aboard the flying command center ‘Tu-2’. A total of ten ‘Yak-9’ aircraft have been converted into dosimetric control machines. Losses during the flight through the ‘mushroom’ amounted to two UAVs.

In 1960, when a ‘U-2’ spy plane led by G. Powers was shot down over the territory of the USSR, the Americans did not start the development of unmanned aerial vehicles to respond on this action.

The incident led to the creation of faster manned aircraft flying at high altitudes (such as the supersonic spy plane ‘SR-71’) and the concentration on the development of space reconnaissance. Priority was given to these two more advanced technologies.

The unprecedentedly expensive supersonic UAV launched from the ‘SR-71’ was developed in the 1960s and used four times in operations but has been disarmed because of the accidents, high cost, and because obtaining reconnaissance images with the help of satellites was more effective.

The history of the reconnaissance UAVs participation in real fighting began in 1964. The United States used the UAV ‘AQM-34L Fire bee’ for the first time that was launched from the aircraft carrier during the Vietnam War. Originally created as a jet target for US and Canadian aircraft training, it was later developed as a whole family of UAVs for various purposes, including reconnaissance. By 1971 several thousand of ‘Fire bee’ UAVs had flown and as the result considerable experience has been accumulated and new methods of combat use have appeared because of this. Most of the aircraft flew on programmed routes, some of them were remotely controlled by pilots from the C-130 aircraft where the launch was carried out. During the period 1964-1974 the U.S. Air Force made more than 3,000 flights against Vietnam, China, and North Korea, losing about 600 aircraft.

Despite the positive results of the tests in real combat conditions, the end of the war in Vietnam has suspended the development of the topic of expanding the scope of UAVs in combat, limited to reconnaissance missions. The use of the ‘AQM-34L Firebee’ for surveillance and reconnaissance actually ended in 1978. According to American experts data, some of them flew in the war against Iraq in 2003. Subsequently, UAVs began to be used as air targets. One of the reasons for the introduction of UAVs at that time was the reluctance of pilots, who, understanding the situation, resisted for fear of losing their jobs, as well as fame in favor of such devices.

Keeping in mind the experience of combat use and the information received about the development of new unmanned aerial vehicles in the West, the Soviet Union stepped up work on the creation and improvement of UAVs. In the mid-1970s a new tactical unmanned reconnaissance complex BP-3 ‘Reis’ with the ‘Tu-143’ UAV created in ‘OKB-156’ of A. Tupolev.

In the late 1960s and early 1970s US experts and military analysts made assumptions that the Air Force would consist mainly of remotely piloted vehicle (RPV). By the end of the 1970s opinions had changed somewhat with assumption that unmanned aerial vehicles began to be seen as an adjunct to combat aircraft and as a self-functioning weapon system.

The rapid development of equipment and technology in the postwar period as well as the experience of using UAVs in real combat conditions of local wars, were a precondition for the creation of unmanned systems at a qualitatively new level. The development and industrial production of small on-board control and data transmission systems, special equipment has significantly expanded the scope and capabilities of unmanned aerial vehicles, especially with the advent of GPS in the 1980s. Before GPS appearance, the difficulty of an unmanned vehicle piloting seemed almost insurmountable. The control of missiles and aircraft was based on inertial measuring systems, which were quite heavy for small vehicles. Data lines were also quite heavy, limited in their technical capabilities and not as reliable as on-board computers

Thus, during the Syrian-Israeli conflict in Lebanon in the summer of 1982 a new class of small-scale unmanned aerial vehicles debuted for the first time. These are the Israeli-designed ‘Scout’ and ‘Mastiff’ UAVs which were used to reconnaissance of individual targets and objects with real-time information transmission in the interests of artillery, missile and air strikes.

At the same time the Syrian side used the Soviet unmanned reconnaissance complex ‘BP-3 ‘Flight’ for the first time in Lebanon. It proved itself well at that time, especially in mountains area.

The results of the successful use of Scout and Mastiff reconnaissance UAVs prompted the leadership of the USSR Armed Forces to develop requirements for the creation of a new generation of UAVs under the ‘Lad’ program. Within the framework of this program since 1982 several complexes of various range of application were developed and created: regimental: ‘Stroy-P’ from the UAV ‘Bee’ (‘Bumblebee’); army ‘Stroy-A’ from the UAV ‘Woodpecker’; front - line ‘Stroy-F’ with the UAV ‘Kite’. At the same time an operational and strategic UAV ‘Eagle’ has been created under a separate program. The idea of creating an unmanned reconnaissance and strike system was also substantiated and worked out in the Soviet Union.

The ‘Bee-1TM’ UAV of the ‘Stroy-PM’ complex (1987) became the first Soviet small-scale reusable unmanned aerial vehicle designed to reconnoiter ground objects with the transfer of information to a ground point in real time.

The United States did not consider creating a new generation of UAVs until the 1980s. But in 1980 the Americans purchased reconnaissance UAVs in Israel, accepting this as a temporary measure to provide air reconnaissance. At the same time a plan was developed for the gradual creation of its own reconnaissance UAVs including long-distance aircraft with the construction where was planned to use the latest advances in low-visibility aircraft technology.

In the early 1980s after operations in Grenada, Lebanon, and Libya, U.S. Navy Command showed great interest in unmanned reconnaissance vehicles with capability to perform tasks of reconnaissance, surveillance, adjust and direct fire support to the landing. A program to create a naval reconnaissance UAV was also proposed. In 1985 a contract was signed with Pioneer UAV Inc. for the development of RQ-2. The first flight of the UAV happened in December 1985 and the first RQ-2 Pioneer entered service with the battleship ‘Iowa’ (BB 61) in December 1986.

The portable manually launched small-scale FQM-151A Pointer reconnaissance UAV with a shorter range and altitude than the Pioneer UAV, has been in service with the U.S. Army, Marine Corps and Navy since 1986 to provide operational surveillance for battlefield.

During the same period work on the creation of reconnaissance drones has been activated by European countries such as Germany, France, Great Britain, Italy and others. However, during the first Iraqi campaign in 1991 only the French armed forces were able to use a RPV Mart in combat.

The results of the use of reconnaissance UAVs RQ-2 Pioneer, FQM-151 Pointer and Mart during the fighting in the Persian Gulf have confirmed the perspectives for continued work on the creation of small reconnaissance UAVs with long stay in the air, and necessity of the development of medium-altitude and high-altitude reconnaissance UAVs reconnaissance and strike UAVs.

The development and production of reconnaissance UAVs in the United States were carried out mainly under four programs: Tier I, Tier II, Tier II plus and Tier III minus. There was also the Tier III program which involved the creation of a large inconspicuous reconnaissance UAV. However, due to the high cost of the program it was canceled. Instead of this, work began on two intermediate projects as Tier II plus and Tier III minus.

In 1989 small-size tactical reconnaissance UAV Gnat-750 with long-range airborne made by General Atomics under the Tier I program has performed its first flight. Since 1994 UAVs have been used by the US CIA over Yugoslavia for long-term reconnaissance of targets belonged to the Serbs. These devices were operated from the territory of Albania and vide recordings could be transmitted to the United States via satellite. However, the UAVs were not be able to fly in the winter, as the result two UAVs have been lost due to icing. Despite the problems and accidents, the Gnat-750 UAV became famous because it actually ‘kept an eye’ on the target that was defined as conducting of constant reconnaissance.

As part of the Tier II program, General Atomics company developed a medium-altitude long-range reconnaissance UAV RQ-1A Predator. Structurally it was a Gnat-750 UAV with biggest size, higher power plant and satellite communications which allowed to control it from a long distance. In 1994 the Predator made its first flight and the following year it began its combat use over Bosnia territory with control from Hungary and the transmission of near-real-time video information across the Atlantic to the United States to Pentagon offices. The name of the UAV was changed in 1994 from the infamous ‘Gnat’ (with meaning ‘fly’) to the sinister ‘Predator’.

Since 1995 within the framework of the Tier II plus program the development of inconspicuous high-altitude UAVs with a long stay in the air and with a significant payload has begun. It was the UAV RQ-4A Global Hawk whose first flight took place in 1998. And in 1999 the drone flew from the Florida (USA) to Portugal and back without refueling.

The Tier III minus program was aimed to developing and creating an inconspicuous high-altitude unmanned aerial vehicle Dark Star which has a boomerang shape. Its first flight which took place in 1996, and since 1999 further work on this project has been suspended.

The fourth local conflict where reconnaissance UAVs were tested and the first one where the reconnaissance UAVs of several NATO countries were used together was the Allied Combat Force in Yugoslavia (1999). Seven types of UAVs have taken part in Operation Allied Force: Predator, Hunter, Pioneer (USA), SL-289

(Germany and France), Mirach-26 (Italy), Crecerelle (France), Phoenix (UK). Thus, the number of types of reconnaissance UAVs from European countries has increased to four.

In February 2001 the United States have made experiments with a reconnaissance and strike version of the Predator UAV at the Nellis Air Force Base at the US Air Force (Nevada). It was the first unmanned reconnaissance and strike aircraft with remote control with capability of striking ground targets. The idea to rebuild this UAV from a reconnaissance to a combat experimental version was announced in 1999 during Operation Allied Force in Yugoslavia. Then at Egpin Air Force Base (Florida) American experts performed work on the installation on the ‘Predator’ UAV board laser rangefinder with capability of illuminating targets. However, the war ended before this device was ready prepared for combat use.

The UAV reconnaissance and strike version was tested during the counter-terrorism operation ‘Unbreakable Will’ (Afghanistan 2001) when the ‘Predator’ acted together with attack aircraft and also struck with ‘Hellfire’ remote-controlled anti-tank missiles.

At the same time, experimental sample of long-range & high-altitude reconnaissance UAV ‘Global Hawk’, developed as part of the Tier II plus program, have been tested. However, the participation of this UAV in the reconnaissance support of combat operations of the US armed forces in Afghanistan was limited to several flights to work out technical issues of combat use and interaction with ground forces. The main complexity was the organization of remote devices control.

The beginning of the 21st century marked by the massive development of unmanned aerial vehicles. Since 1993 the number of such devices has almost doubled. Countries such as the United States, Israel, Great Britain, France, Germany, russia, China, Italy, Spain, the Czech Republic and others took an active part in their creation

During the Second Iraq War (Operation Iraqi Freedom, 2003) the United States demonstrated the ‘Shadow-200’ reconnaissance UAV which was used to provide commanders of subdivisions and units directly involved in hostilities with information, as well as the small ‘Raven’ UAV which was a reduced version of the ‘Pointer’ UAV and acted for commanders of the same level. Small-sized ‘Dragon Eye’ UAVs carried by servicemen in backpacks and also quickly mounted within 10 minutes were also actively used and launched directly from the hand.

UAVs were used during training and the period of Abkhaz-Georgian conflict (2007 - 2008) when the Georgian army used foreign-made UAVs as Israeli-made ‘Hermes-450’ reconnaissance vehicles.

Active use of reconnaissance and multi-target UAVs took place during the counter-terrorism operation of the international coalition forces led by the United States (since 2014) and the group of russian forces (since 2015) against ISIS in Syria, where military conflict between government army and opposition army (civil war) happened in 2011. Coalition forces for air reconnaissance used operational and tactical reconnaissance UAVs as ‘MQ-1 Predator’ (USA), ‘Heron’ (Israel), ‘RQ-21a’ (USA) and multi-role UAVs as ‘MQ-9 Reaper’. Periodically the US military used strategic reconnaissance UAVs as ‘RQ-4 Global Hawk’ and ‘RQ-170 Sentinel’.

The ‘Orlan-10’ UAV and the ‘Forpost’ UAV (licensed copy of the Israeli ‘Searcher 2’) were used as part of the russian fleet of operational and tactical reconnaissance drones. The most common tasks for drones in Syria were the following: day-and-night monitoring of the situation in the country; reconnaissance of targets for air strikes; assessment of losses; adjustment of Syrian artillery artillery fire.

Nowadays the leading countries of the world and Europe are engaged in the development, creation, and widespread use of unmanned aerial vehicles for military purposes as: reconnaissance and strike, retransmission, obstacle settings, etc. Non-military UAVs are used to solve a wide range of tasks where the performance by manned aircraft for various reasons is impractical. Among such kind of tasks can be monitoring of airspace, land and water surfaces, environmental control, air traffic control, maritime control, development of communication systems, field logistics, transfer of spare parts, batteries, ammunition, medicines, art photography, etc.

In conclusion, it should be noted that modern UAVs did not come out of nowhere. They are the end product of a long process that began with simple experiments using any of the technologies available at the time. The next step was to be continued as special and more complicated systems which adapted new technologies as soon as they became available.

2

CLASSIFICATION, FUNCTION AND MISSION OF UNMANNED AVIATION

Unmanned aerial vehicles are reusable unmanned vehicles equipped with a power plant with remote, semi-autonomous, autonomous or combined control which are capable of carrying different types of payloads enabling them to perform specific tasks in or outside the Earth's atmosphere during the time appropriate for the task performance.

Classification. Modern military UAVs can be divided into several classes. In terms of purposes UAVs can be multi-purpose (reconnaissance and strike) and specific ones (reconnaissance, targeting, strike, relay communication, electronic warfare, artillery fire correction, mine detection, radiochemical reconnaissance, targets, false targets, etc.).

Depending on the range of the UAV can be divided into tactical, operational-tactical, operational and strategic. The class of tactical UAVs includes devices which range does not exceed 70 km: micro-UAVs (<10 km); mini-UAV (<10 km); close-range action UAVs (10-30 km) and short-range UAVs (30-70 km) (Table 2.1).

Operational and tactical UAVs have a range limited by 300 km. These include medium-range (70-200 km), deep reconnaissance (> 250 km) and striking (up to 300 km).

Operational UAVs, according to foreign classifications, include long-range vehicles as well as medium-altitude aircraft of long flight duration and have a range of more than 500 km. Strategic UAVs have a range of flight up to 1000 km and more.

According to the method of launching the UAV they are classified on the following types: manual launch; launch using weapons systems; launch with the use of catapult launchers (rubber, hydraulic, pneumatic); launch with the use of a solid propellant rocket engine; take-off by plane on a wheeled chassis; vertical takeoff and landing; air launch; underwater launch and automatic takeoff.

Accordingly, UAVs are also classified according to the method of landing: with landing on the fuselage; with boarding on skis; with landing in a grid; with landing by plane on wheeled chassis (without brakes, with brakes, with air finisher); with parachute descent; vertical landing; automatic landing; with automatic self-liquidation.

The mass of UAVs allows them to be divided into micro-UAVs (<5 kg), mini-UAVs (5-200 kg), medium (<2000 kg), large (<5000 kg) and heavy (> 5000 kg).

Table 2.1

European classification of UAVs

UAV's class	Abbreviation	Range, km	Flight duration, h	Height, m	Purpose	UAV (example)
Micro UAV	μ	<10	<1	250	Reconnaissance, surveillance, targeting, Relay communication, searching, radiation and chemical reconnaissance (RCR), radio electronics resistance (RER)	Black Widow; Microbat; Microstar
Mini-UAV	Mini	<10	<2	250	Reconnaissance, surveillance, targeting, relay communication, searching, RCR, warfare (RW)	Pointer; Raven
Close-range action UAV	CR	10-30	2-4	3000	Reconnaissance, fire correction, mines detection, relay communication, searching, RW	Luna; Dragon; Vigilant; 'Bee-TM', 'Bumblebee'

Table 2.1 continuation

UAV's class	Abbreviation	Range, km	Flight duration, h	Height, m	Purpose	UAV (example)
Short-range UAV	SR	30-70	3-6	3000	Reconnaissance, surveillance, targeting, evaluation of the blows results, mines detection, RCR, RW	Mirach-26; Phoenix; BP-3 'Flight'
Medium range UAV	MR	70-200	6-10	3000-5000	Reconnaissance, surveillance, targeting, evaluation of the blows results, mines detection, RCR, RW, relay communication, searching	Pioneer; Shadow-200; CL-327; Brevel; BP-2 'Strizh'
Low altitude of deep reconnaissance UAV`s	LADR	>250	0.5-1	50-9000	Reconnaissance	CL-289; Mirach-100
Long range UAV`s	LR	>500	10-18	5000-8000	Reconnaissance, surveillance, targeting, evaluation of the blows	Hermes-450S; Shadow-600

Table 2.1 continuation

UAV's class	Abbreviation	Range, km	Flight duration, h	Height, m	Purpose	UAV (example)
					results, RCR, RW, relay communication	
Medium altitude UAV`s of long flight duration	MALE	>500	24-48	5000-8000	Reconnaissance, surveillance, targeting, evaluation of the blows results, RW, relay communication	Predator; Hermes-1500; Altus
High altitude UAV`s of long flight duration	HALE	>1000	24-48	15000-20000	Reconnaissance, surveillance, targeting, evaluation of the blows results, RW, relay communication, interception in the active area	Global Hawk; Raptor; Condor
UAV`s strikes	LETH	300	3-4	3000-4000	Anti-tank, Anti-transport, anti- ship, anti- object actions	Predator; K-100; Taifun; Futura; X-45

Depending on the duration of the flight, UAVs are the following: short-range to support maneuvering forces (range up to 50 km; flight duration up to 6 hours), medium range to support the actions of brigades, divisions and naval forces (range up to 200 km; flight duration up to 10 hours), long duration flight to support the actions of forces in the theater of war (range over 800 km; flight duration over 24 hours).

According to the altitude, UAVs can be divided into low-altitude (up to 300 m), low-altitude (up to 3000 m), medium-altitude (up to 8000 m) and high-altitude (over 8000 m).

Specialists of the State Research Institute of Aviation (Ukraine) have proposed to classify UAVs also by engine type: electric, with piston, with rotary-piston, with turbojet and turboprop. Today each of these classes of UAVs is represented by a wide range of current and experimental samples.

Functions. The main functions of unmanned aerial vehicles in military conflicts are the following: conducting air reconnaissance, targeting, battlefield control, radioelectronic warfare, striking, relay communication, chemical and biological reconnaissance, mine detection, correction of artillery fire, meteorological reconnaissance, search and rescue in combat situations, firefighting, etc.

Mission. Due to the given set of functions, the range of tasks to be solved with UAVs is quite wide (Table 2.2). During the air reconnaissance UAV solves the following tasks: collection of reconnaissance information about enemy ground objects during the preliminary reconnaissance and post-reconnaissance; direct support of the field command; control of the blows results on enemy objects; checking the degree of camouflage of their armies, etc.

To perform different aerial reconnaissance and surveillance tasks, the following various technical means are used: imagery intelligence equipment of visible range (with the formation of images of reconnaissance objects); infrared imagery intelligence equipment; radar stations with synthesized aperture; multispectral imagery intelligence equipment; spectrozonal equipment of imagery intelligence; radio technical reconnaissance equipment.

Implementation of the targeting function is carried out by solving the problem of transmitting from the UAV data on targets in real time for artillery, missile and air strikes, as well as laser illumination for aiming high-precision weapons. The solution of these tasks is carried out with the help of imagery intelligence equipment that provides air reconnaissance on a real scale time, and laser targeting equipment.

During the control of the battlefield UAVs provide with information of support for ground combat, special forces operations, interception operations at sea, naval artillery fire on ground targets, etc. This uses imagery intelligence equipment.

Use of UAVs during the participating in electronic warfare will give the opportunity to resolve tasks of suppressing enemy air defense means (setting incorrect targets, noise electronic suppression, etc.) and conducting radio-technical reconnaissance will be solved.

The implementation of the strike function is associated with solving the problem of rapid detection and destruction of ground (surface) objects of the enemy by missiles or aircraft bombs, which are equipped with reconnaissance and strike or strike UAVs.

Table 2.2

UAV's function and mission

no	Functions	Mission	UAV (example)
1	Air reconnaissance conducting	- collection of reconnaissance information about enemy ground objects during preliminary reconnaissance and post-reconnaissance; - direct support of the field command - control of the blows results on the enemy; - check the degree of own army camouflage	Black Widow; Pointer; Luna; Mirach-26; Phoenix; Pioneer; Shadow-200; CL-327; Brevel; CL-289; Mirach-100; Hermes-450S; Shadow-600; Predator; Hermes-1500; Global Hawk; 'Bee -TM', 'Bumble bee'
2	Target	- real-time data transmission from the UAV on targets for artillery, missile and air strikes; - laser illumination for targeting high-precision weapons	Crecerelle; Mirach-26; Shadow-200; Phoenix; Hermes-450S; Predator; Global Hawk; 'Bee -TM', 'Bumble bee'
3	Battlefield control	information support of ground combat, special forces operations, interception operations at sea, naval artillery fire and missile systems of volley fire on ground targets	Microbat; Phoenix; Pioneer; Searcher II; Altus; I. Gnat; Predator; Raven; Dragon Eye; 'Bee -TM'

Table 2.2 continuation

no	Functions	Mission	UAV (example)
4	Radioelectronic Warfare	- suppression of enemy air defense means (setting false targets, noise electronic suppression); - radio technical reconnaissance conducting	ADM-160A; CL- 327; Sperwer; D-4; Raptor; Mirach-26; Mirach-100; Dragon; Eagle Eye
5	Blows Inflicting	Detection and destruction of ground (surface) enemy targets by missiles or aircraft bombs	Predator; K-100; Taifun; Futura; X-45; Lark; Marula; Harpy
6	Communication relay	- increasing the range of UAV command and control systems; - retransmission of information	Sentry; CL-327; Ka-137; CL- 227; Mirach-100; Hermes-450S
7	Radiation, chemical and biological reconnaissance	- monitoring of potentially dangerous areas; - assessment of radiation levels; - threat detection; - identification of toxic substances; - identification of biological agents; - warning and locating the threat	Fox; Sniper; Super Vulture; Prowler II

Table 2.2 continuation

no	Functions	Mission	UAV (example)
8	Mines detection	- detection and establishment of the minefields location and obstacles from the air; - support for landing on the coast of the sea landing.	Luna; Mirach-26; Pioneer; Shadow-200; CL-327; Brevel; CL-289; Mirach-100; Hermes-450S; Shadow-600; Hermes-1500; 'Bee -TM'
9	Correction of artillery fire	- control of strikes on enemy targets; - transfer of information regarding the results of losses (damage) to the enemy; - guidance of artillery fire and missile systems of volley fire at enemy ground targets.	ASN-206; Phoenix; Eagle Eye; Pioneer
10	Meteorological reconnaissance	gathering information over enemy territory, in areas of tropical cyclones and hurricanes, in difficult weather conditions of natural (sandstorms) and artificial origin (high smoke from oil fires), as well as its transmission to land	Camcopter 5.0; Chacal-2; Mirach-26; Sperwer; Ka-137
11	Search and rescue in combat situation	identification of the rescued personnel location and transfer of information to the established points of its acceptance	Dragon; Observer; Vigilant; Luna; Raven

The function of communication relay is performed by solving the tasks of increasing the range of command and control systems of the UAV, as well as the task of relaying information using special communication equipment installed on the UAV.

The possibility of the enemy's use of chemical and biological means of influencing on personnel determines the need for chemical and biological reconnaissance. Chemical and biological reconnaissance equipment is installed on UAVs or on disposable unmanned devices to perform tasks of potentially dangerous areas monitoring, detecting chemical hazards or threats, identifying toxic substances, detecting biological hazards or threats, identifying biological agents, preventing and locating hazards and threats.

In conditions of possible radiation contamination, special sensors are used to conduct radiation reconnaissance Carrying out anti mine action is aimed to preservation of personnel, weapons and military equipment. The UAV is entrusted with the following tasks: detection and establishment of minefields and airborne obstacles; support for landing on the coast of the sea. Multispectral and spectral imagery intelligence equipment is used to solve these problems.

Another important function of the UAV is the correction of artillery fire. Its implementation is ensured by solving the tasks of controlling the impact on enemy targets and transmitting information about the results of losses (damage) to the enemy; aiming artillery and missile systems of volley fire at enemy ground targets. Tasks are performed using airborne reconnaissance equipment.

Unmanned aerial vehicles are also responsible for meteorological support. They collect information over enemy territory, in areas of tropical cyclones and hurricanes, in difficult weather conditions of natural (sandstorms) and artificial origin (high smoke from oil fires), as well as its transmission to land. To perform these tasks, special sensors of temperature, pressure and humidity are installed on the UAVs. A GPS system is used to measure the vertical wind profile.

Another important point in the use of UAVs is their involvement in the search and rescue of personnel in combat situations. During the flight over the battlefield, UAVs with the use of imagery intelligence equipment detect the location of the rescued personnel and transmit information to the designated points of its reception.

The mentioned classification and tasks of unmanned aerial vehicles allow us to understand the place of each UAV in modern combat conditions.

3

UNMANNED AIRCRAFT COMPLEX AND ITS COMPONENTS

3.1. Basic terms and definitions

The rapid development of unmanned aerial vehicles in modern conditions has raised a number of issues in its conceptual, theoretical, methodological and terminological support that require its operational and qualitative solution.

First, it’s related to terminology, as the lack of a common terminology basis for unmanned aerial vehicles makes it very difficult for developers, manufacturers, and operators to interact.

The main disadvantages of the terminological basis for unmanned aerial vehicles are due to:

- lack of a number of terminological definitions;
- incomplete (sometimes wrong) formulations of terminological definitions;
- the use of ambiguous terminology and definitions;

- the lack of a unified classification system and a unified list of the main classification features.

An analysis of modern publications on unmanned aircraft [1…6] confirms these disadvantages. So, for example, along with the well-known concepts as aviation equipment (AE), aircraft (AC), aviation complex (AC), combat aviation complex (CAC), etc., such concepts are often used in publications on unmanned aircraft under the assumption that there is no crew on board. However, using of these definitions is not always justified due to the fact that the specifics of the use of unmanned aerial vehicles based on unmanned aerial complex

(UAC) is fundamentally different in comparison with aircraft that has a crew on board. For the correct use of these definitions in unmanned aircraft, it is necessary to add the term “unmanned” to them, i.e. to use UAVs, UACs instead of AV, AC, etc.

One of the common mistakes in UAV terminology is also the identification of the concepts of «aviation complex» and «aviation system», which causes confusion in the terminology [92].

The definition of «system» (complex technical system) [7, 8] has a number of definitions that consider it as a set of elements (aggregates) acting together and ensuring the performance of specified functions. Under the definition complex (technical) [7] we understood it as a set of its constituent elements (complicated technical systems, products or equipment appropriate means of their application and technical support), which are functionally united by a common control agency and are jointly used to solve a given list of tasks performed by this complex.

Taking into account these definitions, the complex, first of all, provides for the presence of complicated technical systems in it, therefore, it should be higher placed in the terminological hierarchy.

Hence, the conceptual basis for constructing terminology for unmanned aircraft should reflect the hierarchical elements: «structural elements - aggregates - functional systems - UAV - UAC - organizational and technical system.»

One of the most frequently used definition in unmanned aviation are the terms «unmanned aerial vehicle», «unmanned aircraft complex», «remotely controlled vehicle (RCV)» and several others. These definitions have fundamental differences, but in practice they are often replaced and incorrectly used.

The term UAV is generally understood as an machine designed for flights in the Earth's atmosphere or in outer space, which has no crew and is controlled automatically using on-board devices or at a distance from a command control center [7, 8]. This definition covers a wide class of military and civil UAVs.

A military *unmanned aerial vehicle* is usually understood as an unmanned aircraft designed to perform tasks specific to manned combat aircraft and controlled automatically or remotely by an operator from a control center according to a given program. In accordance with this definition, UAVs primarily include unmanned aircraft, helicopters, gliders, target aircraft, missiles, guided projectiles, and torpedoes. To be fair, it should be noted that a number of authors speak about the exclusion of missiles, guided projectiles and torpedoes from this list.

Along with the UAV, another definition «unmanned aerial complex» (UAC) is often used. The use of this term is justified by the requirements of a systematic approach during the studying processes of using unmanned aircraft and emphasizes that the operation of the UAV is carried out within the framework of a complex where air and ground components are existing. At the same time, the effectiveness of the use of the UAC is determined by the performance indicators of each of its components.

Taking into account the air and ground components under an *unmanned aerial complex (UAC)* for military purposes we will understand a functionally connected set of one or more several UAVs, its (their) technical means of communication and control, ground support, means of launching, landing, rescue, transportation and storage, designed for independent performance of military tasks.

The concept of «civilian UAC» will differ from military purpose only in the specifics of the civilian tasks to be solved.

The structure of the organizational and technical system (OTS) of unmanned aviation, taking into account the requirements of a systematic approach, can be represented in a hierarchical three-level form (Fig. 3.1), where the UAV is located at the first (lower) level of complex technical systems, the UAC is placed at the second level and on the third level the organizational and technical system the technical element (UAC) is combined with the ergatic one. Such a representation for the structure of the OTS of unmanned aircraft allows us to interpret the concepts of UAVs, UACs and their elements from a unified standpoint, as well as to determine their relationships.

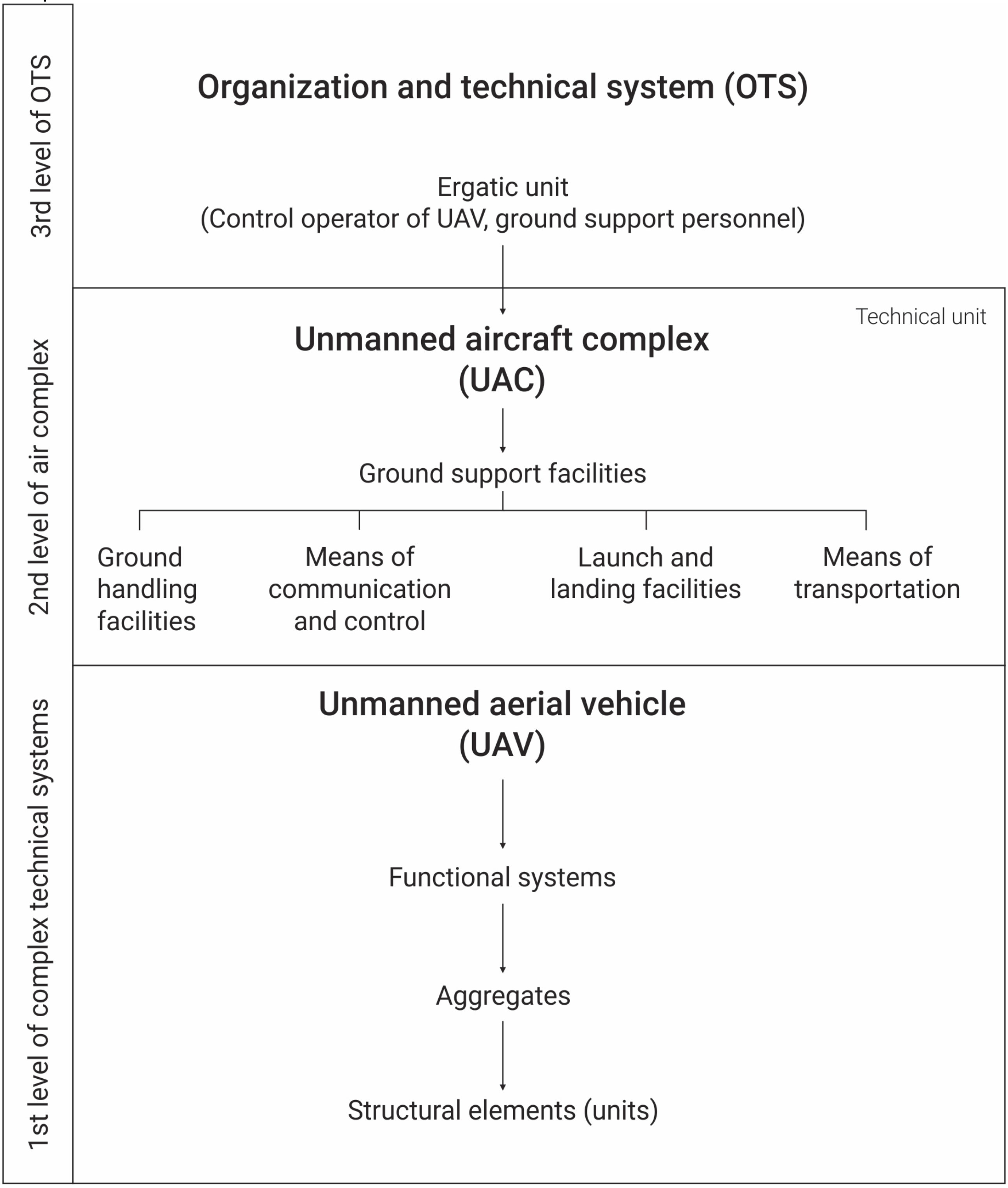

Figure 3.1. Organizational and technical system based on UAC

As part of the ergatic unit, the following main elements can be distinguished: the head - the decision maker (DM), the UAV control operators and the service staff of the complex.

In addition to the UAV, the UAC includes ground support facilities as communications and control, ground handling, launch, landing, rescue, transportation and storage (Fig. 3.1, 3.2). Some options of ground facilities placing as communications, control and provision of UACs on mobile transport are shown in Fig. 3.2.

UAC ground handling facilities usually include a set of facilities: technical operation and repair, refueling with fuel and lubricants, UAV diagnostics, flight task preparation and post-flight maintenance (Fig. 3.3).

Along with the definition UAV, which is often used in a broad sense of the word, another definition is used as remotely piloted aircraft (RPA), which is often confused with the concept of UAV. One of the main differences between RPA and UAV is interactive piloting method of aircraft [101]. The RPA operates differently from the UAV, for example, as the 'Reys' UAV, which performs a flight according to a adjusted program and returns to the starting position with the captured photographic material.

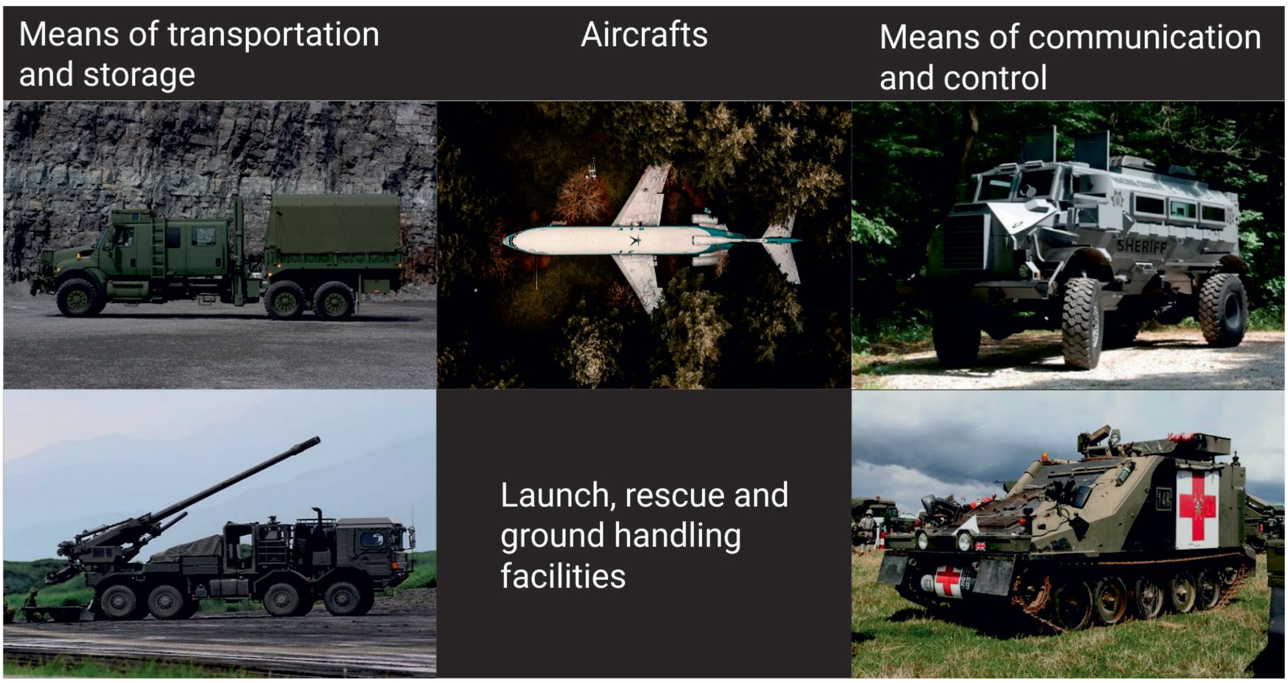

Figure 3.2. The main components of UAC

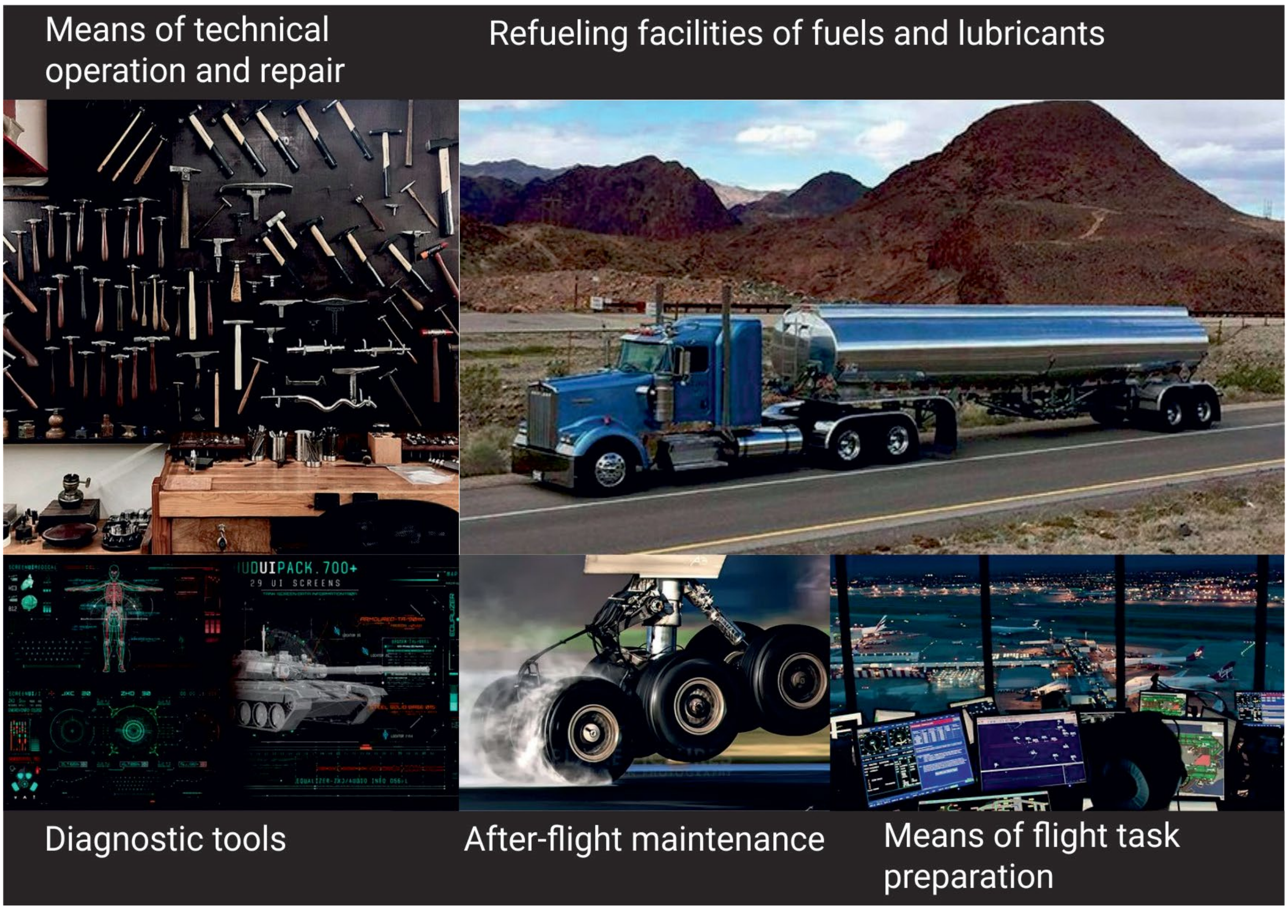

Figure 3.3. The main components the of ground handling facilities complex of UAC

In the process of performing the task of searching (reconnaissance) a target RPA transmits over a radio channel in real time to a ground control point reconnaissance (for example, television) information about the terrain and the target (reconnaissance objects) on it. RPA operator being at the ground control point evaluates the incoming information and controls the UAV itself and its target load (for example, a television camera) via a command radio channel.

In this case, the task of management is to organize monitoring of a target (targets) as well as clarifying its (their) types and coordinates. The most important feature of the use of RPAs is the possibility of multiple repeated visits to the target (reconnaissance objects), which determines the interactive property and the main differences between RPAs and UAVs.

The RPA is an integral part of the UAV and cannot function outside the complex. Only in the interaction of the RPA with the ground control point and its central element (the human operator), the main feature of the RPA that is interactive control could be realized.

The unmanned aircraft complex (UAC), consisting of air (RPA) and ground components (control points, support facilities, etc.), in combination with the ergatic unit, forms an organizational and technical system.

The most important elements of such a system based on RPAs are:

- a radio channel for transmitting of current intelligence information to a ground control point;
- command radio channel for controlling the RPA and its payload.

Only in the presence of such channels is it possible to interactively control the RPA. Thus, an RPA is an aircraft capable of operating both in automatic and automated modes as to fly along a given route and maintain its orientation in space without human intervention, and also ready to immediately respond to the control actions of a human operator.

In connection with the above, the use of terminology in unmanned aircraft should be correct and justified, taking into account the characteristics of the tasks being solved and the functionality of the UAV.

3.2. Brief description of the elements of unmanned complex

In accordance with the above definitions, let’s consider the components of the UAC (Fig. 3.1, 3.2) and give a brief description of them.

Communication and control facilities is a set of technical means designed to ensure the takeoff, landing, flight of an UAV (RPA) along a given profile and route in automatic or automated modes, as well as to control the processes of using onboard equipment. The onboard equipment of the UAV includes means for receiving and transmitting reconnaissance (monitoring) information. At the same time, such information can be delivered to consumers and removed after the UAV returns to its home base or, to increase efficiency, relayed in flight to a ground (surface, air) control point.

Control point (remote) of UAV (RPA) is ground (ship, air) technical means of controlling the UAV (RPA) and its special equipment, means of processing flight, reconnaissance and other information.

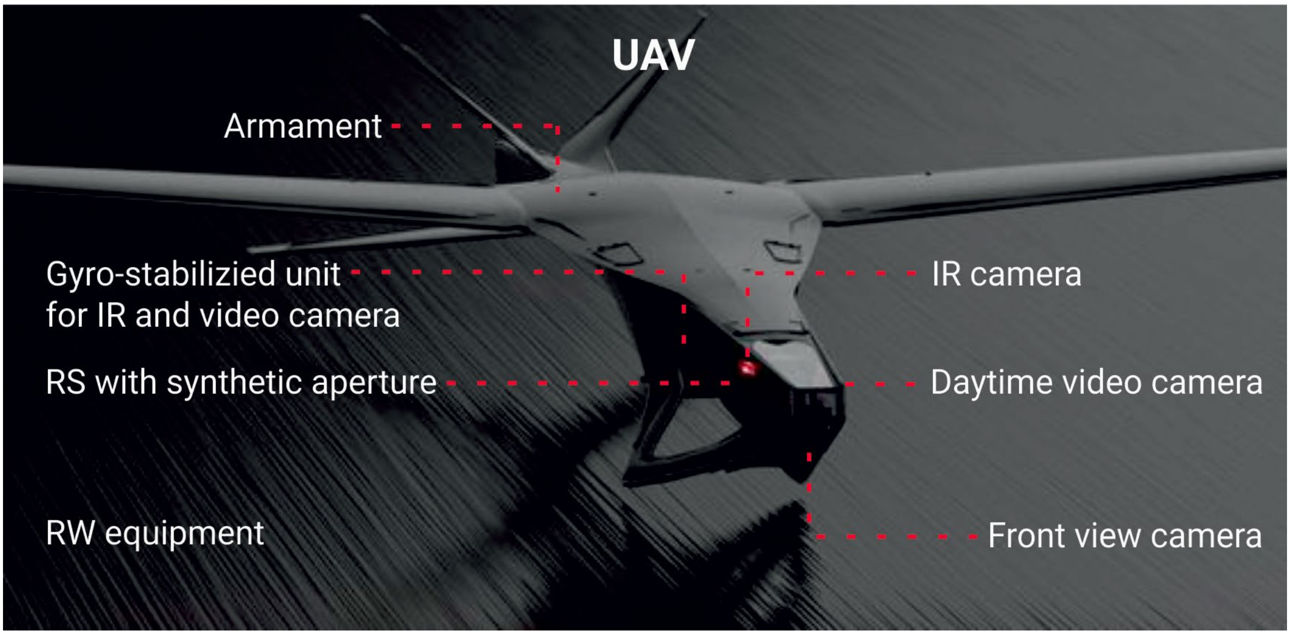

Figure 3.4. The main target load of UAV

UAV (RPA) control operator is a specialist who, with the help of technical means, controls an UAV (RPA) and its equipment at the stages of flight provided for by the assignment.

Target equipment (target load) of UAV (RPA) is on-board technical means designed to perform the tasks of the UAV for its intended purpose as means of reconnaissance, radio electronic warfare, target designation, relaying, imitation of air targets, search and aiming equipment (daytime and IR cameras), etc. (Fig. 3.4). Often, the payload of a military UAV also includes its combat load (armament).

The combat load (armament) of a strike fighter or multi-purpose UAV is aviation guided and unguided weapons, its cannon weapons, protective equipment (for example, heat traps), etc. The composition of the target load of the UAV largely depends on the tasks it solves, the UAV class, etc.

Special support facilities include launch, rescue and landing facilities, transportation, and storage facilities.

The composition of the main elements of the complex of *UAV ground handling facilities* (Fig. 3.3) can vary depending on their functional purpose and the specifics of the tasks being solved. So, for example, the means of preparing a flight mission may include means for preparing and equipping with means of destruction (for strike-type UAVs), protective equipment (for all types of UACs), jamming (for electronic countermeasures UACs), etc.

The post-flight maintenance facilities for reconnaissance-type UACs will include a ground-based reconnaissance information processing complex, etc.

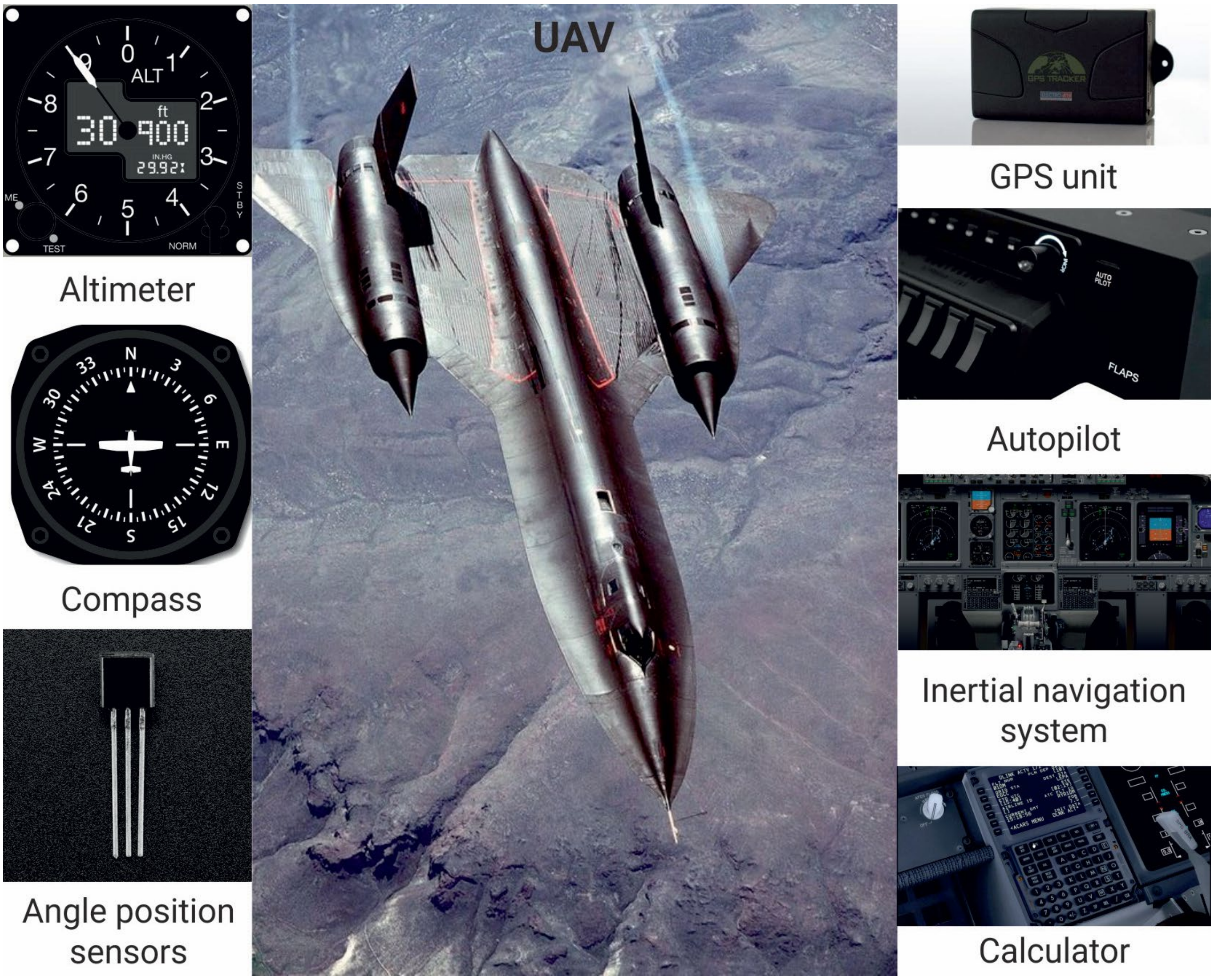

Figure 3.5. Basic onboard equipment of UAV

The main elements of the onboard equipment of the UAV are shown in Fig. 3.5.

These include altimeter, compass, angle sensors, GPS unit, autopilot, inertial navigation system and calculator.

The features of the use of reconnaissance-type UACs are considered using the example of solving the problem of detecting and subsequent destruction of a target (Fig. 3.6). To perform the task, an RPA is launched from the launcher installation and is flown by the operator's commands to the intended target area. After detecting a target, the RPA fixes its coordinates and image, and then transmits them to the command post. From the control point information is transmitted to the means of destruction, which

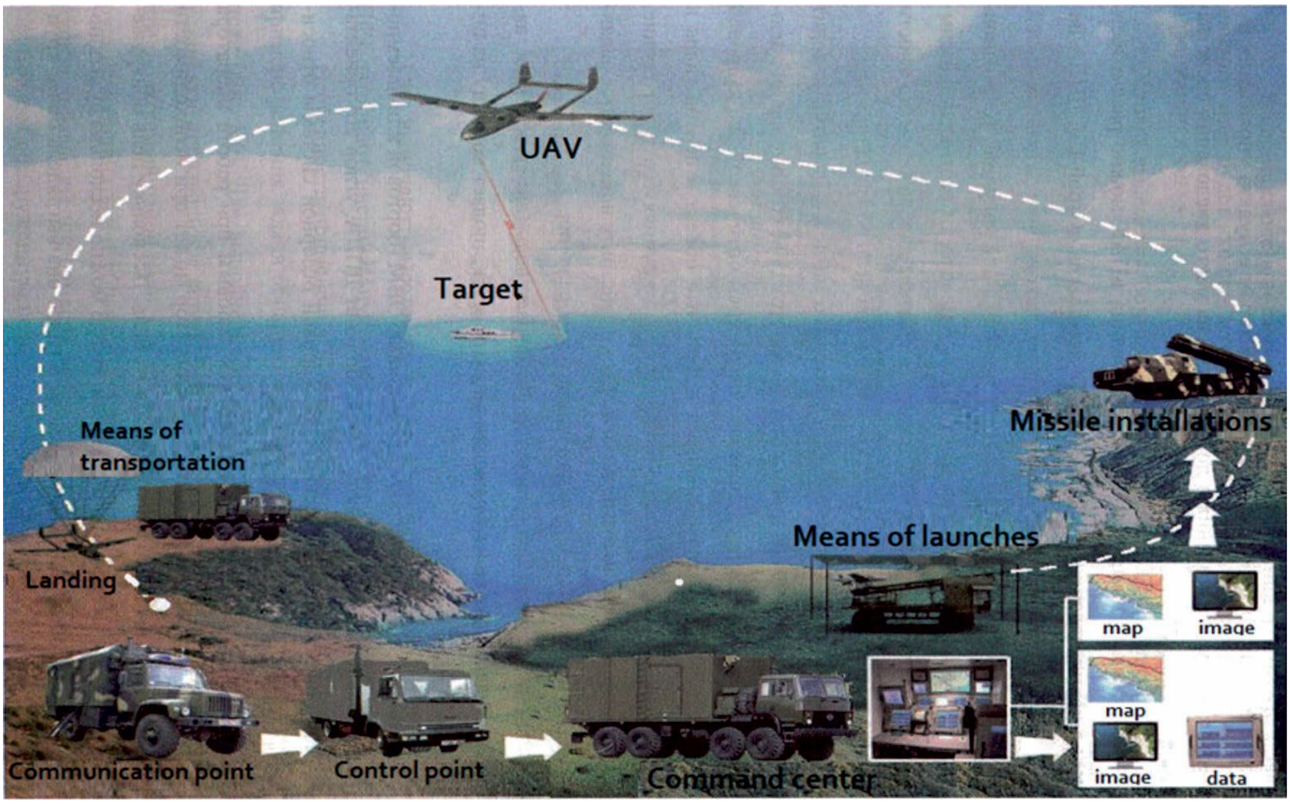

Figure 3.6. Option of application UAV in the UAC of OTS

destroy the detected target.

After completing the task, the RPA is sent to the landing site by commands from the control center and delivered to the location by means of transportation.

In more detail, the processes of functioning of the UAC can be considered using the example [101] of the control of the RPA ‘Pchela-1’ related to Stroy-P complex. RPAs are sent along the route where the specified targets are expected to be found. At the same time, a wide field of view of survey frame television system is established, and its optical axis is set in the plane of vertical symmetry of the RPA and tilted down at such an angle, so that the image of the terrain on the screen allows the operator to notice objects similar to the target.

When an object similar to a target appears on the screen, the operator points the optical axis of the frame survey system at this object, placing its image in the center of the frame. Further, by controlling the position of the optical axis of the frame survey system, the operator keeps the selected object in the center of the frame and narrows the field of view of the frame survey system, enlarging its image. The decision that the selected object is indeed a target it is possible when the image is enlarged.

After detecting the target, the operator recognizes the target (for example, a tank, a car) and, holding its image in the center of the frame, gives a command to determine the coordinates of the target.

The target coordinates are determined by a computer (on-board or ground control station) using the coordinates of the RPA, its orientation angles and the orientation angles of the optical axis of the personnel surveillance system relative to the associated RPA coordinate system.

The process considered above is typical when an RPA operator works with a target. By setting the coordinates of the target, the operator can command the UAV to re-enter the target, if necessary. Since the target has been detected and its position is known, it is possible to slightly narrow the field of view during the second approach so that when the target appears in the frame, it looks larger.

RPA control, from the point of operator's view, is not particularly difficult. The RPA independently maintains the initially set route where the autopilot ensures that the specified heading, roll and pitch angles of the RPA are maintained. The operator's work is reduced to performing such functions as searching, detecting, recognizing a target, issuing commands to control the width of the field of view and the direction of the optical axis of the personnel surveillance system, as well as commands to determine the coordinates of the target and re-enter the RPA (if necessary).

This nature of the operator's interaction with the RPA and its target load (equipment) distinguishes the RPA from the UAV that performs its flight according to the program.

4

FACTORS WHICH INFLUENCED ON THE APPLICATION AND DEVELOPMENT OF UNMANNED AIRCRAFT

4.1. Conditions for armed struggle

Military conflicts that took place in the late 20s - early 21st century featured by changes in the nature of armed struggle and complex physical and geographical conditions of hostilities, which affected the use of all types of weapons and military equipment (WME) including unmanned aircraft systems.

After the Second World War, the military art of the world's leading states was focused on the preparation and maintenance of large-scale (world) nuclear and conventional warfare, on the development of forms and methods of action of the armed forces in these wars. The leading role was played by ground forces, the main form of which was a strategic operation made under the common plan and leadership of the general commander with the participation of other types of troops.

The first changes in opinions regarding the role of ground forces took place after the creation of nuclear weapons. The main purpose of the ground forces was to consolidate the results of nuclear missile strikes and perform occupation functions. The leading role was given to the growing of number and quality of nuclear missiles. However, nuclear weapons had not the basic type of weapon for a long time, under the «dictation» of which operational art was going to be developed. Nuclear missiles were relevant during the period of confrontation between «multipolar» systems led by the United States and the Soviet Union, where they played two opposing roles: as deterrent and main weapon in case of the beginning of world war.

A long confrontation between the two world political systems has been ended by the collapse of the USSR. At first sight, the threat of a new world war has disappeared. The civilized world has entered a phase of nuclear disarmament. However, local wars and armed conflicts remained. Based on experience, their characteristic feature was the active use of air strikes which led to radical changes in both theory and practice of operations (combat).

The use of significant air forces during military conflicts influenced the overall process of armed struggle, the nature and final results of ground, sea and air operations. The Air Force was involved in a significant range of tasks both in the interests of other types of armed forces and to perform independent actions that took the form of special-purpose air operations. For the most local wars and armed conflicts it was typically that they began and took place with a significant advantage in the air force on the aggressor’s side.Thus, during the conflict in the Balkans in 1999, the correlation of parties in aviation was 1 (1,050 NATO aircraft versus 352 Yugoslav aircrafts which mainly had obsolete types). The same correlation was 3:1 during the Iraq conflict in 1991 (2,260 aircraft versus 700 Iraqi aircraft).

The experience of local wars of the late 20s - early 21st centuries proves that mainly the attacking side managed to achieve significant results already in the process of setting the first air strikes. The wars in the Persian Gulf (1991), Yugoslavia (1999) and Syria (since 2015) have confirmed the high tempo of the combat capabilities growth for modern aircrafts and also clearly demonstrated the need for their combat use as element of the common system which includes not only aviation but also air, ground, sea, space reconnaissance, RW, exchange of information about the tactical situation, combat management, etc.

The success of Operation ‘Desert Storm’ against Iraq in 1991 has been achieved due to changes in the role of aviation in operations. Thus, according to classical theory and practice, the Air Force’s independent actions in the air offensive operation took 2-3 days. However, in the Iraqi considering the probable confrontation of Iraqi troops, the American command has radically revised the traditions and allocated almost 40 days instead of 3 for independent action of aviation. As a result, more than 30% of the enemy’s losses on the ground were ensured, the will to active confrontation was broken, the command-and-control systems of troops and weapons were completely disorganized, and communications has been disrupted. The Iraqi army was demoralized and has lost its combat effectiveness. This determined the transience and high efficiency of the coalition’s ground forces. Additionally, the command of the multinational force was able to limit the loss of its ground forces by shifting the main mission to achieve the goal of the operation on the air component of its group.

During the 40 days of fighting in Iraq, the MNF aircraft have made more than 100,000 flights using so many bombs and missiles that their total power can be compared to the explosions of several nuclear bombs. From the day the operation began (from January 17th to March 1st of 1991 - the day of the official ceasefire), 88.5 thousand tons of various types of ammunition were dropped on troops and facilities in Iraq and Kuwait.

Another changes in the concept of warfare took place during the preparation for Operation Iraqi Freedom in 2003. The smaller but incomparably better equipped and trained U.S. forces have replaced heavy units of the 1991 Gulf War period. 740,000 troops, 2,260 aircraft, and about 150 warships were stationed in anti-Iraqi forces, but at the beginning of Operation Iraqi Freedom in 2003 the MNF numbered up to 295,000 troops, more than 700 warplanes and more than 100 warships. The emphasis was not in massive firepower and numerical superiority, but on the purposeful use of aircraft and quite small ground forces, the wider use of special forces with advanced military technology.

Instead of large armies opposition (except the Gulf War in 1991) local wars began with limited use of heavy military equipment, a lack of a clear front line, and fighting was conducted by small mobile units, usually such capturing strongholds as certain military facilities and settlements. Thus, at the beginning of the operation in Iraq in 1991 the MNF marines, which numbered 90 thousand servicemen and was armed with 240 tanks, 1.5 thousand guns, mortars, ATGM launchers and anti-aircraft firearms, but in the Balkans in 1999 the ground group didn't have any planned tasks.

The role of fire damage in local wars has significantly increased. However, as it was established, neither a further increase in the firepower density, nor an increase in the resource and cost of ammunition have not led to a significant increase in the effectiveness of fire damage. The problem of increasing the effectiveness of fire damage became directly dependent on the information support of troops, especially firearms and data on the objects coordinates in real time.

The main devices for objects destroying were high-precision sea-based and air-based cruise missiles (SBCM and ABCM respectively) which were widely used due to reconnaissance data, including those obtained with the help of a large number of UAVs for various purposes. For example, only during the first phase of the Operation Allied Force 80 SBCM and 50 ABCM were launched at facilities in Yugoslavia. At the same time, 46% of Air Force (AF) and Air Defense (AD) facilities, 32% of military facilities, 16% of control points (CP) were affected. The share of the use of high-precision weapons in military conflicts between 1991 and 2015 has increased from 9% to 70%.

Therefore, mission of achieving an information advantage over the enemy has became highly important. The main way to solve this problem was to create reconnaissance systems for various purposes and bases. From one conflict to another in terms of providing with reconnaissance data, UAVs began to come to the fore which could solve their tasks more effectively than manned aircrafts.

As a result, long offensive operations which conducted mainly by numerous ground forces, have been receded into the background. Thus, during the war in Iraq in 1991, the air offensive Operation Desert Storm which proved to be the main and decisive stage of the war, lasted 38 days, and the air-ground offensive Operation Desert Sword only 5 days. Based on the experience gained in Iraq, the plan for an air-to-ground operation in the Balkans in 1999 predicted two active phases without the involvement of a ground group: the first - air and missile strikes on military facilities in Yugoslavia for 3-5 days, the second - aerial damage to infrastructure for 5-6 weeks. As known, the plans of the operation were aimed at forcing the Yugoslav ground forces to leave the territory of Kosovo without the use of their own ground forces. This resulted in a decrease of manpower losses which usually accompanied operations of such scope. The occupation of the enemy’s territory was unnecessary, which according to historical experience, often became a heavy burden for the victor.

The strategy of the war has become more focused, first of all, on destroying the enemy’s economic potential. Without economic leverage, the enemy became unable to maintain its armed forces which after a while stopped to be any threat. Thus, the ground forces were no longer considered as direct targets of the attack, and victory became possible even without the occupation of enemy's territory. An example of such a strategy was the NATO Allied operation in Yugoslavia. During the war, according to various estimates, Yugoslavia's economic losses exceeded $ 100 billion, the country's infrastructure was destroyed, the number of refugees amounted to more than 700 thousand, and more than 2 thousand civilians have died. Because of NATO strikes on Yugoslavia, 24 bridges have been destroyed and 36 have been damaged, 16 large transformer and 6 distribution stations, 5 energy-saving power lines were destroyed and 250,000 people have lost their jobs. The economic potential of Yugoslavia was so badly damaged that it achieved the political goal of the war - the subversion of the Milosevic's regime.

Together with changing the emphasis on understanding the main components of the victory's «formula», the usual ideas in strategy, operational art and tactics in military conflicts have been changed too. Due to the fact that the main aim of modern wars was the synchronous defeat of the enemy in large areas, strategy began to play the main role instead of tactics. The definition as the direction of the main strike gave over to exist because strikes were made synchronous from all strategic directions. Moreover, some forms and methods of hostilities began to lose their usual sense.

Airspace became the main theater of war. Thus, while at the beginning of Operation Allied Force in the Balkans in 1999 the air force numbered 450 aircrafts (290 of them were combat aircrafts) but during the escalation their number has grown to 1,050 aircrafts and helicopters (630 of them were combat aircrafts). At the start of Operation Iraqi Freedom in 2003, the anti-Iraqi air force already numbered more than 700 fighter jets. During the first and second phases of Operation Allied Force 240 SBCMs, 74 ABCMs, and 1,680 tactical aircraft sorties have been launched at facilities in Yugoslavia. At the same time, during the transition to the second phase of the operation, the insufficiency of the air component was proved. Therefore, in the region of the aircraft carrier group, additional deployment and increasing of combat aircrafts and support aircrafts, as well as SBCM carrier ships was carried out.

The fact that in both Iraq and Yugoslavia the ground forces of the Iraqi and Yugoslav armed forces significantly exceeded the MNF, has facilitated the shifting the focus of armed struggle to air and conducting it in the form of air offensive operations. As the result, it has forced both Iraq and Yugoslavia to leave most of their combat capability outside active armed conflict. And this despite the fact that, for example, Iraq in 2003 remained the largest military force in the region: 424 thousand troops, 2,200 units of battle tanks, 3,700 units of armored personnel carriers, 2,400 artillery barrels, up to 80 ballistic missiles systems «Scud», etc.

As the focus of the armed struggle shifted to the air, terminology began to change. The following new concepts have appeared as «needs to be detected», «needs to be explored», «needs to be clarified», «needs to be destroyed», etc.

As a result, existed terms during the period of contact wars gradually began to lose their meaning, among them are the following: «front», «rear», «front edge». In accordance with this, a new management system of RSS (reconnaissance and strike systems) has been created and which programmed to execute several commands as: “detect”, “make a decision”, “destroy”, “to document the results of destruction”. And, as the experience of modern military conflicts has shown, UAVs has started to be a tool for implementing most of these commands. And since 2001, since the beginning of the use of strike UAVs in combat operations, drones have rightly been considered one of the simplest and most effective elements of reconnaissance and strike systems.

The desire of man to distance himself as much as possible from the enemy and the area of direct combat operations has influenced on the nature of the armed struggle. If in contact wars the main object of defeat was the armed enemy’s forces, the economic destroy after defeat, overthrow the enemy’s political regime, achieve victory after the occupation of the country, in non-contact wars the main aim was destruction of the country’s economical potential.

Man’s desire to distance himself from the enemy and areas of direct combat has accompanied the whole historical period of armament development. Only in the conflicts of the late 20s – beginning of 21st century non-contact has become determinative due to the appearance of new technologies used to create new types of weapons. Under these conditions, the role of man in the military conflict ha started to be transformed. The man was pushed out of the battlefield step by step. Those types of weapons and military equipment that anticipated and created dangerous for human life via their using, have been replaced by robots. The same accrued to aircraft because intensified work on the creation and use of aircraft without pilots on board (UAVs) has started to crowd out manned aircraft.

According to some sources, about 100 jets were lost annually in the armed forces of the former Soviet Union due to accidents and catastrophes (losses amounted to approximately 750-800 million). The causes of accidents and catastrophes were either technology or man. The main piece of these aviation accidents was the failure of the power plant, errors in piloting techniques, violations in the organization and management of flights, as well as personal indiscipline of pilots. At the same time, only 20% related to the failure of the power plant, and the rest was all a human factor.

Analysis of aviation accidents due to «piloting error» showed that mainly this term is hiding ability of technology to fall into flight conditions where the pilot is fighting for his life and saving the jet, loses precious time and opportunity to escape. A pilot of shunting aircraft is driving an aircraft in conditions close to the limits of stability and controllability of the aircraft, when even a single minor pilot error in combination with the circumstances, often leads to sad consequences. Typically, such situations are happening when the pilot's attention is not focused on piloting but on the object outside the cabin (on targets, the environment, etc.).

The desire of the developers to increase the maneuverability and stability of the aircraft at large angles of attack has brought an idea to create aircraft with new aerodynamic configurations. However, the peculiarities of the aerodynamic layouts for modern aircraft are such that the vortex structure around the sailplane during the flying at large angles of attack is destroyed suddenly and asymmetrically. The result is an unbalanced aerodynamic moment when the pilot is not able to fend off due to the loss of aircraft control at large angles of attack. In the absence of sufficient altitude and due to the transiency of the situation, the pilot usually dies.

Analysis of a large number of aviation accidents due to «error in the piloting technique « allows us to do a very sad conclusion: out of 100 cases in such conditions, about 70 of them end in a crash (eg the destruction of the aircraft and the death of the pilot) regardless of the level of training and experience of the pilot. In this case, the line between conscious error and error due to the physiology of the pilot is very conditional. Moreover, according to statistics, more than 80% of all aviation accidents for these reasons occurred in simple daytime (over 70%) and night (about 10%) weather conditions.

The transition to more advanced technology during the generations changing of aircraft was accompanied by the hope of accidents reducing. However, as experience shows, no positive changes have taken place. First, due to the increase of psycho-emotional load of the pilot. If a pilot needed about 22 minutes for restoration of working capacity between flights on a third-generation aircraft, it took almost 40 minutes on a fourth-generation aircraft. The required duration of rest between flight shifts has increased from 18 to 48 hours. The growing complexity of aviation has led to a doubling of the number of mistakes made by pilots.

Experience with the use of combat aircraft in military conflicts has shown that with the growing of aircraft complexity, it has become difficult to provide the necessary intensity of hostilities due to the rapid accumulation of physical and psychological fatigue of pilots. Pilots began to increase the number of mistakes during the flight. This happened not only due to the complexity of aviation equipment, but also due to the complexity of the information environment with help of which the pilot interacted with the equipment. The new modern aircraft with added an additional work for pilot with the conversion of different information signals from devices, boards, light bulbs and displays in the relevant semantic concepts that initiated functional activity.

As an example of the high level of pilot loading was the description of the F-18 aircraft cabin which indirectly reflects the aircraft cabins of most combat aircraft that have participated in modern military conflicts. Yes, the aircraft cabin is equipped with three multifunction displays with 20 programmable switches on each. Each display shows 675 short messages and 177 different characters. In addition, there are expected 40 different display formats and reflecting more than 100 different messages about threat, danger warnings and various recommendations. There are 22 separate windshield indicator configurations that use the same base symbols in different parts of the information area. These include switching and radio control devices, instrument landing system, direction finder, recognition and autopilot, aircraft control lever with seven switches and engine control lever with nine switches. A person being in such an information filled cabin must think, aviate in combat conditions, adequately perceive the reality and predict the results of actions. According to aviation medicine experts, the optimal crew for such a cabin would be a crew of six people: two pilots, a flight engineer, navigator, shooter, computer operator and translator. However, the crew consisted of only one person. The pilot’s mistake in flight, if he uses all this cabin equipment, is in fact doomed because of cabin conditions.

In addition, during the flight, the pilot experiences the effects of overload, stressful situations and information flows. Despite all the efforts of scientists and designers, he is still prone to faint, lose orientation, fall out of the temporary area of situation development and so on.

Improving the maneuverability of combat aircraft has seemed by many as one of the powerful arguments in favor of creating more expensive aircraft. However, it turns out that high angular speed of spatial aircraft rotation in combination with spatial overload led to a significant decrease of loss threshold of spatial orientation by the pilot. The discrepancy between the dynamic characteristics of technology and the human body began to become more visible.

As a result, in the 1990s there was a tendency to ignore such «weaknesses» of the human body as short-term loss of consciousness and spatial orientation and, therefore, the redistribution of flight control functions to displacement of the pilot from area of active flight guidance. Programs of intelligent rescue systems for the crew saving in case of consciousness loss, spatial orientation or the inappropriate actions by the pilot have started to be implemented.

Considering the pilot training cost growing in the existing views on the perspectives for the development of shunting aircraft, such a question was justified. On the other hand, according to experts' opinions, in real life the use of over-maneuverability modes did not give any special advantages to maneuverable aircraft. Such well-known exotic maneuvers such as «dynamic exit», «bell», etc. are unlikely to be available for simple pilots. The complexity of the technique and process of piloting became a completely different level of requirements for the pilot, both to his physical condition and to his intellectual capabilities. The process of training a pilot who had fully meet the requirements of the latest samples of aircraft and piloting conditions, and at the same time to ensure his safety, was becoming increasingly complex.

All this forced to intensify work on the creation of UAVs as devices that could perform complex tasks without risk to the pilot's life, considering the difficult conditions of execution, tasks, and mainly to ensure contactless combat.

At the same time, the principle of transition to contactless warfare did not immediately become typical for military conflicts in recent decades. This process developed step by step and the stages of development were directly dependent on the understanding by both parties of the importance and role of unmanned aviation innovations in the war.

Thus, if the military conflict in Iraq in 1991 was a kind of prototype of contactless war, the fighting in the Balkans in 1999 was already a real trace of contactlessness. Strikes on military and economic facilities in Serbia and Kosovo (during the new complex air-space-naval operation in the martial arts) were not inflicted by groups of the Air Forces and Naval Forces, which formally existed there, but specially created on their basis reconnaissance and strike combat systems (RSCS). The basis of the RSCS were space systems for various purposes, air and sea carriers of high-precision weapons, as well as reconnaissance UAVs. Unlike Iraq, where in 1991 drones acted separately and were performing separate reconnaissance tasks in the interests of coalition forces, in Yugoslavia UAVs became a full-fledged element of the reconnaissance system which continuously provided «strike forces» with accurate information about objects of enemy defeat in any weather conditions. This is verified by the number of UAVs: while in 1991 only five types of UAVs with a total number of about 30 units were used to carry out reconnaissance missions in Iraq, in Yugoslavia there were 7 types of UAVs in RSCS and a total of them were higher than 40. In 2003 there were about 120 different types of UAVs in Iraq.

Aircraft carriers and numerous carriers of the US and other NATO navies which were operating in the RSCS, performed only role of «ammunition carriers». Air carriers took off from air bases in the United States, NATO countries in Europe, from aircraft carriers in the Adriatic Sea, delivered to launch sites beyond the reach of Yugoslavia’s air defense system according to the coordinates determined by reconnaissance systems, including UAVs, precision cruise missiles for specific objects. These missiles were launched from an altitude of 8-9 thousand meters and the aircraft carriers again followed the new ammunition or returned to US air bases. SBCMs were launched from numerous ships and submarines of the US Naval force, which were based in the Adriatic Sea and were also part of reconnaissance and strike combat systems.

At the same time, the UAVs, as well as other elements of the reconnaissance subsystem of the RSCS, continued to perform day and night tasks of monitoring the results of strikes, pre-reconnaissance and reconnaissance of other objects for the next strikes.

Thus, it can be concluded that since the war in Yugoslavia, the main coordinates of operations began to be transferred to the airspace, which became a modern theater of war where only one side was dominating and capable to perform contactless combat.

Under the influence of military conflicts, the principles of martial arts were filled with new meaning, which led to corresponding changes in the nature of armed struggle. First, the main actions in the wars were the synchronous actions of reconnaissance and strike systems. At the same time, the carriers destruction means, were not in direct contact with the enemy which increased the requirements for accuracy, efficiency and continuity of reconnaissance data. Secondly, groups of ground force, power and means, weaponry of the battlefield began to play a secondary role. Airspace became the main theater of war. Third, the desire of man to distance himself as much as possible from the battlefield has led to the large-scale implementing of robotic equipment and weapons in the army.

UAVs, as better than any other type of weapons and military equipment (WME), in their characteristics and capabilities corresponded to the new format of armed struggle which led to their priority use in this historical period.

If changes in the nature of armed struggle affected the general trend of UAV use, the physical and geographical conditions of military conflict areas has contributed to the emergence of new forms and methods of their use, the development of certain areas in the creation of UAVs.

The analysis of the regions where modern military conflicts took place showed that they (mainly South-West Asia and Central Europe) are mountain-desert or mountain-forested areas which are a kind of mountain landscape and desert areas of different climatic zones, which combine different geological and climatic factors.

Physical and geographical conditions are objective and their impact on hostilities directly or indirectly reflected in the use of UAVs and manifested through the tactical properties of areas, the conditions of orientation and tasks, operation in different climatic conditions. Adverse factors affected the UAV via the negative impact on hostilities, the use of other forces and means, which were impractical or impossible to use in the specific physical and geographical conditions of these regions. The action of these factors created special conditions when UAVs received certain priorities over other means of armed struggle, in particular over manned aircraft. Factors of direct impact should also include those which were reflecting in the planning, organization and use of UAVs as well as the results: landscape, lack of landmarks, weather and climatic conditions, and so on. Most physical and geographical conditions affected the use of UAVs at one time and directly, as well as indirectly.

One of the main factors which impact must be taken into account as the first during the using UAVs, is the landscape. The main distinguishing feature of the landscape of the regions where modern military conflicts have taken place is the mountainous terrain, desert area, hot and dry climate. In addition, in such landscape conditions, the fighting was influenced by road conditions, hydrography, vegetation, sanitary and epidemiological situation and the ecological condition of the region.

Despite the big variety of conditions, the mountain-desert area of the conflict areas had a number of common features, which include: significant intersection of the terrain with a large number of hard-to-reach (for troops) areas; limited number of roads and their poor condition; disconnection of directions available for troops; the presence of stony and rocky soils, which turn into sandstone, loam and salt marshes; hot climate and low average of annual rainfall, etc.

Terrain was the most important element of physical and geographical conditions which had the greatest impact on combat operations and the use of UAVs in particular. Mostly mountain, in combination with complex soils, determined the main content of the tactical properties of the mountain-desert area. In difficult terrain troops were forced to fight in separate, isolated areas, in dismembered battle formations. This significantly increased the amount of intelligence tasks assigned to UAVs as means the most undemanding to the action of mentioned factors of reconnaissance.

Mountain passes, plateaus and intermountain valleys where troops were deployed were key landforms that influenced where the fighting took place. The influence of these landforms significantly limited the ability to use large groups of troops in battle. At the same time, it helped to increase the effectiveness of combat use of small mobile units and individual firearms. The cross-section of the area made it difficult to identify them and created better conditions for action from ambushes. This fully applies to the actions of both opposing parties of the conflict. As a result, there was a need to identify and monitor small mobile forces.

Manned reconnaissance aircraft were not suitable for mentioned tasks as they had limited opportunities to search for small mobile teams. This was related to the high speeds of reconnaissance aircraft and the short time they were in the air which made it very difficult to search for and detect such objects from the air. Mainly, the pilot of a reconnaissance aircraft could detect a small mobile object only via visual observation and given high speeds of modern aircraft and their short time above target, the chance of detecting and determining the exact location of such an object was very low. Mentioned tasks in such conditions could be solved only by mobile small UAVs which had significantly lower speeds than manned reconnaissance aircraft and could be launched from any area (did not require specially equipped airfields), were able to stay for a long time above the search area and transmit real-time intelligence to the ground control point.

These requirements regarding UAV were taken into account later. Thus, if the speed of reconnaissance for operational and tactical reconnaissance aircraft «Tornado ECR» and «Mirage IV» which were involved in air reconnaissance in 1999 in Yugoslavia was 700 km/h, the speed of the UAV Predator and Hunter, used during the Balkan crisis to search for small mobile groups was only about 100 km/h. The speed of the small Skylark UAVs used by Israel in 2006 to search for terrorists was about 60 km/h with possibility to stay in the air for 2 hours, which allowed not only to detect the object of search and transmit video information about it to the ground control point, but also to keep the object under continuous surveillance for a long time. The ability of small UAVs to carry out silent flight which did not attract attention to it, and long-term observation allowed in time to draw up object shock forces to the location of the search and destroy the object. A successful example of the effectiveness of small UAVs occurred on April 17, 2004. Israeli reconnaissance UAVs discovered Hamas leader Abd al-Aziz Rantisi when he and his security got into his car. A few minutes later, a combat helicopter appeared in the path of the car and fired two missiles that destroyed the car and everyone in it.

The need to expand the capabilities of UAVs to independently and quickly solve the problem of destruction the objects, especially in areas with difficult terrain, where there are no airfields for combat aircraft near and almost impossible to work in «on call» with strike forces, has set the task for the designers regarding equipping the

UAV with percussion means. As for the desert terrain of Iraq, experience has shown it to be no less difficult to carry out reconnaissance missions for manned aircraft compare with the mountainous Balkans. Thus, the most problematic task for reconnaissance aircraft in Iraq were availability of Iraqi operational-tactical missiles Scud. If the stationary launchers of the Scud OTM were destroyed due to previously obtained intelligence data during the first day of the operation, finding the location of mobile complexes turned out to be quite problematic. During the first two weeks, up to 30% of the total number of Allied combat sorties was used to solve OTM search tasks. However, all mobile complexes could not be destroyed, even though for almost an hour before launch they were in the open area in a stationary position. Moreover, it was known that Iraqi OTM complexes were based in only two areas in a relatively small area. Only a small number of complexes have been detected at the initial stage of preparation for launching, which made it possible to target attack aircraft. Inconspicuous from the air missile systems which also periodically changed their location, due to the skillful use of the camouflage properties of the desert terrain, still remained a problem for the coalition until the end of the war.

The Iraqis' use of the camouflage features and various structures (tunnels, bridges, overpasses, etc.) in 1991 has repeatedly complicated intelligence data obtain. For example, Iraq has managed to hide the location of AD equipment not only from US reconnaissance satellites, but also from MNF reconnaissance aircraft whose command later admitted that 50% of the strikes on air defense targets were for false targets. Adverse desert conditions in Iraq, which is almost completely devoid of any landmarks, have had a negative impact on the effectiveness of drones. An example of this was the results of the Pointer UAV. Devices designed for low-altitude reconnaissance and surveillance have not been able to achieve the expected results due to the inability to work in the desert. The main reason for this was the lack of landmarks with help of which the operator could determine the location of the UAV from the ground point and manage it. Because of this, in the future, Pointer UAVs were equipped with a Global Navigation Satellite System (GPS) receiver and a night vision device, which allowed them to navigate the difficult terrain of Iraq in the next party and successfully perform reconnaissance and targeting tasks.

In the mountainous areas of the Balkans and Afghanistan, as well as the desert areas of Iraq, road network was poorly developed. Roads in the mountains mostly had a complex profile, passed, as a rule, through narrow valleys, along gorges, on mountain slopes. Their width was 4-6 m, they had many turns with a small radius. In the deserts, the number of roads was generally limited, and they were also unsuitable for the movement of troops and equipment. All this complicated the maneuver of troops during hostilities. The possibility of using such roads sections for launching and landing UAVs was also limited. As a result, UAVs, such as those in Iraq in 1991, were launched from ships and from the border states with Iraq. This feature in the future influenced the trend of creating and using small UAVs, launched by hand and landed on a parachute. The density of geodetic net points was much lower than in Iraq and Afghanistan. The epidemiological situation there was not enough favorable. Water sources had a high bacterial contamination. Boiling water did not give the desired result and, therefore, the water required special treatment. Additionally, these regions were unevenly supplied with water sources suitable for the organization of water supply to army. This minimized, and in some areas made it virtually impossible the use of ground reconnaissance units, forcing them to use mainly aerospace reconnaissance data as sources of intelligence. As the most efficient in reconnaissance support were UAVs of medium and small class, information from them in real time came directly to the user and the role of UAVs in such conditions became decisive.

It was established that the combat capability of the UAV has also significantly affected by the operating temperature. Their capabilities were limited to both low and high environment temperatures. Low temperatures caused the vehicle to freeze, and at high temperatures, such as in Afghanistan, a UAV launched from a shelter at a temperature about + 38 ° C was to be launched within 5–10 minutes. Otherwise, the device could not perform a combat mission because the air temperature inside it reached +66° C, and at this temperature the normal operation of reconnaissance equipment became impossible.

The United States began working on the problem of operations laying in all weather conditions after the 1991 Gulf War but failed to solve it. At least two of the three Predator UAVs were lost due to icing. The same problem followed these UAVs during the operation in the Balkans. As it turned out, during the icing, the so-called Pitot tube was covered with ice, and as a result the readings of the speed of the oncoming flow fell. The autopilot, which was given a false speed reading, lowered the UAV's nose to restore speed. This cycle continued, as a result the drone turned into an increasingly steep peak and crashed into the ground. As a result, the rules for piloting the drone have been changed.

The UAV operator on the ground knew that if he noticed that the speed was falling due to such circumstances, he would have to turn off the autopilot, take control of the flight and turn on the heating element on the Pitot tube. Similar problems were associated with icing of the wings. Some planes had «crying wings» that could scatter anti-icing fluid. Despite this, with such a system Predator UAV could only fly through the icing zones, but not work in them. Therefore, in the Balkans, it was decided to stop using the Predator UAV in winter and resume it only in spring.

Frequent fogs and low clouds over the territory of Yugoslavia, sandstorms in Iraq as the turbulence of the atmosphere, have significantly affected the use of all optoelectronic means of air reconnaissance, not just UAVs. If for manned aircraft these meteorological conditions were often impossible to perform flights, the UAVs, with special reconnaissance equipment on board, which allowed to conduct reconnaissance in such conditions, were able in most cases to perform the tasks. One of the solutions of the clouds impact problem on the application results was the use of UAVs such as Global Hawk which were able to find a target in any cloud.

The specific physical and geographical characteristics of the regions of military conflict have significantly influenced the organization and conduct of other types of reconnaissance. This impact was mainly negative, which significantly increased the demand for data obtained by UAVs. The large number of invisibility zones of mountainous terrain has negatively affected the ability to conduct ground optical reconnaissance. The shielding effect of the mountains on the propagation of the sounds of shots and bursts of shells reduced the possibilities of sound, radio and radio reconnaissance. According to data collected from open sources, the capabilities of these reconnaissance types have been decreased by 20-60%, and errors in determining the coordinates of targets have been increased by 30-40%.

Analysis of maneuverability and features of the location of combat units elements related to these types of reconnaissance in the field showed that the organization of ground reconnaissance in mountainous conditions required considerable time. In addition, the shielding effect of the mountains, many areas, including roads, made it difficult and sometimes completely ruled out radar reconnaissance due to the uneven terrain. The low density of points in the geodetic network the heavily rugged terrain, and significant fluctuations in meteorological conditions depending on altitude and time of day made complicating topographic surveying, shooting preparation, and fire control much more difficult. Terrain features virtually ruled out the possibility of using telephone communications, and the organization of stable radio communications required higher than usual costs.

The military conflicts in Afghanistan and Iraq (2003) were characterized by fighting that took place in the city streets. In these conditions, where each building was a separate shelter, finding small mobile objects, which were the majority in these conflicts was a difficult task for ground reconnaissance and quite difficult for manned aircraft, given the high speeds and low maneuverability of aircraft. A similar situation took place in the Syrian conflict where much of the fighting took place in the city.

Therefore, it can be stated that the physical and geographical conditions were a significant factor influencing the use of UAVs. Difficult terrain, urban conditions, climatic and meteorological conditions of the mountain-desert areas of the conflict areas significantly reduced the possibility of using ground reconnaissance and manned reconnaissance aircraft. At the same time, the impact of these conditions on UAVs was much smaller, which determined the priority of their application. Features of the physical and geographical conditions of theaters of war put forward additional requirements for UAVs: difficult terrain and urban conditions forced to intensify work on the creation of low-speed long-range UAVs and small UAVs with the ability to run manually; difficult climatic and weather conditions, sharp changes in temperature required the improvement of onboard equipment; the need to fly over large areas without landmarks forced the UAV to be equipped with an additional navigation system.

Thus, the peculiarities of military conflicts, characterized by changes in the nature of armed struggle and difficult physical and geographical conditions of hostilities became one of the key factors influencing the use of UAVs.

4.2. Scientific and technological progress

Despite the fact that the history of UAV's development and use began in the early twentieth century, until the end of World War II UAVs did not become widespread. The reason for this, according to experts' opinion, was the current state of science and technology which did not allow to create small, reliable and cheap aircraft, automatic and remote control systems, special equipment for searching, detecting, recognizing targets, transmitting and documenting intelligence information. Only with reaching a certain critical level of progress in technology, the idea of creating and using UAVs has received the necessary additional impulse.

Another reason for the slow development and use of unmanned aerial vehicles were the priorities of manned aviation typical for this period of history. As a result, almost to the second half of the twentieth century manned aviation included all the modern achievements of science and technology at that time and developed quite dynamically in contrast to UAVs. An example of this is the development of Soviet combat aircraft. The latest achievements of science and technology progress in aerodynamics, aircraft engine, electronics, automation and other industries in the 1970-1980s have embodied in the creation of the most modern MiG-29 and Su-27 which remain one of the best in the world in several decades. At the same time, Swift (Tu-141) and Reys (Tu-143) reconnaissance drones, which have been created in the 1960s, have long remained the main unmanned components of the armed USSR forces remains the same in the Armed Forces of Ukraine.

However, historically the very presence of manned aircraft has constantly stimulated the desire of man to create their unmanned counterparts. One of the first examples of the implementation of scientific and technological progress, which laid the foundation for the further development and use of UAVs, was the emergence of automatically guided projectiles and missiles. The most famous of these were the V-1 projectile and the V-2 ballistic missile which struck the British Isles during World War II. As a result, developments in the field of unmanned aerial vehicles have significantly intensified with the advent of the jet engine.

The use of modern jet engines in the early 80's of the last century has allowed to increase the range and speed of unmanned aerial vehicles, as well as to obtain UAVs with flight-technical capabilities of combat aircraft. At the same time, the manned aircraft had fourth-generation aircraft equipped with modern control systems and other equipment, the main part of them could be effectively used in UAVs. The reason for this was the vision, which is very firmly entrenched in the minds of the military that unmanned systems can only be additional systems. The above example of UAV «Swift» and «Reys» confirms this. Therefore, the basis of aviation of the 80s of the twentieth century were manned aircraft which rapid development and dissemination of opportunities provided scientific and technological progress.

However, as has already been established, such a simplistic understanding of evolutionary processes has led to skewed approaches to the growing problems in manned aviation and underestimated the impact of artificial intelligence technical systems on the strategy and tactics of modern warfare. These problems were especially acute in extreme conditions, when a person performed a management function at the limit of their physiological capabilities. The result has been a slowdown in the growth of manned aviation performance, despite increased efforts to improve it technically. As a result, by the end of the twentieth century the development of scientific and technological progress has not led to a significant increase in the efficiency of manned aircraft and reduce their accident rate.

The way out of this situation was the transition to the use of systems where the negative impact of the human factor would be minimized. In aviation all the achievements of scientific and technological progress which have already been implemented in manned aircraft, as well as those that reappeared, began to be transferred to UAVs. This began to ensure the gradual development of unmanned aerial vehicles in general, which contributed to its more active use.

The most important UAV subsystems which reflected the achievements of STP which, in the end, led to the evolution of unmanned aerial vehicles, are divided into several groups: on-board electronic equipment, automatic and remote control systems; onboard reconnaissance equipment and data transmission lines; glider, as well as power plant.

It is clear that the main task in removing a person from the contour of the «man-plane» was to create appropriate equipment for flight control without a pilot on board, that became possible only after a number of discoveries, primarily the creation of a new element base.

Thus, semiconductor active elements (diodes, transistors, etc.) began to be used in on-board electronic equipment which have replaced electronic-vacuum devices (electronic lamps). This discovery of science has significantly improved the situation in terms of energy, size, strength, and cost characteristics of the equipment installed on the UAV. Electronic-vacuum devices had several features that limited their use in electronic equipment and in on-board electronic equipment of unmanned aerial vehicles. These are such features as insufficient resistance to mechanical loads; low resistance to vibration; high energy consumption; a large amount of heat released during operation; significant dimensions due to which there were corresponding difficulties in the use of equipment based on UAVs; low reliability of systems built on their basis due to the large number of elements and connections; high cost of electronic lamps both due to the complexity of their production and due to the use in structural elements of a relatively large number of precious metals.

An example of how difficult it was in the 1950s to create electronic equipment based on this elemental base was the US Air Force B-58 medium bomber. If we express the value of this aircraft in correlation to gold, the mass of these gold bars would be equal to the mass of the bomber. In addition, the excessive weight of electronic equipment limited the combat payload of aircraft.

The creation of the world's first integrated circuit and differential amplifier in the early 1960s during research on the moon's flight program has opened a new stage in the development of electronic equipment element base. The rapid progress of microelectronics has allowed in a historically short time to create reliable, economic and small-sized electronic and, most importantly, electronic computing systems that allowed to solve the problems of automatic flight control, search, detection, recognition of targets, guidance at any time and weather conditions. The American discovery contributed to the fact that the United States became one of the pioneers in the field of unmanned aerial vehicles. Initially, American designers have created relatively primitive UAVs Firebee Model 124I, and then more advanced UAVs MQM-74A which formed the basis not only of American but also Israeli drones in the future.

The new element base has opened new opportunities for the development of radar, remote control, optoelectronic and television equipment. Based on information sensors of different physical nature and computers with a large amount of memory and high performance, automatic control systems and navigation systems have been created that allowed to work in new modes based on complex mathematical algorithms. It has become possible to implement the mode of digital synthesis of antenna aperture in radar systems. This allowed to obtain such a radar image that its resolution was almost inferior to the photographic image. It became possible to detect, identify and automatically track targets over long distances with high accuracy and noise immunity in all conditions, regardless of time of day, season, weather conditions, as well as in the presence of natural and artificial obstacles.

Detecting the use of antennas with phased array antennas has significantly expanded the capabilities of radar systems. They allowed the synchronous detection and tracking of several objects and characterized by high energy performance, speed of inspection and stability of automatic tracking (due to the use of electronic scanning instead of mechanical ones the same as in mirror antennas). The development and application of multi-position radar methods has improved the accuracy of detecting the coordinates of objects. The use of RS (radar station) with a synthesized aperture on the UAV has allowed to expand the search area, increase the range of target detection, and ensure the implementation of combat missions at any time of day and in any weather conditions.

A significant push in the development of onboard radars was obtained in the creation of integrated chips based on gallium arsenide (AeGa) operating in the ultra-high frequency range. The main advantages of RS on such chips were a large frequency band, improved pseudo-random adjustment of the operating frequency, versatility, inertial tracking for several purposes, high reliability.

The development of laser and television technology has contributed to the emergence of new air reconnaissance systems, which has created real opportunities for the detection of small and masked objects (targets). Combining information sensors of different physical nature and computers into a single complex has significantly increased the effectiveness of reconnaissance. For example, in the USSR this principle was implemented in the UAVs «Reys» and «Swift».

An important factor that significantly expanded the combat capabilities of UAVs was the development of space. The creation of global space reconnaissance, communications and navigation systems has made it possible to carry out automatic flights, identify targets, pinpoint their coordinates, and transmit information quickly to ground or air control points.

Achievements in the study of aerodynamics of flight at subsonic and supersonic speeds allowed UAVs to fly at low altitudes, and the growth of computer capabilities made real complex flight path, anti-aircraft maneuvers with high overload values which made it difficult their interception by air defense systems and increased the secrecy of combat use.

The most successful period of implementation of STP achievements in the development of unmanned aerial vehicles was the 1970-1980s, when the Soviet Union has created a multifunctional automatic control system for the first unmanned orbital spacecraft «Buran» which successfully flew on November 15, 1988. The most incredible achievement which allowed to perform a complex space flight in automatic mode for the first time would be shift the stagnation in the field of UAVs, but this did not happen. At least in the two superpower countries as the United States and the Soviet Union, which were engulfed in an arms race, primarily nuclear, and a space conquest competition, there was little room left for UAVs at the time.

As a result of the lack of fundamentally new developments in UAV during this period, the center of effective influence of scientific and technological progress on the development of unmanned aerial vehicles moved from America and Europe to the Middle East where almost continuous regional armed conflicts intensified Israeli science and military industry. Initially, this led to the need to develop and use its own air targets and unmanned reconnaissance aircraft, and later to enter the world market with their developments and start international cooperation, first with the United States. In 1991 during the Gulf War, the Israeli American Pioneer unmanned system has formed the basis of a UAV group coalition.

Since that time a new period of NTP influence on UAVs has begun, due to a rethinking of their place and role in the overall system of combat use. This period matched with new advances in science and technology, which together with the gradual change of priorities in aviation, contributed to the beginning of rapid development and intensive use of unmanned aerial vehicles.

Between 1990 and 2000 the US and European aerospace industries had a sharp leap in development, a qualitative technological revolution related to the transition from metal to composite materials. This leap can be compared to the transition from wooden to metal aircraft construction.

Due to the combination of several components, materials were obtained with properties that were not inherent in these components one by one. Polymer composite materials which in comparison with traditional structural materials have unique physical, chemical, and mechanical properties, as well as the ability to change them in accordance with the purpose of the structure, began to displace steel and aluminum from aircraft. The use of composite materials has allowed to reduce the weight of aircraft structures and significantly increased their strength. In addition, aircraft construction from the gradual increase in the percentage of composites in glider design and, consequently, the gradual accumulation of experience in the application of new technologies in the field of composite structures, gradually began to move to the creation of fully composite aircraft.

The use of composite materials in the UAV has allowed not only to significantly reduce its weight but also to develop, in particular for the Predator UAV, a variable pitch propeller which improved the performance of the engine when working at all heights. Prior to the use of composite materials, the optimal speed and pitch of the propeller were determined for each altitude which increased fuel consumption and reduced flight duration when the altitude changed rapidly. After using a variable-pitch propeller made of composite materials, the flight duration has been increased to 70 hours.

In addition, the use of composite materials in the design of UAVs, due to their absorption properties of electromagnetic waves, has reduced the visibility of UAVs in the radar range.

In the early 1990s, as a result of the composite materials emergence and the development of nanotechnology, intensive development of small drones began. As the result, this was made possible by the creation of a new generation of small reconnaissance equipment. In the United States and Israel, small -

scale on-board reconnaissance equipment (optoelectronic and infrared cameras, laser devices) has been developed where high tactical and technical characteristics have been combined with small volume, weight, and power consumption. Creation of small reconnaissance complexes became possible based on the latest technical and technological achievements at that time which include photodetectors of radiation on new materials; focal-plane IR gratings of increased size with high resolution; alternative ways of reading information; new layout methods; improved gimbals and drives; much more efficient ways of signal processing, etc.

Modern thermal imaging cameras with standard linear detector gratings measuring 480x4 elements based on cadmium telluride and mercury, which operated in the mid-wave part of the spectrum, began to be used as reconnaissance vehicles. Over time it was managed to increase the size of the scanning lattice to 640x512 pixels and increase the number of receiving elements, which increased the capabilities of thermal imagers. No less important characteristic of cadmium-mercury-tellurium detectors is a significant reduction in the mass of the cooling device of the thermal imager. Reducing the weight of the cooling device allowed to reduce the weight of the thermal imager, as well as increase by 40% the life of its batteries which is very important for the onboard equipment of the UAV.

The next step in the development of thermal imagers was the development of long-focus uncooled detectors on the quantum well QWIP (Quantum-Well Infrared Photodetector) operating in the range of 8.0-9.2 microns. Such systems operated without special cooling devices which made it possible to further reduce their weight and size characteristics. For UAVs this innovation has increased the range and duration of the flight by reducing the weight, as well as reduced the size of thermal imagers.

The ability to increase the number of image elements in the frame has allowed enlarge images to explore objects and places many times more. After the fighting in the Persian Gulf in 1991, the US Air Force have received a new camera that could form a frame of 4 million (2048x2048) pixels. A camera with 25 million (5040x5040) pixels in the frame has appeared in 1996. Modern cameras such as the KS-146A already provide 12,000 pixels x 32 lines.

For a long time, the main way of documenting intelligence remained the usual photographic or «wet» film which took time to be removed from the camera, develop, capture and dry before it could be used for thematic analysis. The creation and use of video imaging in on-board reconnaissance equipment has allowed us to refuse a photographic film in general and to make remote data processing.

Gradual rejection of aerial cameras which required the development of photographic film, began at the end of the 1991 Gulf War with the advent of digital video cameras. During the war, the U.S. military and its allies processed about 40 million reconnaissance photographs. The process of obtaining information from these images, which would be suitable for use in the planning of combat operations, took about a day. During this time highly mobile military facilities, such as mechanized troops, had already advanced far, and the fighting situation was changing. Therefore, information from aerial reconnaissance was often useless.

The installation of digital video cameras on UAVs has provided significant advantages compared with aerial cameras. Digital video processing made it easy to improve the quality of images, to compress and transmit them directly from the drone to users on the ground in real time. Video cameras on charged devices provided sensitivity in a two times wider way of electromagnetic radiation spectrum than aerial cameras, and provided more information about the situation in the surveillance zones. Mentioned video cameras were able to operate in smoke and fog conditions, and IR cameras made it possible to do aerial reconnaissance at night. The addition of radar stations with a synthesized antenna aperture has made it possible to obtain images that do not differ from photographs, even during the viewed through the clouds. However, as the fighting in Kosovo in 1999 showed, weather phenomena continued to have a significant impact on reconnaissance and its results.

The main circumstances of the most complete use of new intelligence equipment were the availability of appropriate data transmission lines in real time. The equipment of these lines was created due to successes in the development of broadband radio lines, data and image compression techniques, ground stations for processing and storage of intelligence and methods of information security. At the same time together with the increase of on-board processors performance with help of which video information was processed on board of the reconnaissance UAV and only the results were transmitted to the ground station, difficulties began to arise due to the capacity of radio transmission lines which are used for this. Thus, as of 2004 the Global Hawk UAV radio line with a data transfer rate of 274 Mbit/s was considered as the best. In the future it was planned to increase this speed to 548 Mbit/s.

An analysis of the possibilities for thematic decryption of ground facilities showed an absence of one-dimensional imaging for guaranteed identification. As a result, two-dimensional images have been used to increase the ability to detect and recognize objects. The main goal was to get more complete information about the signatures of objects, not just to improve the discernible ability. However, obtaining only a two-dimensional image of the observed object was often insufficient to detect it until it was supplemented by vibrational and polarization characteristics. To provide 3D real-time images of objects, in addition to normal RS, laser locators with range selection (LADAR and LIDAR) began to be obtained, while providing 3D images of probable targets in real time. The use of laser locators has provided significant advantages over other means of air reconnaissance: the possibility of using in the conditions of the enemy's use of means that make it difficult to observe; more effective target identification due to high resolution; more accurate assessment of the degree of damage to targets.

Thus, UAVs began to be actively used at a certain stage of science and technology development and have combined the latest advances in various fields of science and the latest technologies. The development of jet engines, the creation of remote and automatic control systems introduced the concept of the prospects for the use of aircraft without a pilot on board. The emergence of a new element base, the development of opto-electronic and electronic-computer technology have ensured the creation of small, strong, and reliable, economical, and energy-intensive systems that formed the basis of UAVs. The development of new reconnaissance equipment, the invention of digital information recording, the creation of radio lines for real-time data transmission, the invention of data and image compression methods, information security have increased UAV capabilities and ensured their further development and priority in comparison with manned aircraft.

4.3. Military and economic factors

The impact of military-economic factors on the use of UAVs should be considered in three main areas. Firstly, the process of development of combat aviation was accompanied by an increase in the cost of manned aircraft, secondly, costs for combat training of flight personnel constantly increased, and thirdly, the cost of operating combat aircraft in peacetime and wartime significantly increased as well.

The degree of technical excellence and qualitative differences of the aircraft is defined by the concept of «generation». It is known that the average cost of an aircraft is steadily increasing from one generation to another.

For example, the cost of one American A-4 aircraft in 1997 was

6 million USD. The cost of MiG-29 and F-16 (fourth generation) aircraft is in the range of 22-28 million USD, Su-30MKI, F-15, F-18 aircraft - from 25 to 37 million USD. The fifth-generation Su-37 aircraft cost more than 60 million U.S. dollar. As of 2007, NATO's cheapest fighter jet the Rafale C cost $ 62 million, American F-117 110 million USD, and the most expensive aircraft was the F-22A Raptor with cost 177 million USD.

The nature of the dependence allows us to estimate the average probable cost of the sixth generation aircraft as more than 150 million USD. One of the main reasons for the rising of the aircraft cost is the complexity of the requirements for it, the technology of creating and expanding combat capabilities. However, considering that the evolution of the human body is incomparably slower than the evolution of aviation technology, it can be argued that the gap between the physiological limit of man and the technical capabilities of technology, which emerged in the late 1970s, has steadily progressed. The desire to bring the technical performance of aircraft to the theoretical limit of capabilities, despite the limited capabilities of the pilot as the main element of the aircraft control system, only intensified the dynamics of growth for material costs per unit of technical improvement. Complicating the design, use of expensive materials and expanding the functions of combat aircraft has led to a progressive increase in the cost of aircraft. At the same time, despite the «rapid» growth in the cost of combat aircraft, most countries continued to improve combat aircraft. The growth of relevant costs is believed to have been based on two main components: the technical level of aviation technology and the degree of its compliance with the tasks to be solved; levels of preparation of flight and engineering staff to perform their functions.

Both components are closely linked and it is in the interest of any country to be at the highest level. At the same time, the cost of the aircraft significantly affects the cost of one hour of flight, which considering the generations of combat aircraft, has grown very rapidly. For the fourth-generation aircraft this figure is about 20-25 thousand U.S. dollars.

The full cost of 1 hour flight includes direct costs (costs for consumables, fuel, electricity, cash, etc.) and part of the cost of the aircraft equivalent to the cost of the assigned resource in the flight lasting 1 hour. Part of the cost of the aircraft, which reflects the cost of the resource is transferred to the pilot (that is decrease in the «value» of the aircraft). The pilot, spending the resource of equipment, increases his level of flight skills. Therefore, the part of the aviation resource that is not spent on flight training (for example, the aircraft did not fly but was in storage) should be considered as a direct economic loss.

In addition, the cost of the aircraft directly affects the cost of training the pilot. To prepare a pilot for a certain level of skill, which is determined by the level of qualification, an annual flight during several years is required at least 100-120 hours on the plane and about 200 hours on exercise equipment. The sum of all costs (fuel, aircraft life and equipment, ammunition, simulators, etc.) to prepare the pilot for the appropriate level of qualification gives an interesting result: the cost of training a first class pilot on fourth generation aircraft roughly corresponds to the cost of the aircraft which is used by this pilot. If for aircraft up to the fourth generation the cost of the aircraft exceeded the cost of training for the first-class pilot, then the technology of future generations is changing: training a pilot and maintaining his skills will require increasing costs.

Research of the combat aircraft effectiveness in modern full-scale warfare has shown that fighting with an equal enemy is a very expensive even for superpowers. Short-term military conflicts, for example in the Yugoslav scenario (without military resistance of the country where hostilities are taking place against this country), are also proving to be costly even for an economically viable country.

The most advanced combat aircraft complexes such as F-18, F-117 have approximately the same level of vulnerability to ground air defense systems and the same level of probability of combat missions at disproportionately higher cost (progress in air defense systems can not be ignored). The cost of air combat is a clear example of the rising cost of war. Convincing evidence of this is the growing cost as the cost of air combat. This indicator considers lost aircraft, lost pilots (costs of their training and preparation for losses), necessary military repairs, spent ammunition and fuel per aircraft).

One of the tendencies to increase the efficiency of close air combat was the creation of over maneuverable aircraft.

At the same time, the results of the assessment of the effectiveness of close air combat for over maneuverable aircraft and using missile weapons show that increasing the angle of attack of the attacking aircraft inevitably increases the probability of missile miss and makes air combat even more unpredictable for both sides.

According to experts, the only way out of this situation is to provide additional funding for the development of more expensive and complicated missile weapons for promising aircraft to bring the characteristics of airborne weapons and aircraft in line.

Comparing the obtained data with the economic capabilities of any state and, given that not only aviation is at war, we can draw conclusions about the prospects for the development of aviation. Even though the intellectual reserve and technological level of many countries allows to create great aircraft of new generations, not every country is able to stand the economic burden of full operation of this equipment with all its inherent costs (there are other types of troops and problems). It is impossible to solve the problem of improving the efficiency of combat aircraft while reducing the cost of its maintenance. Even such a superpower as the United States is forced to cut funding for some of the most valuable promising projects in the military sphere from year to year.

Therefore, economic considerations began to become decisive in choosing the concept of development and use of combat aircraft. The circumstances that led to this conclusion include the following: continuous increase in the cost of new aircraft; the increase in the cost of aircraft entails an increase in the cost of maintaining equipment and combat training of flight and engineering personnel; the most costly, unreliable, vulnerable and at the same time the main link in the man-machine system «combat aviation complex» is the man, or the pilot; technical capabilities of aircraft, starting with the third generation aircraft, began to significantly exceed the physiological level of the human body.

The above allows us to identify several possible ways to increase the economic efficiency of combat aircraft. One of them is the creation of inexpensive multi-purpose aircraft with a high survival rate and high combat effectiveness. For example, with the lower cost of a combat aircraft it's easier to restore it, repair and maintain, the cheaper the onboard equipment and weapons, the lower the requirements for the qualification of service personnel. At the same time, there is a clear contradiction of this way to increase economic efficiency, as a high level of survival and combat effectiveness can not be achieved by reducing the cost of individual elements and the aircraft as a whole.

Another more effective way to increase the economic efficiency of aviation is the gradual rejection of manned aviation and the transition to the use of unmanned aerial vehicles.

UAVs have proven their economic effectiveness in modern military conflicts. Thus, during the period of hostilities in Yugoslavia from April to the end of June 1999, the total losses of UAVs amounted to 47 aircraft. At the same time, the UAVs almost completely covered the needs of the coalition's ground forces in operational intelligence. The total economic damage suffered from the loss of these aircraft was less than bad from combat manned aircraft loss (for comparison, the cost of the Predator UAV about 7 million USD, F-16 -28 million USD).

There are already examples when the economic factor under the influence of STP allowed the UAV to solve previously unavailable technical problems. For example, the creation of high-altitude manned reconnaissance aircraft with a combat radius of more than 25 thousand km and a flight duration of more than two days, even today is an extremely expensive task. Although continuous monitoring of a potential enemy's territory is an important task. At the same time, UAVs allow not only to achieve the desired result, but also to combine the solution of several tasks in one flight. For example, to solve the problem of strategic reconnaissance and at the same time perform the functions of a high-altitude interceptor of ballistic missiles that are launched. Such plans exist for the US Global Hawk UAV.

It should be noted that another area is environmental feasibility, which according to experts, has begun to significantly affect the use of UAVs and the gradual displacement of manned aircraft. However, this direction is not decisive for the impact on the development of UAVs, so it should be related to the military-economic factor.

It is also established, that the issue of environmental feasibility of using UAVs instead of manned aircraft began to receive an appropriate attention only in economically developed countries, first of all in those whose combat aircraft took a major part in military conflicts. Considering that the direct use of aviation took place in territories far beyond these states, the issues of training, operator preparation, obtaining the necessary management and operation skills took place within national borders, which affected the environmental feasibility of the maximum possible replacement of manned aircraft with unmanned. Thus, in order to maintain the level of training of the flight crew, in contrast to UAV pilots, a certain flight is constantly required as 120-200 flight hours per year. Aircraft power plants run on hydrocarbon fuel (kerosene), and oxygen from the air is used to burn it. The power plant, for example, only one MiG-29 aircraft burns as much oxygen per hour as it needs to consume about 300,000 people in one hour. At the same time, carbon monoxide CO, nitrogen oxides NO, unburned hydrocarbons, which are regulated today by the International Civil Aviation Organization - ICAO - for civil aircraft, are emitted into the atmosphere.

The aviation noise of aircraft, which is restricted, is also normalized, and the forced release of fuel after stopping the engine is forbidden. In the interests of enforcement of these requirements commercial aviation where a number of appropriate measures have been implemented was the first to react. At the same time, no activities are carried out on military aircraft, and in most cases, they could not be carried out, except for the design of new aircraft with new engines. At the same time, the world fleet of combat aircraft exceeds the world fleet of commercial aircraft and the total annual flight of all military aircraft is probably not lower than that of all civil aviation. Therefore, the cost of one flight of a military aircraft should include the cost of compensating for damage to the environment and the population, including spilled kerosene and unfavorable acoustic background in military aircraft bases. All this will amount to quite significant amounts, which will ultimately affect the economies of states.

Thus, along with the search for new raw materials to create cleaner and more energy-intensive fuels, at a certain stage (late 1990s - early XXI century) there was an objective need to find new cleaner aircraft. One of these means was UAVs, the noise and emission of which is much less than in manned aircraft, due to lower power of UAV engines, smaller size, speed and other indicators.

In conclusion, the ‘cost-effectiveness’ indicator has been increasingly used to evaluate WME. Given that an airspace became the main theater of operations, WME development programs in most countries around the world have begun to focus on aerospace. However, this was accompanied by a significant increase in the cost of WME and, first of all, of manned aircraft. The cost of combat training of pilots has increased significantly, the cost of operating combat aircraft has increased too. All this stimulated the use of unmanned aerial vehicles, gradually transferring the functions and capabilities of drones to manned aircraft. The benefits in favor of drones have also been confirmed by the environmental problem.

Thus, the most effective way to solve the problem of economic efficiency of aviation was to gradually denial manned aircraft and the transition to the use of drones.

5

APPLICATION OF UNMANNED AVIATION IN MILITARY CONFLICTS

5.1. Operational and tactical reconnaissance

A turning point in the history of UAVs, marked by the first regular combat use of reconnaissance drones, according to experts, can be considered 1964 when the United States began full-scale intervention in the war in Vietnam. Based on analysis of the experience of UAVs, the beginning of the 1970s in 20th century was more interesting. This period is considered the main for the further development and use of UAVs.

The preconditions for this were laid by Israel when in 1970 Tel Aviv secretly purchased 12 of ‘Firebee’ Model 124I UAVs (Israeli name ‘Mabat’) from the United States, which became the basis for creation of the first drone squadron. It was a primitive in today’s view but modern for that time UAV, which could develop a speed of up to 900 km / h. Despite the developers' stated purpose of reconnaissance and air targets, the 'Mabat' UAVs were primarily air targets. Proof of this is the high speed, which allowed simulate better the flight of a combat aircraft. Nevertheless, the Israelis used the UAV as a reconnaissance aircraft due to aerial photography equipment installed on board. The first combat flight of the 'Mabat' UAV for reconnaissance took place in Israel on August 13th, 1971, and regular reconnaissance flights began in September of that year. Thus, it can be stated that the Firebee Model 124I UAVs became the second unmanned aerial vehicles after the AQM-34L 'Firebee' which took part in military conflicts.

The urgency of the mass use of such vehicles came to Israel after the Yom Kippur War of 1973, when Israeli UAVs were first tested in combat. As it turned out, then there was a significant increase in demand for aerial photography of ground objects, but the Israeli Air Force could not fully to satisfy it. Often the photo targets were covered by a powerful air defense system and, as a result, the Israeli air force suffered heavy losses. Reconnaissance with the help of simple aircraft has become problematic and risky. At the same time, most drones were used by Israel as bait to detect enemy anti-aircraft missile systems (AAMS).

The initial phase of the creation of own reconnaissance drones in Israel is associated with the names of two Israeli aeronautical engineers Yehuda Mazi and Elvin Ellis. As a result of the Yom Kippur War, they suggested that a small UAV equipped with a television camera could best meet the requirements for carrying out certain reconnaissance missions in the context of active AD operations. A prototype of such a device, called the Mastiff, has been created in the garage of one of the enthusiasts. In 1978, another drone Scout was developed in Israel.

For the first time and with success, the Israeli army used Mastiff and Scout reconnaissance UAVs in 1982 during ‘Operation Peace of Galilee’, which began on June 6, 1982 and lasted until August 13, 1982. In this operation the Israeli army was opposed not only by Palestinian terrorist groups, but also by regular Syrian troops.

The group opposing the Tzahal (Israel Defense Forces) consisted of four AD brigades, equipped with AAMS ‘Kub’, S-75M ‘Volga’ and S-125M ‘Pechora’, a total of 24 anti-aircraft missile divisions deployed in close combat formation for 30 km on the front and 28 km in depth. The main purpose of these forces was to cover the Syrian troops in the Lebanese Beqaa Valley, where at least 600 tanks were concentrated.

The operation to destroy the enemy’s AD began at 4 o’clock on the morning of June 9, 1982. 4 hours before the first strike, the Israeli Air Force stepped up all types of reconnaissance (radio, radar, television) by tactical aircraft, LRRD, RTR and UAV AQM-34, Mastiff and Scout. The UAVs were used for reconnaissance and surveillance. To accomplish this task, the UAV reconnaissance was equipped with a television camera and a communication system capable to transmit a continuous stream of images to the dispatcher on the ground. Other modifications of the UAV were equipped with reflectors of radio frequency radiation, which reflected the radiation of the RS of such intensity like strike aircraft that gave wrong impression. Unmanned aerial vehicles also intercepted and analyzed enemy radar radiation and retransmitted them to ground stations or aircraft in the air for the use of anti-radar missiles.

A thorough analysis of the literature proves that the AAMS suppression operation began with a series of UAV reconnaissance flights equipped with television cameras. As soon as one of them found the AAMS battery and transmitted its image to the ground command, two more UAVs took to the air, one as a false target simulating an attacking aircraft to force the AAMS battery to turn on the radiation, the other equipped with equipment to intercept AAMS radar radiation and its transfer to the command post. The received information about radiation parameters was processed and data were issued in real time for guidance of anti-radar missiles. Such an unusual common use of UAVs for various purposes allowed the Israelis to destroy almost all AAMS batteries in the area without losses. Thus, since 1982 reconnaissance UAVs have been widely used in the Israeli armed forces. The main tasks to be solved with their help were the following: identification of targets; assessment of damage caused to the enemy by air strikes; conducting joint operations with manned aircraft and ground units. In addition, UAVs were used to track terrorist subdivisions and jet artillery fighting vehicles in border areas. There was primitive, but relevant at the time tasks that led to the beginning of the first stage of UAV development.

UAVs were equipped with special equipment to perform reconnaissance tasks. In particular, the first Israeli Mastiff UAV in 1982 had a video camera and transmitted information in real time. However, the range of information and its quality have not yet fully satisfied the military, especially when it comes to transmitting high-quality images of reconnaissance objects over a distance more than 80 km.

Scout UAVs were better suited for reconnaissance missions. In addition to a television camera with real-time data transmission equipment, the Scout UAV was additionally equipped with a panoramic camera and an IR sensor, which significantly increased reconnaissance capabilities it allowed reconnaissance of masked objects in the dark.

During reconnaissance missions it was very difficult to solve the problem of providing round-the-clock surveillance of the battlefield and enemy targets. This required many UAVs that would be used sequentially, and appropriate reconnaissance equipment that could conduct reconnaissance at any time of day and transmit information to ground points in real time. By this reason after the military operation in 1982 the UAV began to improve. The duration and altitude of the flight have been increased, payload capabilities were expanded, and ground control stations were improved too. Some shortcomings in the use of UAVs identified during military conflicts have contributed to the further improvement of UAVs.

As a result, by the end of the 80s of the 20th century UAV ground control stations were equipped with new modern computers. The on-board electronic equipment included sensors that provided round-the-clock reconnaissance. The duration of the UAV flight was gradually increased to 24-36 hours. Thus, during the conflict in Lebanon in 1982 the maximum duration of the UAV was 4.5-6 hours, then in the late 1990s in the Searcher II UAV it was already

10-12 hours. The Hermes-450 UAV was able to be in the air for up to 20 hours, the experimental twin-engine Hermes-1500 for more than 24 hours, and the Heron / Eagle UAV whose fuel tanks are in the wing, for more than 50 hours.

The next favorable period for the use and development of UAVs began in the mid-1980s and was associated with the progress made in establishing communication and control systems. The initiators of the new wave in the use of UAVs were the US Naval Forces which identified the urgent need for UAVs to perform air reconnaissance tasks and assess the results of raids by assault teams of aircraft carriers. They required ship-based UAV able to fly to a given area at up to 200 km from the ship and a two-hour patrol there, followed by a return to the ship. As a result, in 1985, in the interests of the US Navy, Israeli designers developed the ship based RQ-2A Pioneer UAV. The prototype of the Pioneer UAV was the already well-known Israeli UAV Scout. While maintaining payload weight, flight duration and maximum altitude, Pioneer UAVs have increased their cruising speed to 170 km / h (in the UAV Scout it was 100 km / h), which allowed to increase application radius to 185 km.

In the same year Pioneer UAVs passed the first test in real combat conditions during the war in Lebanon. Existing open sources do not provide with detailed information on the results of UAVs in Lebanon, but experts believe that the success of the Pioneer UAV is evidenced by the fact that the United States has purchased more than 200 such devices in the future.

Since December 1986 Pioneer UAVs began to enter service with

US Navy ships. From the beginning they were armed with the Iowa battleship, then all battleships of this type and helicopter landing craft-docks of the Austin type. In 1987 the UAV was already adopted by the US Marine Corps and was included in the means of providing marine units on universal amphibious ships such as Tarawa.

The first regular combat using of the Pioneer UAV happened during the fighting in Iraq in 1991. The process of preparation and conduct of hostilities in Iraq had several stages, but the value in studying the experience of UAVs were presented in the following operations: ‘Operation Desert Shield’ (02.08.1990-16.01.1991), air offensive ‘Operation Desert Storm’ (17.01- 23.02.1991) and air-ground offensive ‘Operation Sword in the Desert’ (24.02 - 28.02.1991).

One of the features of ‘Operation Desert Shield’ was the activization of the multinational force’s efforts to establish an extensive network of reconnaissance support for the operation (space, aviation, ship, radio and radio engineering, agency and military reconnaissance). Reconnaissance data were used to study the troops of the MNF theater of operations, its features, purposeful preparation of personnel for possible offensive and defensive actions; preparation of weapons systems and equipment for combat use for specific purposes; systematic and comprehensive preparation of the first strike. The main attention was to air reconnaissance which focused on monitoring the operational deployment of Iraqi forces, collecting and processing data about military targets, and ensuring control of the naval blockade in the

Persian Gulf. According to an analysis of data collected from open sources, the air reconnaissance forces and means, in addition to manned reconnaissance aircraft, included six units of Pioneer UAVs, which provided reconnaissance and data transmission to the relevant control points.

With the beginning of the air-offensive ‘Operation Desert Storm’ UAV reconnaissance tasks were aimed at assessing the results of missile and bomb strikes, detection of new objects of damage, first of all mobile OTM ‘Scud’, tracking the movement of Iraqi troops and aircraft, airspace control, primarily to detect Iraqi missile launches.

Experts estimate that three from six Pioneer UAVs in Iraq acted in the interests of the Marines, one in the 7th Army Corps and two in American battleships. Each of them was armed with five UAVs. Among the reconnaissance missions, carried out by the Navy, there were the search for waterside launch complexes of Iraqi Silkworm anti-ship missiles. The Special Forces Airborne Units (SEAL) of naval forces were interested in solving this problem. UAV operators observed a color image of the territories and objects where aircraft flew over on the displays of the ground control station and the remote video reception. As a result, the command promptly resolved the issue of destruction of the found targets. A significant step forward was that the image was stored in the memory of an electronic computer (EC), which allowed for further detailed analysis. In the ground forces, Pioneer UAVs were tasked with reconnaissance the flight routes of Apache AN-64 attack helicopters.

The operations involved 30 Pioneer UAVs which made more than 500 combat departures, performing not only reconnaissance tasks but also providing with targeting, estimating enemy losses and adjusting the fire of battleship artillery systems. The flights were performed both during the day and at night, as a result the total flight time took more than 1000 hours. Despite heavy losses (12 destroyed and 11 damaged devices), the US NF praised the actions of the Pioneer UAV, as the result of special UAV units have been introduced in each Marine division.

The special value of the Pioneer UAV was that the UAV video image of the detected targets and areas was transmitted directly to the Marines in real time. This made it possible to respond quickly to changes. However, the US Navy Command still planned to replace the Pioneer UAV with new ones, as it considered them outdated. First of all, this type of UAV did not satisfy the fleet with a take-off and landing system that did not allow their use from unprepared areas and significantly limited the ability to use UAVs from ships. NF needed more mobile devices, preferably vertical takeoff and landing.

During the ‘Operation Desert Storm’ they used long-range multi-role US reconnaissance Shadow-600 UAV. At the fighting time in Ira, the Shadow-600 UAV had the best indicators of the reconnaissance duration that are up to 14 hours. By this parameter it was second after the strategic reconnaissance UAV Gnat-750 which was able to conduct air reconnaissance for 40 hours. At the same time, the capabilities of the Shadow-600 UAV in terms of maximum reconnaissance radius (that is up to 200 km) did not fully meet the military needs in data about targets in operational and tactical depth. Most of the searched objects were located about 400 km from MNF UAVs location which made their reconnaissance with the help of existing types of UAVs impossible.

Such an important feature as the height of reconnaissance (up to 5000 m), from which the device could control a much larger area didn’t help UAV Shadow-600. Experience with Iraq has shown that high-altitude reconnaissance flights have rarely been successful. The reason for this was difficult climatic and weather conditions as frequent sandstorms, which nullified the efforts of air reconnaissance with the use of opto-electronic means. During the war in Iraq the Shadow-600 UAV had not been officially adopted. As per the results of its combat use, which were mostly considered successful, the US military leadership has decided to purchase this type of UAV for the national army. One of the factors that negatively affected the use of UAVs in Iraq was the limited number of areas suitable for launching and landing for UAVs. The main method of landing for UAVs used at that time in the Middle East was landing on a wheeled chassis. This method required a fairly large flat area as the weight of such a UAV (for example, as Shadow-600), was more than 200 kg. To reduce the braking distance of the landing UAV, additional devices such as a cable stretched across the glide path or special landing nets were used. When the start of the UAV was not possible due to the lack of specially prepared areas, hydraulic launchers with rail guides were used for launch. The tactics of using reconnaissance UAVs during the Gulf conflict has not changed. The main way of combat for UAV remained the gradual launches of individual UAVs, which were performed to conduct aerial reconnaissance of various objects and ensure the continuity and duration of observation. In most cases, the following well-known techniques were used: search on a given route; exit to a given point and its flight; overflight of a mentioned frontier.

Thus, the MNF troops used small number of operational-tactical UAVs (about 30 units) Shadow-600 and Pioneer to perform reconnaissance missions during the fighting in Iraq in 1991. However, in the process of preparation and conduct of operations this allowed to provide command of the BNS with detailed topographic and geodetic data with accurate reference of important objects, locations of armed forces, control and communication points, communications, engineering fortifications. The information received from the UAV became the basis for the calculation and selection of rational routes for attack aircraft to target (objects), determine the order of forces, the required number and weapons composition.

The experience of Iraq remains important because of the fact that UAVs were first used together with other forces and means of various types of military intelligence. Thus, complexing of reconnaissance means was carried out not only based on types of reconnaissance, but also inside them. At the preparatory stage of ‘Operation Desert Storm’, a type of space reconnaissance with the use of optoelectronic means was actively used. After airstrikes on Iraqi facilities, sand and smoke from oil well fires have risen in air, reducing the transparency of the atmosphere. Temporary restrictions on the use of optoelectronic means of space reconnaissance have been compensated using UAVs.

The main result of the fighting in the Persian Gulf in 1991 is the recognition of the main role of UAVs in carrying out reconnaissance tasks in the modern war. The reason for this was the peculiarities of the fighting that the military faced in the Persian Gulf. These features concerned, first of all, the rejection of the traditional advantages in the forces and means of the attacking troops over the defending ones (except Air Force and Navy). The lack of such an advantage was compensated by continuous flow of reconnaissance, a significant amount of which was obtained by UAVs, and which allowed to carefully coordinate the action of troops (forces), to ensure effective fire damage to enemy's targets.

It should also be noted that the military conflict in the Persian Gulf has provided the military with experience in using UAVs at different stages of the conflict, both in preparation and in combat. For the first time, the United States and its allies have succeeded in creating a global information and strike system on a unified basis, where reconnaissance UAVs became one of the main elements.

In 1991 in Iraq war only two countries used reconnaissance UAVs - the United States and France, then in 1999 during the fighting in the Balkans the armed forces of three more other NATO member states as Britain, Italy and Germany have gained the first experience of combat use of UAVs.

Formally, the date of the beginning of large-scale UAVs use in the conflict in the Balkans can be considered October 30, 1998, when the air reconnaissance 'Operation Eagle Eye' has began. The mentioned operation allowed the NATO Force Command, to conduct an intensive (up to 10 -12 reconnaissance flights per day) comprehensive air reconnaissance throughout Yugoslavia for five months under the guise of supporting the OSCE Verification Mission in Kosovo. Its unmanned component played a significant role in obtaining reconnaissance data. The operation involved three types of UAVs of the operational and tactical levels of three countries: Hunter and Pioneer from the United States; CL-289 from France and Germany.

The UAV's main tasks during the operation were to detect, find location and to take a photo of the Serbian air defense system, other stationary and mobile facilities, and to obtain documentary evidence of so-called 'ethnic cleansing.'

However, it is believed that the first full-scale test for UAVs was 'Operation Allied Force', conducted by NATO in Yugoslavia in 1999. It was here that the UAVs have firstly met the first serious opposition as the Yugoslav AD system.

The leadership of the Alliance's North Atlantic Allied Forces has created a powerful group of reconnaissance UAVs (up to 40 units) in the conflict zone, which is two times more than the previous one in 1998 by the quantitative and qualitative indicators. UAVs performed reconnaissance tasks of the troops (forces) locations of the Yugoslav Army; battlefield observation; control over the situation in the territory occupied by the Albanian separatists. In addition, they were involved in reconnaissance of targets and targeting aircraft during the striking targets on the territory of Yugoslavia with high-precision weapons, and to rate the results of NATO's tactical and bomber aircraft.

The first combat flights during the operation have been performed by new American Hunter UAVs, which were specially designed for the reconnaissance of the US Army. The Hunter UAV troop was based at Petrovets airfield in Macedonia. It consisted of 8 UAVs and two ground mobile control and communication points. The main task of this troop was to conduct air reconnaissance over the territory of Kosovo.

During ‘Operation Allied Force’, the Hunter UAV has performed 670 fights during 2,864 hours, more than any other NATO unmanned reconnaissance system. Hunter UAVs have been used in practice as conventional reconnaissance aircraft of operational and tactical reconnaissance, performing an average of 2-3 flights per day lasting 8-9 hours. At night UAVs often flew for up to 2 hours. The devices were used more often to detect Serbian artillery positions on the Kosovo-Albania border. The flights were performed on the specified routes. Often their flights route passed along the border of Macedonia with the exit to the central part of Kosovo (Pristina area) and back. The special reconnaissance equipment MOSP (multi-mission optronik stabilized payload) which was installed on the Hunter UAV, allowed to conduct observation and reconnaissance of targets almost around the clock.

A feature of the Hunter UAV in the Balkans was the consistent launch of several vehicles for aerial observation. This method was used for the first time when one pair of UAVs completed the reconnaissance mission and returned to base, another pair of UAVs was launched into the reconnaissance area. Due to this, the Americans achieved one of the most important requirements of reconnaissance that is continuity.

As the analysis shows, there were two main reasons that influenced the use of this method of reconnaissance flight. First, most of the reconnaissance objects were small mobile objects, which required low-altitude flights in the difficult mountainous and forested terrain of the Balkans. On average this height was about 300 m. And at this height the capabilities of UAV reconnaissance equipment were significantly limited in the width of the area. For example, the maximum transverse capture of a panoramic camera at this altitude was 3000 m.

In the image, the decoder operator could detect the reconnaissance object only in the 1500 m band, which made alone UAV flights ineffective. In the case of a pair flight the probability of detecting an object was doubled. Secondly, low-altitude flights increased the risk for UAVs to be shot down not only by anti-aircraft guns but also by small weapons fire. In case of defeat of one UAV, the second one fixed a place of firing (missile launch) and directed striking means on it.

The Hunter UAVs provided real-time television images of air strikes and the results of air strikes directly to command posts and headquarters. The relatively small size of the UAV and the small values of the effective reflective surface made it much more difficult to detect them by air defense (during the first period of the air offensive operation only one Hunter was shot down). In addition, to reduce the capabilities of Serbian AD means, UAV pilots used special tactics when most flights were conducted at night, and the flight over the endangered areas took place at extremely low altitudes.

In addition to ground-based UAVs, the US military used Pioneer UAVs based on the US NF Ponce. Mentioned UAVs were used to monitor the movement of maritime transport along the Adriatic coast.

As it was established, not only American reconnaissance UAVs took part in the fighting on the Balkan TOW. UAVs were actively used by military contingents of Germany and France.

On the French side, two UAV batteries from the 7th Reconnaissance Regiment took part in the fighting. The CL-289 UAV battery was deployed in Bosnia near Mostar, where the headquarters of the Southeast Multinational Division were located. The battery was armed with two CPs and eight UAVs. A mixed UAV battery was located in Macedonia (Kumanovo), consisting of one CP and four CL-289 UAVs, as well as two CPs and four Crecerelle tactical UAVs. These batteries were used sporadically in the interests of the French military intelligence department. A year later, the French battery of the CL-289 UAV was replaced by a battery of the same UAV of the German Armed Forces.

In the interests of reconnaissance support for ‘Operation Allied Force’, another German CL-289 UAV battery was deployed in Macedonia in late 1998.

The battery had 16 drones, four launchers, a ground control station for data receiving. From December 1998 to July 1999 the battery has performed 237 reconnaissance flights over Kosovo. For Germany it was the first combat experience using of UAVs. All-weather UAV CL-289 performed about 1-2 flights per day lasting 30 - 40 minutes in light and dark time of day. The UAVs were launched from a Macedonian base in Tetovo deep into the territory on 320 km. The flights were performed on specified routes, most of which passed directly through the areas of location of the main means of air defense of Yugoslavia. The CL-289 was equipped with a stereoscopic camera, an IR sensor, a system for recording and transmitting real-time images of the operator at up to 70 km. With the help of the UAV, we were able to obtain high-quality images that showed the positions of air defense equipment, the location and movement of Serbian armored vehicles.

Among the tasks resolved by the CL-289 battery before an ‘Operation Allied Force’ were the following: observation of Yugoslav army and police facilities, and military camps of Kosovo Albanian in the province; control over the flow of refugees; aerial photo of the area in order to clarify the topographic maps in the interests of the Bundeswehr, etc. Since the beginning of the operation its main task has been to assess the results of strikes by Tornado aircraft.

The CL-289 was a relatively outdated type of UAV. The first such UAVs came to arms of the German armed forces in 1990. The high speed of the aircraft (over 700 km / h) and the short flight duration (about 30 minutes) significantly limited the range of tasks, and sometimes made them impossible, especially during the reconnaissance in mountainous and forested areas and searching for small mobile objects. UAVs with flight characteristics were intended primarily for flights on programmable routes using stationary objects or those that are known. In the case of Yugoslavia, where the coordinates of most stationary objects were already known, the main targets for UAVs were mobile and masked objects, which are virtually impossible to detect at high speeds.

The high intensity of the use of reconnaissance UAVs in Yugoslavia had a corresponding effect on the level of their losses. The first losses were suffered by the American contingent when the Hunter UAV was shot down by ground anti-aircraft artillery fire on April 7, 1999. Research sources reveal that 11 units of NATO UAVs had been destroyed by mid-May 1999. As of June 3, 2000, it was estimated that forces of Allied Land Command had lost 23 operational-tactical UAVs. The losses of the United States amounted to the following 14 UAVs: 9 UAVs Hunter, 4 Pioneer and 1 unidentified type; Germany - 7 CL-289; France - 2 CL-289. For comparison, in Iraq in 1991 the loss of UAVs was only 13 units.

The fighting in the Balkans which became the third local conflict (the Arab-Israeli conflict, the war in Iraq in 1991) where UAVs were actively used, should be attributed to the second period of UAV development. During the conflict UAVs provided with continuous receiving of reconnaissance data.

The information obtained through the gradual launch of several UAVs significantly supplemented the occasional reconnaissance data from satellites (it was cloudy for a long time) or manned reconnaissance aircraft, whose stay over the observation area was limited due to the danger of being shot down by AD and their capabilities in terms of flight duration.

At the same time, the combat use of UAVs during the Balkan crisis has found the following significant shortcomings: low efficiency of the existing tactics of UAV in the conditions of changes in military conflicts character; transition to partizan methods of fighting in small groups; low level of technical reliability of UAVs, especially in difficult weather conditions (up to 40% of all losses); difficult conditions of flight control of a large number of UAVs; a significant degree of UAVs vulnerability from ground air defense (according to various data, up to 60% of all lost UAVs were shot down by anti-aircraft artillery fire and individual air defense means of ‘Arrow-1M’ type).

Mentioned disadvantages have become the basis for the formation of directions for further development and use of UAVs. The change in the nature of military conflicts have made the problem of revising the tactics of UAV use as urgent one, increasing the time spent by UAVs over the observed area. The need of fighting with small mobile groups (targets) has proven the feasibility of creating a reconnaissance and strike UAV. The low level of technical reliability of the UAV contributed to the development of new methods and approaches to the creation of such equipment, the improvement of reconnaissance equipment. Increasing the intensity of flights for the first time raised the question of the need to include UAVs in the unified air traffic control system. The high degree of vulnerability of UAVs because of air defense has led to the feasibility of measures to increase the survival of UAVs. Among the measures that have been applied are the following: installation of firefighting equipment on board the UAV, active and passive means of counteraction in different wave bands, armoring of life-important units against bullets, reduction of visibility in the radar and infrared ranges.

In 2003 the “ test proving ground ” for unmanned aerial vehicles had to become the territory of Iraq once again. 1991 Gulf operation was truly a test for UAVs at the time, but 2003, according to an analysis of the data collected, has marked the beginning of a new, more advanced generation of unmanned aerial vehicles.

Between March 20 and May 2 of 2003, the US-British coalition has launched an ‘Operation Iraqi Freedom’ against Saddam Hussein’s regime. The first distinguishing feature of the operation compared to 1991 was the lack of massive air and missile strikes. New tactics were used against Iraq via inflict numerous point-of-attack strikes by means of naval and air-based air strikes.

Almost from the very beginning of the operation, large groups of ground forces were brought into battle.

At the start of the force action against Saddam Hussein, the US Air Force and its allies in the Gulf region numbered 978 combat aircraft (411 deck aircraft and 557 ground based aircraft). The number of ground groups of the US Armed Forces and their allies numbered 207 thousand servicemen, 145 thousand people of the US Armed Forces and 62 thousand people of British Armed Forces. NF consisted of 134 warships, including 35 carriers of SBCM.

Coalition air reconnaissance has played an active role in the preparation and conduct of the operation. During the immediate preparation of the operation to increase the intelligence capabilities of the US-British coalition, a joint reconnaissance center was deployed, the main focus of which was to collect information on the current situation in Iraq, deploy control points, air defenses, units and Iraqi armed forces, potential targets for the production and storage of mass destruction weapons, Scud operational and tactical missiles, as well as possible places of Saddam Hussein's shelter. For this purpose, together with reconnaissance aircraft, drones were actively used which greatly expanded the coalition's air reconnaissance capabilities in Iraq.

As Iraqi forces widely used the natural conditions of TOW and artificial shelters, camouflage and disorientation means, the effectiveness of manned reconnaissance aircraft has declined, especially for mobile purposes. Because of this, special importance was given to the use of UAVs.

One of the main UAVs of the operational and tactical level, which proved its need in Iraq, was the staff of USA GF UAV Hunter. As it turned out, at the beginning of operations in Iraq, Hunter UAVs already had enough combat experience (a total flight time about 8,000 hours and about 1,400 flights). During 'Operation Iraqi Freedom', Hunter UAVs transmitted real-time images and results of air strikes directly to command posts and military headquarters. The UAVs, which were in service with the 3rd and 4th Infantry Divisions, performed 500 combat flights during the operation, losing only two aircraft.

According to estimates, totally about 40 operational-tactical UAVs were involved in the operation, including more than 20 Pioneers and 16 Hunters. Hunter UAVs (190 sorties, over 1000 hours) took the first place in the raid. There were also losses which amounted to 1 for Pioneer UAV and 3 for Hunter UAVs (two were shot down, one was lost due to malfunctions). Following 'Operation Freedom of Iraq' the use of UAVs in Iraq has become even more intense. After the end of active hostilities, a new phase that is maintaining order and stabilizing the situation began. In fact, guerrilla warfare has begun in the country and the Iraqi resistance became more active day by day. Terrorist acts became more frequent which required measures to prevent and counter them. UAVs was the best to solve these problems, they were used to identify both terrorist groups and individual terrorists. The main advantage of UAVs was that commanders at all levels had the opportunity to receive real-time information about the situation in the area that was hidden from them by the terrain. These features of UAV use have become t of typical for the third stage (which began in 2001) of UAV development.

US ground forces continued to use the Hunter UAV. Another example of its successful use was the participation in support of operations during the revolt in Fallujah. A group of drones from the squadron, a ground command post located in Najaf, as a result of air reconnaissance has found an ambush along the planned route for patrol in Najaf and has directed fire from AC-130 aircraft, Apache helicopters and mortars on the identified targets.

It should be noted that the effectiveness of UAVs was significantly affected by the new tactics used to search for objects. The tasks of the UAV in the third stage began to change and, as a result, this required a change in search techniques. The main task of reconnaissance UAVs was to search for small mobile objects, and it was almost impossible to detect and observe the object due to outdated methods of flights on programmed routes.

UAVs had all the necessary characteristics (the ability to remotely control the flight of UAVs and transmit reconnaissance in formation directly from the UAV operator to the ground CP, speed, maneuverability, appropriate reconnaissance equipment, etc.), which made it possible to use more efficient methods of manned aircraft: search for a target in a given area and barrage in a given area.

Similar techniques were used during the second company in Iraq with the Pioneer UAV ship based. The most common reconnaissance tasks for them were the following: air reconnaissance with real-time data transmission; reconnaissance and identification of targets; monitoring of sea economic and territorial waters.

UAVs were launched directly from the deck of the ship by means of a catapult and a jet accelerator, patrolled in a given area and landed on the ship with the help of a special trap net. However, such actions significantly complicated the operations of ship helicopters, so the commanders of the ships preferred not to use UAVs very often. By mid-September 2003, the 6th Squadron of the US NS, based on ships and armed with four Pioneer UAVs, had flown only about 92 hours, and the same unit of the US Marine Corps more than 2600 hours.

The use of ship-based UAVs had its own peculiarities. The main ones were extremely difficult conditions of launch and landing: rocking, limited size of the launch site on the ship, the probability of landing on water and others. In addition, the application was affected not only by the aggressive environment, but also by the difficulty of providing stable communication and navigation. These features of the use of Pioneer UAVs, which took place during the first and second Iraqi companies, influenced the choice of design scheme of the device that airplane or helicopter in the future should be in the service of the NF.

The traditional scheme by air was more technologically simple, which allowed to reduce the possible risks during the application. Such UAVs had a longer action range and duration of flight than helicopter-type UAVs. However, the use of such UAVs from ships was complicated by limited space for the carrier, the launch of UAVs of the aircraft type was possible only from a catapult-type launcher or from a rail CP with solid fuel accelerators, which were then reset. Landing of such UAVs was carried out either by means of special trap nets, or aero finisher devices, or by direct splashdown of the device.

The helicopter scheme of the UAV allowed to fit the device more organically on the warship, the ability of such a device to take off and land vertically allowed to place it even on ships with low displacement, simplified operation during landing, speeding it up and less affected the ship's maneuverability. However, this scheme had such disadvantages as the complexity of the structure itself and its high vulnerability to high loads associated with operation at sea. In addition, the onboard optoelectronic devices were adversely affected by vibration during the flight.

In the end, the decision of the NF was 'Solomon's' to bet on both UAV schemes, in each to solve its most specific tasks. The future of the helicopter-type UAV was the Fire Scout, which was based on the Schweizer light helicopter. Two modifications of the Fire Scout UAV were created: RQ-8A on assignment and on behalf of the US naval forces, and MQ-8B for the US ground forces.

While the designers tried to invent the best version of the ship's UAV, the fighting in Iraq required the continuation of regular reconnaissance flights in the interests of the naval forces. In late 2004, the Iraqi Marine Expeditionary Force received new ScanEagle UAVs. At the beginning of July 2005, ScanEagle UAVs flew about 3,600 hours, providing continuous observation and reconnaissance in certain areas of Iraq for potential targets and dangerous areas.

The ScanEagle UAV performed the task for 15 hours day and night. Due to the ability to stay in the air for a long time in case of adverse weather conditions on the landing deck, the aircraft was delayed elsewhere until the weather conditions improved.

The increase in the number of US military UAVs in Iraq in 2007 compared to 2003 shows the great importance that was given to reconnaissance UAVs. Thus, while in March 2003 the US Army had 14 UAVs, by the end of 2007 military units had already used 361 UAVs of various types, including small ones, which indicates the significant advantages of unmanned aerial vehicles and their irreplaceability in most reconnaissance tasks. According to the studied sources, in the first 10 months of 2007 the raid of army UAVs amounted to about 300 thousand hours. For comparison, in 'Operation Eagle's Eye' in Yugoslavia in 1998, which involved seven types of UAVs, the total flight time of all UAVs was 3.8 thousand hours.

Insufficient bandwidth of communication channels was a major problem for US troops in the Persian Gulf. Thus, in order to provide one soldier with continuous operational data on the environment, it was necessary to transmit about 5 Mbit per minute, which was not provided by the existing communication systems. In addition, the lack of communication channels prevented the use of the required number of UAVs and, as a result, the effective management of troops.

The results of the use of UAVs in combat operations were still considered successful and the military leadership increasingly considered the need to gradually replace manned aircraft with UAV. One of the first to reach this conclusion was the Israeli military.

At different times and sometimes, Israel was opposed by large forces in the Arab world around it: Palestinian terrorist groups, armed Hezbollah wing, Syrian and Egyptian troops. This required constant air control of combat zones, dangerous areas and border areas, and the search for and detection of terrorist groups. Reconnaissance with simple aircraft became problematic due to the large number of objects that had to be constantly monitored, and at the same time it became quite risky.

An addition to this was the direct conduct of hostilities (ground and air), which forced the Israeli leadership, which sometimes put ‘under the gun’ almost the entire adult population of the country, to think about the need to save human resources and withdraw people from the battlefield. UAVs could partially solve this problem.

According to the analysis, in 2005 18,000 hours out of 28,000 of the country’s air force that were flown belonged to the UAV. At the same time, most UAV missions were reconnaissance flights over the Gaza Strip. According to the spokesmen of Israeli Air Force, using the UAV instead of simple aircraft, the command not only saved the pilots, but also increased the efficiency of reconnaissance aircraft. Thus, in assessing the combat potential, Israeli military experts came to the need to compare the effectiveness of one UAV with three simple reconnaissance aircraft.

This trend was demonstrated by the Israeli Air Force in 2006 during another confrontation between Israel and Lebanon happened in July 12 - August 25, 2006. During the operation, codenamed ‘Decent Revenge’, 1,350 UAV combat flights were conducted, flying more than 20,000 hours, performing reconnaissance collection tasks.

Most of the reconnaissance tasks during the operation were performed by Hermes UAVs. Before the beginning of operation, according to the experience of regular use of UAVs since 1982, Israeli experts concluded that it is advisable to create UAVs of different heights. At the same time, the decision was made to focus on the development of only low- and medium-altitude UAVs.

High-altitude reconnaissance UAVs (such as the strategic American UAV Global Hawk) were not in the priority list. Along with the small number of tasks for such UAVs, the eventual influence on decisions about their unpromising for Israel was due to the very high cost of development and production of vehicles.

As a result, a series of medium-altitude Hermes unmanned aerial vehicles such as Hermes-180, Hermes-450 and Hermes-1500 have appeared in Israel in the late 1990s. Despite the fact that the devices had almost the same range (about 200 km), their main difference was the length of staying in the air: 10 hours for Hermes-

180, 24 hours for Hermes-450 and 40 hours for Hermes-1500. The existence of such a various line of drones was explained by the difference in the tasks assigned to them and, accordingly, by the criterion of ‘efficiency-cost’, which is increasingly being used to evaluate any military equipment.

During ‘Operation Decent Revenge’ medium-altitude Hermes-450 UAVs with a long flight duration have been used the most actively. The mentioned UAVs provided with data collection for ground forces and raised their situational awareness, including locating and identifying missile launchers, ensuring their further destruction. During the operation, three Hermes-450 UAVs crashed due to technical problems and operators’ mistakes, but this did not affect the prospects for their use.

It should also be noted the intensive use of another medium-altitude UAV Mahatz-1 (Xeron-1) during the conflict. The flight of this UAV in various reconnaissance operations of 2006 amounted to several thousand hours (more than 10% of the total flight of the UAV), which was a very attractive estimate for the new device.

The Xeron-1 UAV was created to gradually replace the Searcher UAV. The main purpose was to collect real-time data in the interests of the command of the TOW. It was a new generation vehicle that could stay in the air for 52 hours and had fully automatic takeoff and landing. The payload of the UAV, in addition to reconnaissance sensors, included equipment for conducting RW and receiving devices for satellite signals.

The UAV’s actions during the Lebanese-Israeli conflict were not unilateral like only on the part of Israel. Thus, the first intrusion of a

Hezbollah UAV into Israeli airspace was registered in late 2004. Moreover, in early August 2006, Israeli troops shot down a Hezbollah UAV over the Mediterranean. The UAV is an Iranian-made Ababil that has been destroyed most probably by a Piton-4 missile fired from an Israeli F-16 aircraft. According to Hezbollah representatives, the UAV could have delivered 40-50 kg of explosives deep into Israeli territory, but American experts cast doubt this: with a wingspan of 3-3.25 m, the engine power of such an UAV could not exceed 25 hp. Despite these conclusions, the Israelis clearly understood the real threat that could be expected from such a UAV, so they were forced to counter the UAV’s flight, preventing it from approaching the forthcoming to state border.

The experience of the simultaneous use of unmanned and manned aircraft by Israel has raised a very important question of the need to develop rules for UAV flights in the airspace. While such rules did not exist, a clear altitude approach was taken during combat operations between Israeli strike aircraft and UAV reconnaissance aircraft. This is one of the characteristic features of the use of UAVs by the Israeli army which ensured flight safety. For example, manned aircraft did not appear at altitudes where aircraft could be damaged by air defenses, while low-speed UAVs flew at about 3,000 meters, the most dangerous altitude for anti-aircraft attacks.

There was another, no less important issue. Since reconnaissance UAV flights in Israel have become daily to ensure the control of ground and air conditions in dangerous areas, real threat has appeared for civil flights in these areas. This contributed to the intensification of work on the development of flight rules for these aircraft in the airspace, which was also used for flights of civil aircraft. In addition, a characteristic feature was the study of promising opportunities for the use of reconnaissance UAVs not only for military purposes.

In general, the results of the analysis show that the experience of Israeli military operations has played a major role in global trends in the use of UAVs. The Israeli military was one of the first to conclude that in a fleeting environment, UAVs can be much more effective than manned aircraft in solving the task of conducting air reconnaissance in the interests of all levels of government (from company commander, brigade to high command).

At the same time, it should be noted that the experience of using UAVs in the Arab-Israeli conflict differs from the combat experience of the conflicts in Iraq and the Balkans. First of all, due to the nature of hostilities and the tasks set for UAV reconnaissance. During the first military campaign in Iraq and the conflict in the Balkans powerful military groups opposed each other, which defined for the UAV such tasks as monitoring the progress of operational deployment, collecting data on military facilities, as well as assessing the results of missile and bomb strikes, detecting new targets, searching for mobile and disguised objects. In the Arab Israeli conflict, especially in the 1990s and at the beginning of the 21st century, when there was no confrontation between large military formations, UAVs performed almost the only task as to search for terrorist groups, as well as their leaders. This in some way directly affected both drones and their tactics. UAVs searched for objects in a given area, and when they were found, they continued to monitor until a decision was made to destroy them (if necessary). In order to keep the object of observation under constant control, the operator of the ground CP could perform almost any necessary tactical approach by the drone: shifted turn, turn at 270º, two or four turns at 270º, two turns at 180º, low-altitude battle turn, combing, spatial snake.

Tactics of reconnaissance UAVs in the early 21st century became similar to the tactics of reconnaissance aircraft, therefore, pilots from manned aircraft began to be increasingly involved in the management of unmanned aerial vehicles.

The end of the 20 - beginning of the 21st century characterized by the beginning of a phase of new wars (counter-terrorist), and this, accordingly, has formed new requirements for the use of UAVs. Afghanistan was actually the first assigned to fight against terrorism. 16 among 19 NATO's member states have deployed troops to participate in a military campaign in Afghanistan. UAVs were also actively used there. A special feature was the priority use of long-range UAVs, primarily such as Predator and Global Hawk. The reason for this was the main task assigned to reconnaissance that was search for terrorist groups. This task required the UAV to conduct long-term surveillance of large areas, as well as on-board reconnaissance equipment capable of transmitting high-quality images of objects to ground-based control points in real time. At the same time, operational-tactical UAVs were also used in Afghanistan. One of the mentioned UAVs was the French UAV Sperwer.

The first Afghan company for the Sperwer UAV took place in 2003-2004. The Canadian military has demonstrated the ability to use the Sperwer system without infrastructure and airstrip. The vehicle was launched from a catapult and conducted reconnaissance in an autonomous mode for 6 hours within a radius of 150 km from the ground control point. It should be noted that all six UAVs sent to Afghanistan in 2003 either crashed or remained on the ground due to technical problems. This was influenced by several factors. First, it is the imperfection of the devices, as well as unfavorable physical and geographical conditions where the UAV performed reconnaissance (operation from a high mountain plateau at elevated temperatures).

The second Afghan company has started for the Sperwer UAV in 2006. Since the beginning of March 2006, the Canadian contingent in Kandahar city has used the Sperwer UAV as part of an initial security mission in southern Afghanistan. UAVs were used during the daytime for reconnaissance, collecting of information and raising the situational awareness of the leadership of the military contingent by transmitting intelligence information in real time. At the end of 2006, there were nine Sperwer UAVs in the Canadian contingent.

The aircraft was extremely maneuverable and had a limited practical flight ceiling. Due to the large weight of the aircraft (250 kg), a very large and complex pneumatic catapult installation with a high probability of failure had to be used to launch it, that reduced the combat capabilities of the complex. In addition, the complex had a large number of bulky means, and its combat calculation had 15-

20 people in, which greatly complicated its maintenance. There were many questions about the reliability of the complex. This was primarily due to the landing system: the Sperwer UAV landed using a parachute system that had significant flight restrictions. In addition, the UAV had unreliable reconnaissance equipment, and its flight was accompanied by loud noise, which significantly increased the acoustic visibility and reduced capabilities of reconnaissance. As a result, the identified shortcomings forced the Canadian military leadership to decide to stop using the Sperwer UAV in Afghanistan.

Some of the shortcomings of the Sperwer UAV experience in Afghanistan were typical for the most of the UAVs used there. In the conditions of anti-terrorist operations, when one of the main tasks of UAV reconnaissance was to search for terrorists, such characteristics as maneuverability, length of stay in the air and acoustic visibility became the most important for UAVs.

The final results showed that during the military conflicts in the Middle East and the Balkans, the advantages of UAVs over manned aircraft in reconnaissance missions became quite obvious. Beginning with the experience of the Arab Israeli confrontation, UAVs were used not only by leading industrialized countries, but also by groups (countries) that did not have any regular, ready and modernly equipped armed forces (for example, Hezbollah). With limited funding, a lack of manned reconnaissance aircraft, the same as trained pilots, the military leadership of small countries began to consider UAVs as the main alternative to manned aircraft for air reconnaissance.

This fact has been confirmed in 2007 and 2008, when the Georgian army used foreign UAVs to carry out reconnaissance missions in preparation for and during the Abkhazian-Georgian conflict. These were Hermes-450 produced in Israel. It was established that the first reconnaissance flight of the Georgian UAV was recorded by the Abkhazia in August 2007. An unmanned reconnaissance plane was found at high altitude during military training at the Ochamchire shooting range. Abkhazian AD forces fired it for warning, after this it has disappeared over Georgian territory. Since then, Georgian UAVs have performed regular reconnaissance flights over Abkhazia.

On March 18, 2007 the first UAV of the Georgian Armed Forces has been shot down over Abkhazia. Two Abkhazian fighters took off to intercept an unmanned aircraft flying from Georgia. During the flight of the UAV over the Ochamchira city at an altitude of about 4.5 thousand meters, the UAV was shot down by an Abkhazian pilot. Official Tbilisi has denied the information about the downing of the UAV, but the fragments of the UAV with its board number indicated that it was an Israeli-made device Hermes-450 with serial number 551.

After that, the Georgian army did not stop UAV reconnaissance flights over Abkhazia. Thus, on April 20, 2008, a second UAV was shot down over the Abkhaz settlement of Gagid at an altitude of 6,000 m. The Georgian Ministry of Defense has already acknowledged this loss. In an interview with the New York Times on April 22, Georgian President Mikheil Saakashvili said that Georgia had 40 UAVs, which he considered an extremely useful means of obtaining reconnaissance data in the Caucasus. There are no reliable data about the number of UAVs, but according to Israeli media, Georgia has received 18 Skylark and 5 Hermes-450.

The first losses of UAVs forced Tbilisi to correct its tactics, UAVs began to be launched in pairs at a distance of 20 km from each other. This method was used by the Americans in Afghanistan: in case of one UAV being hit, the other fixed the launch site of the missile and aimed strike aircraft at it. In the case of Abkhazia, the Georgian military probably aimed to capture AAMS positions. As a result, both UAVs were shot down at an altitude of 7,000 meters by air defense.

Another attempt to change the tactics of UAVs proposed by the Georgian side was to use them in the dark time. Thanks to the composite materials which were used in the Hermes-450 UAV creation, their detection by air defense was quite difficult. During the 2 months, 7 Georgian Hermes-450 drones were shot down by Abkhaz troops. Except for the first two, the remaining UAVs (5 units) were shot down by the Buk AAMS. The loss of drones was significant for the Georgian armed forces, but it should be noted that the loss of UAVs, even such expensive as the Hermes-450 (about $ 2 million), cannot be compared to the loss of a manned reconnaissance aircraft. Unmanned reconnaissance has provided the Georgian side with several advantages, including a high level of situational awareness and high efficiency of the received data.

Analysis of the results of UAVs usage in the Abkhazian-Georgian conflict has confirmed the conclusions made from the experience of the Balkan conflict in 1999 that a significant part of combat losses of UAVs were related to enemy air defenses. Therefore, one of the most important and difficult problems to reduce the level of combat losses was the problem of achieving high survival of UAVs.

Survival, which is one of the three (along with combat effectiveness and mobility) basic generalized properties of any means of armed struggle, is determined by a set of tactical and technical characteristics of the sample. This fully applies to UAVs. For the UAV only the factor of combat survivability is considered. The definition of survivability meant the ability of the UAV design to save efficiency under the influence of the enemy's means. However, it was found that combat survivability as alone could not ensure the survival of UAVs. As combat experience has shown, indicators of combat effectiveness depended on a number of factors, such as equipment with RER means; visibility (infrared, radar, acoustic, visual); maneuverability. As a result, to increase the level of UAV survival, the following appropriate measures were taken: fire-fighting means were installed, vital units were armored to be protected from caliber bullets 7,62 and 12,7 mm. To reduce the visibility of the aircraft in the infrared range, special covering of hot parts of the power plant were used, and work began on the manufacture of special devices to reduce the temperature of the exhaust gases. Visibility in the radar range decreased in case of creating propeller blades from composite materials, the use of radio-absorbing coverings and materials in the design of the glider. The possibility of installing active and passive countermeasures on board in different ranges of electromagnetic spectrum waves was studied.

Active use of reconnaissance UAVs took place during the counter-terrorist operation of the international coalition forces led by the United States (since 2014) and the contingent of the russian armed forces (since 2015) against ISIS in Syria where military conflict between government and opposition forces (civil war) began in 2011.

Coalition forces used MQ-1 Predator (USA), Heron (Israel), RQ-21a (USA), and MQ-9 Reaper multi-role UAVs to perform air reconnaissance.

The Orlan-10 UAV and the Forpost UAV (licensed copy of the Israeli Searcher 2) were included to the russian fleet of operational and tactical reconnaissance drones. It should be emphasized that the Orlan-10 UAVs account for a third of the entire fleet of russian drones. It should be emphasized that the Orlan-10 UAVs is taken third part of the whole fleet of russian drones.

The most popular tasks for russian drones in Syria were as follows: round-the-clock monitoring of the situation in the country; reconnaissance of targets for air strikes; assessment of losses; correction of Syrian artillery fire.

Thus, operational and tactical reconnaissance UAVs have proved that in the difficult conditions of modern military conflicts, they are more effective than manned aircraft and solve reconnaissance issues. Such advantages of UAVs, such as low cost, an absence of danger for the pilot, unpretentiousness to operating conditions and others, have forced soldiers to use UAVs for reconnaissance missions’ performance more frequently.

The number of UAVs grew from one conflict to another. Along with this, the range of reconnaissance tasks expanded, which led to the emergence of the ‘specialization’ definition for UAVs, so specific tasks corresponded to certain types of UAVs. However, the allocation was carried out not only by tasks, but also by the flight capabilities of the UAV. Thus, it was illogical and inefficient to use the gradual launch of several UAVs to provide with continuous reconnaissance of the required facility (resulting in long-range UAVs and strategic UAVs). The same problem, but from another side, concerned the performing of reconnaissance within a radius of 5 to 50 km. No reason to send a UAV with a range of up to 200 km, and even more so a manned reconnaissance aircraft. new class like tactical UAVs has appeared.

5.2. Tactical reconnaissance

One of the typical features of military conflicts of the late twentieth - early twentieth century became the performance of hostilities by units of the regular army against poorly organized units and groups. Fighting was increasingly conducted in the absence of a clearly defined front line in mountainous and forested areas or in urban areas where aerial surveillance was significantly more difficult. The main combat unit in operations against small enemy mobile groups were tactical units including the brigade. The rapidity of the situation that accompanied the fighting during the conflict required the commanders of these levels to have operational reconnaissance on the location, condition, and activities of the main enemy targets. In such circumstances, small mobile UAVs became relevant, providing real-time reconnaissance of enemy targets in the tactical depths for commanders of ‘platoon-battalion-brigade’ level.

russian military were the first who felt the need to use reconnaissance UAVs tactical level. This happened during the fighting in the Chechen Republic which took place in the period from 1994 to 1996 and later in 1999-2003, and became known as the First and Second Chechen Wars. Two parties took part in these internal conflicts: the Chechen armed forces and the russian regular army. The main goal of this military conflict that is the repair of constitutional rules, has not been achieved. At the same time, the following new term was used in the theory of martial arts after the Chechen wars as ‘counter-terrorist operation’.

The first war in Chechnya lasted about two years from December 11, 1994 to August 31, 1996 and was 14 times longer than the 1991 Gulf War. Despite this, the armed forces of the russian Federation used only one type of UAV in the war that is ‘Bee-1T’ (for comparison, 5 types of UAVs were involved in the conflict in Iraq).

The ‘Bee-1T’ UAV which was part of the Stroy-P complex, made its first reconnaissance flight in the Caucasus in 1995. The complex included two ground-based remote control points with CPs and 10 Bee-1T UAVs equipped with television hardware. The UAV’s main reconnaissance mission in the first Chechen war was to search and identify terrorists, their routes and transshipment bases.

In the period from April to June 1995, 5 ‘Bee-1T’ devices were used. Launches were carried out from the territory of Dagestan. The main task of these flights was to further research the movement routes of russian units in the Shelkov district. During the first month of hostilities in Chechnya, 14 launches were made. The maximum range of the devices reached 55 km, the height of reconnaissance ranged from 600 to 2000 m. The results of the flights fully justified the expediency of unmanned aerial vehicles as 36 targets were identified along the routes of russian troops. At the same time, during the first sorties, two aircraft were shot down by militants who were able to organize heavy barricade fire from small arms and anti-aircraft guns along the UAV flight route.

An example of the successful use of the Bee-1T UAV was detection of a congress of Chechen field commanders in Vedeno city in 1995. The obtained data, in particular information about access to the settlement, location of defense borders, location of equipment and personnel, were used in preparation for the assault on this settlement.

The second war which began on August 4, 1999, was aimed to clean Dagestan out of Islamic militants who had invaded Chechnya territory. In the Second Chechen War that, as the analysis shows, a significant step forward was made in the development of the russian army's martial arts. The main form of armed struggle in the military campaign of 1999-2003, for the first time in military practice, was the reconnaissance - fire operation (RFO) when the main role was played by unmanned reconnaissance aircraft.

However, even compared to the conflict in the Balkans in the same year, where UAVs became the main extractive reconnaissance system, the situation with UAVs in Chechnya has not improved significantly. The four years (1995 to 1999) between the Chechen wars hadn't expected any benefits for russian army.

Despite some of russia's successes in creating new UAVs, the experience of the First Chechen War has not been taken into account by russia's military leadership. Moreover, during this time, the main part of the equipment, which has repeatedly exhausted the resource, was failed. UAVs designed for 10 flights stopped to perform the commands and landing. As a result, before the beginning of the second campaign, the last Stroy-P complex in russia which was still in working condition was sent to the Caucasu,.

Nevertheless, the results of the use of UAVs in Chechnya have changed the opinions of most military leadership of the Armed Forces in russian federation regarding role of UAVs in modern warfare. This happened because ground reconnaissance, which the russian military relied on to obtain information about the location of the targets, did not meet expectations. In the mountainous and forested areas of the Caucasus, when units of the regular russian army were opposed by small mobile gangs, the capabilities of russia's existing ground-based radar and optoelectronic reconnaissance facilities were limited by short-range visibility and did not ensure the detection of enemy targets behind natural shelters. And this information was extremely necessary, especially for ground means of destruction. UAVs did not have such shortcomings, so UAVs began to play the role of the main source of intelligence on the targets.

UAVs have not been widely used in Chechnya. The information provided to consumers was not enough quality and timely. It should also be noted the low reliability (especially in the cold period) of the UAV ‘Bee-1T’ and its very modest technical characteristics.

If the glider, UAV engine and most of the ground equipment still met the requirements for them, the TV camera and some electronics were outdated. In addition, the device needed an IR camera to conduct night flights, especially since the night version of the UAV ‘Bee-1T’ was already created at that time. The life of aircraft, as well as the duration of their stay in the air required an improvement. Not the least role in reducing the effectiveness of the UAV ‘Bee-1T’ was played by its acoustic visibility.

By eliminating the shortcomings identified during the fighting, russian developers moved on, who based on the experience of using UAVs in the Chechen company have created a modification of the UAV ‘Bee-1T’ - ‘Bee-PM’. The resource of the aircraft was increased 15 times more and gained up to 150 flights. The reconnaissance equipment was made in modular variables sets, which allowed to solve different tasks at any time of the day.

Analyzing the results of intelligence support for hostilities in the Caucasus, it should be noted that one of the main shortcomings in the actions of the russian army was that big part of the military leadership, without understanding the capabilities of reconnaissance UAVs, continued to work under ‘outdated’ rules as to use manned reconnaissance aircraft and ground reconnaissance forces. Even so, the Chechen experience has identified the advantages of UAVs over other means of reconnaissance, including counterterrorism operations. With the help of UAVs it was possible to significantly reduce the level of human losses, ensure the search and detection of terrorists, timely transfer of data about terrorists and their actions to counter-terrorist centers, identify their routes and transshipment bases.

However, the positive aspects of UAVs have remained virtually unclaimed in Chechen companies. The reason for this was the lack of a sufficient number of modern UAVs in the russian army and the outdated system of command and control of intelligence, which was accustomed for the russian military leadership. The experience of the Arab-Israeli conflict and the Gulf War of 1991 has not become a basis for russia in understanding the importance of UAVs in modern wars and conflicts. In addition, the fighting in Chechnya showed an imbalance in Russia's reconnaissance and fire system: the needs of the strike force in information about the targets exceeded the capabilities of the means of reconnaissance due to the lack of air reconnaissance means, in particular UAVs, because of this the capabilities of the means of destruction could not be fully realized.

According to experts, the main conclusion of the fighting in the Chechen wars was the need to include an UAV unit in the armament and military equipment.

In contrast to the russian military, tactical UAVs have been much more widely used by the US, leading NATO and Israeli forces. In the US military, the initiator of the use of tactical UAVs, as in the case of operational-tactical UAVs Pioneer, was the marines. Despite the positive qualities that Pioneer UAVs certainly had, the US marines needed a simpler and more mobile UAV (the weight of the Pioneer UAV was 190 kg with a wingspan of 5.15 m). In 1988, such a device called Exdrone was created, but UAVs passed the first combat tests only in the Persian Gulf in 1991 during ‘Operation Desert Storm’. The aircraft with weight only about 40 kg was launched by US marines from Saudi Arabia and provided information on US military operations to a depth of 90 km.

In addition to the Exdrone UAV, the American troops used Pointer tactical reconnaissance UAVs in the conflict with Iraq. Five complexes, each included four aircraft and two ground stations, were deployed in the areas of the marine corps and the 82nd airborne division. Lightweight devices weighing 3.6 kg in light aluminum cases were carried in backpacks and have been made in the field.

The UAVs, which had a range of 4.8 km and were designed to work in the air for 1 hour, were used to expose enemy ground targets directly along the line of contact. The devices were equipped with a TV camera for daytime reconnaissance, as well as infrared equipment for work in the dark. Video information from the UAV in black and white was transmitted to ground control points.

The effectiveness of Pointer drones, which were primarily intended for low-altitude reconnaissance, was declining due to unfavorable conditions in Iraq’s desert-free terrain. Because of this, the possibility of equipping the UAV with a receiver of a global satellite navigation system (GPS) and a night vision device has begun.

The disadvantages of Pointer and Exdrone UAVs in the experience of their use in Iraq, according to experts, was the dependence on weather conditions and the lack of laser targets to illuminate targets. Nevertheless, the companies that produced these devices recommended to intensify the development of devices of a similar type as small weight, cheaper; equipped with optoelectronic, radiation, chemical and biological reconnaissance, as well as means of RER and laser illumination of targets.

As a result, about 30 Exdrone UAVs have been upgraded during the 1997-1998 in marine corps, after that they were renamed on Dragon Drone. The device had unique capabilities for that time. First, it was equipped with a TV camera and a laser target, which allowed it to be used to guide strike aircraft. Secondly, if necessary, RW and RTR facilities were placed on board the aircraft. The UAV had two times less range of its predecessor Exdrone (up to 40 km), but this shortcoming was compensated by the UAV's expanded reconnaissance capabilities by increasing its payload range. As a consequence of the urgency of UAVs with such characteristics was the intensification of production of these devices in the coming years. In total, about 400 such devices were manufactured.

French UAVs were actively used in the military conflict in Iraq. Four MART drones were based in Saudi Arabia and provided reconnaissance of Iraqi targets within a radius of 100 km. Video information from the UAV was transmitted to the ground station by radio for a distance no more than 30 km.

Before the offensive action of the ground component of the MNF UAVs operated at an altitude of 300 m, but at this altitude they created a danger to manned aircraft. Therefore, in the future, during the offensive operation, in order to avoid a collision with BNS aircraft, the height of their combat use was reduced to 150 meters.

Among the main disadvantages of UAVs, which were revealed during their use, were the short time spent in the air and low reconnaissance capabilities. It is important to note that MART was the only European-made UAV used in the Gulf of 1990-1991. Moreover, it was the only UAV that the French army was armed with at the time.

Positively evaluating the UAV’s reconnaissance system actions in the Gulf conflict, the military has begun to pay more attention to the expediency of using UAVs to provide intelligence to commanders of units and units directly involved in hostilities. In other words, there was a need to adopt the UAV of lowest level ‘battalion-company-platoon’. However, this decision was finally consolidated only in the second period of UAV development during the Balkan crisis.

Three types of tactical UAVs have been used in the ‘Operation Eagle’s Eye’ over the Balkans since October 1998: from the British Air Force, the Phoenix UAV; UAV Crecerelle from the French Air Force; UAV Mirach 26 from the Italian Air Force.

For France’s UAV, this was the second military conflict since Iraq. The experience of Iraq has benefited the French military. The main shortcomings of the MART UAV, such as low airtime and low reconnaissance capabilities, were taken into account, and in 1994 Sagem specialists have created the Crecerelle tactical UAV. The new device carried much more payload and could be in the air 1.5 times longer (up to 6 hours). The UAV was equipped with a panoramic video camera, a high-resolution camera, infrared sensors, and a system for transmitting data to a terrestrial operator at a distance of up to 50 km.

In the Balkans, Crecerelle drones have been used by the 7th Artillery Regiment of the French Army. The main tasks performed by the UAV were to monitor the battlefield and perform reconnaissance operations in tactical depth.

Italy was the first to use a nationally designed drone. The Italian contingent used the Mirach 26 UAV to carry out round-the-clock surveillance of ground objects. It was a short-range device, its combat radius was only 100 km. At the same time, the UAV was equipped with a set of modern reconnaissance equipment which allowed it to be used to detect objects at any time of the day, including disguised ones. The onboard equipment consisted of two high-resolution television cameras (one for reconnaissance during the day, the other for night reconnaissance) and thermal imaging equipment.

In July 1999 when the air operation in the Balkans was almost over, the British Army for the first time has deployed the Phoenix UAV in Kosovo, whose main task was to conduct reconnaissance and surveillance of the battlefield. The device came into service only in 1998, but even then, it could not be called as modern. Such characteristics of the aircraft as low visual, radar, thermal and acoustic visibility and a replaceable container with modern reconnaissance equipment, were not confirmed during the fighting (the most frequent losses are 14 drones out of 48, frequent failure of reconnaissance equipment). And the ‘benefit’ came in 2003, when in the dry and hot climate of Iraq, the military of the British contingent had to completely refuse from this UAV.

The high level of use of reconnaissance UAVs during the fighting in Yugoslavia had a corresponding effect on the level of their losses. According to open sources, the first UAV (Crecerelle) was shot down by enemy fire on May 14, 1998. In total, all losses amounted to 17 UAVs (14 Phoenix and 3 Crecerelle).

In 2000 German military experts, taking into account the previous experience of the United States and France, have performed experimental tests of the new Luna X-2000 UAV in Kosovo. The main requirements for UAVs were the following: the possibility of its use around the clock in any weather conditions; compact placement of ground equipment (maximum of two vehicles); availability of an automatic navigation system that would allow the UAV to fly along the planned route with the possibility of making corrections using the satellite GPS navigation system. A feature of the UAV was the most modern reconnaissance equipment at that time - a television camera of the famous German company Zeiss, as well as a new RS. The drone could conduct reconnaissance within a radius of 20 km during 4 hours. Despite this, the Luna UAV did not manage to prove its advantages because of the end of the military conflict.

Thus, the conflict in the Balkans has finally consolidated the conclusion made during the first campaign in Iraq about the need to use UAVs in the interests of tactical units.

At the beginning of the military operation in Iraq in 2003, such UAVs already accounted for about 80% of the total number of drones. Among the more than 100 UAVs that took part in ‘Operation Iraqi Freedom’, about 80 had tactical-level. Among them 9 RQ - 7A

Shadow 200, 20 Dragon Eye UAVs; 28 FPASS UAVs (SentryOwl option); 6 Sierra Foxe; and the exact number of FQM-151A Pointer, Raven and Phoenix has not been established. Losses in the operation amounted to 4% including 2 UAVs Shadow-200 and 2 UAVs Phoenix.

Shadow-200 UAVs have been widely used in Iraq to provide intelligence to high-level tactical command (brigade) authorities. This was the first combat experience of the new American tactical UAVs.

The Shadow-200 was faster than its predecessor the Shadow-600, but shorter in range, and was designed to conduct reconnaissance and evaluate the results of strikes in the brigade. The total flight time of these drones in Iraq was more than 2,000 hours. Most flights took place at night. The device had a new airborne RS, which allowed to detect moving targets. In several cases, UAVs were used to reconnoiter an area a few days before US troops entered. Combat losses have amounted to two Shadow-200 UAVs.

Commanders of the battalion and squadron level of the US marine crops used in Iraq low weight portable UAV Dragon Eye. Dragon Eye mini-UAVs with weight only 2 kg have been used for reconnaissance and surveillance for 1 hour at any time of day within a radius of 10 km. To increase the range of the UAV, which was sometimes insufficient to reconnoiter of certain important objects, the marines used the method of transferring control of the aircraft from one post to another. This significantly reduced the number of forces and resources required to carry out reconnaissance missions.

Dragon Eye UAVs were carried by soldiers in a backpack, if necessary, quickly mounted for 10 minutes and launched manually that made them indispensable in a rapidly changing environment. At the same time, the possibility of the UAV in the air for only one hour did not satisfy the marines.

There was a need in a drone capable of long-term and, most importantly, continuous surveillance of moving objects at tactical depths. This was caused by need for low-level commanders in the dynamics of hostilities to constantly have up-to-date information about enemy actions.

The first combat tests of such UAV took place in Iraq in 2003 when the US Navy used four new Silver Fox mini-UAVs. During the first combat flights it was found that such UAVs are effective enough to perform reconnaissance missions in a given region. The device with TV cameras and IR sensors on board was able to fly during 5 hours for a range of up to 8 km. The flight altitude was about 300 m.

Despite the fact that most UAVs in Iraq acted for the American contingent interests, in the south-east part of the country in the area of British responsibility, the British contingent actively used drones. These were the Phoenix UAVs, already known due to conflict in the Balkans. UAVs designed to carry out surveillance tasks in Northern and Central Europe during the 1999 conflict in Yugoslavia have shown their low efficiency and reliability. And in the conditions of high air temperatures in Iraq Phoenix UAVs turned out to be completely unusable. Frequent failures of Phoenix UAV engines and reconnaissance equipment did not allow the British contingent to provide itself with the necessary intelligence information. Additionally, there were the results of flights of outdated British reconnaissance aircraft Nimrod, which were also not enough satisfactory.

As a result of the situation with air reconnaissance in Iraq, the leadership of the British units needed other more effective types of UAVs. The choice fell on the unmanned reconnaissance system based on the small American UAV Raven. It was almost twice reduced the Pointer UAV. Compare with the Pointer UAV, the Raven had longer flight duration (up to 1.2 hours) and more advanced reconnaissance equipment, including infrared equipment to detect masked objects and conduct reconnaissance at night.

In general, the use of tactical UAVs in Iraq during ‘Operation Iraqi Freedom’ has provided a solution to most of the reconnaissance missions in the interests of the US-British coalition. An analysis of the combat experience of UAV in Iraq has revealed an increase in demand for small mobile UAVs.

Previously (in the Balkans in 1999 and in Iraq in 1991), UAVs were used mainly for reconnaissance missions over large areas. By the time the fighting has moved to the city streets, the existing military contingent in Iraq UAVs were no longer able to effectively carry out the tasks assigned to them. City infrastructure and large buildings hindered not only the flight of the UAV itself, but also the process of managing it. In addition, there have been significant difficulties in the process of transmitting intelligence, including video, in real time. Small armed groups operating in urban areas has been adapted to UAV reconnaissance flights, responded to the approaching sound of the aircraft in advance, saw it visually, and then disappeared into numerous buildings. The need for a maneuverable, low-speed and low-noise UAV capable of carrying sensors to detect the enemy, including in the middle of buildings, has created new requirements for the creation of promising mini-UAVs.

Another shortcoming identified by the Iraqi experience was the low efficiency of intelligence data coming directly to military units that fought in a particular sector of the city. Received information was outdated due to the rapid change in the situation during hostilities in the city. The enemy managed to disappear from the scene, so the information about him was no longer needed. Due to this, there was a need to adopt units of mini-UAVs to the ground forces, which would be used only in their interests.

A situation similar to Iraq, when low-level platoon-company commanders needed operational intelligence in hostilities against small terrorist groups, has appeared in Afghanistan. Among the new UAVs used there was the German reconnaissance UAV Aladin. Bundeswehr units from the International Security Assistance Force in Afghanistan have started to use it in March 2003. The reason for the creation of the Aladin UAV was the need to use small hand-held vehicles, which at that time were not available in the Bundeswehr's arsenal.

The Luna UAV which the German contingent has tested in the Balkans in 2000, was unsuitable in its parameters to carry out the tasks of the counter-terrorist operation in Afghanistan. The vehicle weighing 30 kg was launched with a catapult, which significantly limited its mobility, that was very important criterion. The Aladin UAV weighed only 3.5 kg and did not require a special launch platform. The UAV was launched by one person, and the aircraft landed with a parachute. The electric motor which rotated the propeller, allowed to develop a speed of 45-90 km/h and patrol the air for up to 30 minutes. On board of UAV there were a video camera and special equipment for data transmission to the command post.

Despite the fact that NATO countries have made rapid progress in a way the creation of UAVs, first of all, due to the participation of their contingents in the military conflicts in the Balkans, Iraq and Afghanistan, the leadership in the development and use of tactical level UAV remained with Israel. At the beginning of the 21st century Israeli units were armed with more than 10 types of tactical UAVs. There were no similar statistics in any country of the world. It is also important that these UAVs were actively purchased by NATO countries, primarily the United States, which used them in military conflicts.

The need to have tactical UAVs was indisputable for the situation in Israel. Only a small, low-noise and low-speed drone could perform the task of searching for terrorists in the city.

The Israeli military used the Mini-V short-range UAV to conduct air reconnaissance at the brigade level. The aircraft had a starting weight of only 55 kg, a maximum height of combat use of 4000 m and was equipped with modern reconnaissance hardware. The UAV was launched by a spring system from a rail launcher, and the landing was performed by parachute. The launcher was located on the roof of the transport vehicle from which the UAV was operated.

Mini-UAVs were used in Israel to conduct air reconnaissance at the platoon-battalion level and in the interests of special forces. One of the first examples of such devices was the UAV Skylight-B. The aircraft weighed only 4.5 kg, was launched manually, and patrolled the area within a radius of 10 km for 70 minutes. Successful use in unfavorable weather conditions was a feature of the UAV. Several Skylight-B systems were deployed at the battalion level and operated in combat areas for ground forces.

Skylark mini-UAV became one of the competitors of the Skylight-B UAV. Skylark had 1.5 times higher duration of Skylight-B (2 hours) at almost the same radius. In the devices with length 2 m and weight only 5.5 kg, the following modern reconnaissance equipment was located: three digital cameras or three thermal imagers which allowed to perform round-the-clock reconnaissance, including disguised objects.

It was established that a significant number of UAVs were used by the Israeli military during the fighting. At the same time, this created corresponding difficulties in their operation and logistical support, as each type of UAV had a separate ground control station and information processing, its own on-board electronic and reconnaissance equipment. In addition to the fact that these elements and systems had special features in the service, their own spare parts and control and testing equipment, each of the devices required special qualifications of service personnel. All this led to large financial and material losses. The experience of military conflicts has confirmed that in order to facilitate their operation in combat conditions, it would be advisable to unify individual equipment and make it common to a certain range of UAVs. This step would not only simplify logistical support and solve the problem of retraining for new types of UAVs, but also save money on new developments and simplify the production of UAVs. One of the first principles of unification of the basic elements has been proposed and implemented by the Americans. In order to control the unmanned aircraft Shadow, Hunter and unmanned helicopter Fire Scout they began to use a single control station. The Israelis have proposed their own kind of unification like the transition to a modular UAV system. An example of this is the emergence of a series of ‘low weight’ UAVs, known as I-View. The UAVs of three sizes with a takeoff weight of 50, 125 and 250 kg, required less logistical support than the existing UAVs at that time. The range of their application was from 50 to 150 km, the duration of stay in the air - from 6 to 12 hours, and the payload - from 8 to 41 kg. All versions used the same software. One of the advantages of the modular approach was the possibility of easy interchange of sensors. Reducing the weight of the payload allowed to take a larger supply of fuel to increase the flight range.

Thus, since the conflict in the Persian Gulf region in 1991, the tendency to use reconnaissance UAVs in the interests of the lowest levels of the military management ‘platoon-company-battalion’ has been intensified. At the same time, with the lower level of the unit, UAV was smaller and more mobile. Tactical-level UAVs, in most cases, have become the only one way of reconnaissance that provided tactical units with real-time information about the enemy. As a result, commanders were able to respond to changes quickly in the situation that increased the effectiveness of their units.

5.3. Strategic reconnaissance

Strategic reconnaissance is able to obtain extremely valuable information about what is happening within the borders of a foreign country or in a fairly remote region. It provides information about secret military preparations or reveals projects that state governments deem necessary to keep in secret.

However, obtaining data about the testing of new combat systems, which deployment is prohibited in a number of countries, or the hidden construction of production facilities to create chemical or nuclear weapons is not actually possible. Many opportunities have appeared with the advent of space reconnaissance, but it has been able to replace aircraft in the task of conducting continuous reconnaissance in remote parts of the world. In this case, in contrast with strategic manned aircraft, remote-controlled high-altitude drone may have much smaller dimensions and, consequently, less probability to detect, and the pilot and operator are not at risk in the process of performing tasks that can be treated as air espionage.

The problem of using UAVs to carry out reconnaissance missions at the strategic level firstly arose in Iraq in 1991. The available UAVs, numbering about 30 in Iraq at the time, prevented the MNF from performing lasting search for Iraqi Scud and other objects on a large Iraqi TOW with its desert terrain. One way to solve this problem was to use several UAVs to reconnoiter one object at the same time. However, it also did not achieve the expected result because the maximum possible radius of flight of the existing reconnaissance UAVs was less than required. Some facilities, such as Scud OTM, required constant, almost round-the-clock, surveillance (during the Iraq war, Shadow-600 had the best duration and range of all UAVs used there: 14 hours and 200 km respectively).

Analysis of hostilities results in Iraq in 1991 has showed the need for long-range reconnaissance UAVs with a range of about 1,000 km or more. These drones had to have an appropriate control and communication system that would provide the possibility to control the aircraft over long distances from the ground command post, and on-board reconnaissance equipment which would allow round-the-clock round the clock reconnaissance and transmission of reconnaissance data over a distance of more than 1,000 km in real time.

At the same time, the issue of creating and using strategic UAVs was not relevant for all participants in military conflicts. If for the Israeli army, whose reconnaissance facilities existed mostly in operational and tactical depths up to 400 km, this issue was irrelevant, for the U.S. Department of Defense, whose potential reconnaissance facilities were located in overseas air defense systems, the issue of having strategic UAVs with the ability to remotely control from the mainland became one of the top priorities after 1991.

During the first war in Iraq, the United States already had a strategic-level UAV. It was a Gnat-750 UAV able to conduct air reconnaissance within a radius of 2,800 km for 40 hours. The Gnat-750 UAV have performed its first flight in 1989, but there is no information on its use during the 1991 Iraq conflict. According to experts' opinion, there are three main reasons why mentioned UAVs were not a part of the MNF in Iraq. First, before 1991 the military had not fully evaluated the role of UAVs in military conflicts. Secondly, at that time, trends in the use of UAVs were determined mainly only by the experience of the Arab-Israeli conflict, when UAVs at the strategic level of intelligence did not exist. Third, the Gnat-750 UAV was released in 8 copies for use only in the interests of the CIA and the military may not have information about its existence or have access to it.

The first combat use of the Gnat-750 (strategic reconnaissance UAV) happened in 1994, when UAVs were used for observation flights over the Balkans. Considering the information that at the time UAVs have already passed modernization, which included the installation of television and infrared cameras, on-board navigation equipment, these devices could be used before as well.

Thus, it was established that the first unit of the UAV Gnat-750, subordinated to the CIA, has been relocated from the United States to the Balkans in late 1993. Its probable base is the Island Brac in Croatian. UAV remote control has been performed from Albania. However, the videos could be transmitted to the United States via satellite.

The presence of this UAV in the Balkans was prompted by the need to collect data to support of ‘Operation Deny Flight’, which began on April 12, 1993. NATO aircraft had task related to supporting UN troops and destroying targets that threatened UN-protected cities. The task related to detecting and continuously monitoring the objects of future selective strikes had particular importance. All this required accurate and operational intelligence data which, according to the experience of the first months, could not be provided by the piloted aircraft. First, because of the constant threat for aircraft to be shot down (at that time in the airspace of Yugoslavia losses of combat and transport aircraft were already existing), and secondly, due to the limited capabilities of reconnaissance aircraft in duration and range. Another reason that made it difficult to use manned aircraft for reconnaissance missions was the high flight speeds, which made very difficult to detect and recognize the object in the mountainous and forested terrain of the Balkans. Thus, only strategic UAVs could become a reliable source of intelligence data.

The UAV unit in the Balkans includes three Gnat-750s, a mobile control and information processing station, and a ground satellite module. The first combat reconnaissance flight of the UAV took place on February 1, 1994. The CIA used one of the most secret American aircraft, the RG-8A Condor, to relay control commands to UAVs and receive intelligence from it. It was a low weight, unnoticeable, super-quiet aircraft capable to perform long flights and equipped with a large variety of sensors, including for communication. The main reconnaissance tasks that have been solved with the help of the Gnat-750 UAV were the following:

finding the location of the armored units, artillery and AAMS positions of the Serbs; control of the UN convoys moving.

Unfortunately, the results of the Gnat-750 UAV did not fully meet the expectations relied on these unmanned aerial vehicles. The vehicles could not provide reconnaissance at night and in difficult weather conditions, as they had optical sensors that were able to operate only in daytime conditions in normal visibility. In addition, there were significant shortcomings in the data transmission system from the UAV to the ground station. Only 12 among the 30 reconnaissance flights conducted in the winter of 1993-1994 have been considered as successful ones. As a result, due to unsatisfactory performance of tasks, SAS units of the United Kingdom (Special Airborne Service) have been relocated to Bosnia to support the Gnat-750 UAV. The British special forces have been tasked with identifying AAMS positions, command posts, communications, depots and artillery batteries, aiming at identified Allied aircraft targets and determining the results of strikes that previously assigned to UAVs. AAMS actions have often been more successful than UAV actions. Due to low performance, the AAMS reconnaissance unit was derived from the Balkans, and the number of SAS has been increased from one platoon to two squadrons.

Gnat-750 UAVs could not fly in the Balkans during the winter, so their operation was stopped after constant issues with icing and due to the loss of two aircraft due to ground fire and accidents. Despite the problems and accidents, the drone became famous for not ‘keeping an eye’ on the target, which later American experts began to define as ‘continuous reconnaissance.’

In the summer of 1995, new UAVs has appeared in Bosnia to replace the Gnat-750. These were American Predator reconnaissance UAVs. In fact, in 1994 General Atomics company has changed the name ‘Gnat’ to the ominous ‘Predator’.

The Predator UAV has received its world-famous spherical nose to accommodate a satellite antennas. The advantage of this device was the use of the widespread GPS navigation system which allowed to achieve accurate positioning, the lack of which was a problem for previous drones. In addition, the drone took off and landed on usual runways.

The Predator UAV has proved to be the best during tests and training and made its first combat sorties from Hungary, operating over Kosovo in 1995. A unit of 10 US Air Force vehicles has been sent to the Balkan conflict zone to monitor the conflict area and identify location of dangerous military objects. The UAV ground control station was based in Albania and the command post in Italy (at the Joint Intelligence Center in Naples). UAVs were used in Bosnia and Herzegovina until October 1995.

The Predator was more than three times (800 km vs. 2,800 km) inferior to its predecessor the Gnat-750, but was able to perform a much wider range of reconnaissance tasks thanks to more advanced onboard reconnaissance equipment, communications and control equipment. Its most important feature was the use of satellite radio lines to communicate with the ground control station and information users. Due to this, the range of the UAV was limited only by its range. The drone, thanks to the reconnaissance equipment installed on it, was able to make video recordings, and as the result, the movement of objects and human behavior was observed, which could not be done before with the help of aerial photographs.

The use of the Predator UAV did not cut off direct radio communication between the device and the ground station. The range of direct radio communication was about 300 km, but radio visibility at such a distance could be provided only at high altitudes, at least 7000 m (maximum altitude of the Predator UAV was 7620 m above sea level). However, frequent heavy clouds in the Balkans made high-altitude flights impossible, and as a result, the UAV's communication with the ground station was ineffective, leaving the satellite channel as the main channel for data transmission and control.

To ensure reconnaissance in all weather conditions and heavy clouds, the device has been equipped with modern color video cameras, infrared sensors, RS and RTR equipment. This is exactly what the MNF lacked during the fighting in the Persian Gulf in 1991.

Regarding the intensity of the Predator UAV in 1995, information is not widespread but it is known that in a few months the flights had losses. Serbian air defenses were able to detect the Predator UAV, which was declared as inconspicuous, as a result, two UAVs were shot down. One has been shot down at a low altitude in low clouds when it escorted the transport convoy for a long time. Among other things, there is information that the operators liquidated it themselves, sending it uphill due to an engine problem.

During the stay of the first unit of the Predator UAV in the Balkans, it turned out that number of reconnaissance drones was not enough to perform reconnaissance tasks in conditions of growing tensions in the region. As a result, it was decided to increase reconnaissance forces via using of additional UAVs. According to the facts, at the beginning of 1998 the total number of Predator UAVs was already 35 units.

The date of the beginning of large-scale use of the Predator UAV in the Balkans can be considered October 30, 1998, when the air reconnaissance ‘Operation Eagle Eye’ (‘Eagle’s Eye’) has started. The sources prove that the Predator UAVs openly conducted intensive air reconnaissance of the entire territory of Yugoslavia with the following tasks: reconnaissance and advance reconnaissance of the locations of the Yugoslav Army; observation of the battlefield: control of the situation in the territory occupied by Albanian separatists.

In Kosovo, the Predator UAVs were the only devices capable to perform reconnaissance at high altitudes and at big distance from the launch site, including in the dark. The speed of the Predator UAVs to obtain intelligence in patrol mode was incomparable to the capability of manned reconnaissance aircraft. Thus, the Predator UAV, using the capabilities of the Global Broadcast Service, provided reconnaissance video information in 15 minutes on demand. The SR-71 strategic reconnaissance aircraft took 36 hours to complete a similar task. Thus, it can be stated that the efficiency of strategic air reconnaissance has increased more than a hundred times due to the use of Predator UAVs.

Despite the widespread use of Predator UAVs, the devices had significant shortcomings that limited their use. In particular, as it turned out, this applied to onboard equipment, which characteristics did not fully meet the requirements of combat operations in various weather conditions. From the beginning of winter, just a few months after the start of flights, flights have been suspended because the UAV was unable to function properly in Kosovo’s winter conditions, including heavy rains and snowfalls, low clouds and severe frosts.

Another disadvantage of using the Predator UAV is that the appearance of noisy and large Predator UAV over the enemy’s positions often led to the loss of the suddenness factor. This often minimized the effect of flight results and gave an extra time for enemy to move and camouflage.

It should also be noted that the basic version of the Predator UAV has appeared only in 2000, and it was expected to be ready for deployment in the US Air Force operation for continuous reconnaissance. Modernization has provided a more powerful engine and radio for negotiating with friendly aircraft in hostile airspace.

The use of the Predator UAV anticipated its inclusion in a classify network. However, the drone has not been certified by the US Department of Defense to communicate directly with such networks. As a result, during the deployment in the Balkans, not only videos but the entire system was disconnected from global networks. The coordinates of the targets were transmitted to the control point on a diskette or through a ‘network of informers’ that are specialists who moved from one place to another and recognize the numbers. The receiving party, who analyzed the videos, observed unrelated data and had little opportunity to transmit feedback or adjust the direction of flight, the drone, the angle of rotation of its sensors. At the same time, it was not clear enough for the pilots and UAV reconnaissance operators what they were doing within the overall picture.

Despite thementioned shortcomings, it can be stated that the use of the Predator UAV in a real combat situation in Yugoslavia has shown that strategic reconnaissance UAVs are able to provide continuous surveillance of large areas more effectively than any other type of strategic reconnaissance. Thanks to the use of strategic drones, it was possible to abandon the refuse from usual method of performing the established number of UAV flights per day, which achieved the continuity reconnaissance of the object (area).

In the experience of military conflicts, it can be assumed that the prerogative of strategic reconnaissance UAVs remains observation flights at medium and high altitudes.

The need to have strategic UAVs has become absolute. It should be highlighted that the Predator UAV in its individual characteristics, for example in range, took an intermediate link between operational and tactical and strategic vehicles. At that time, the armies of the world’s leading countries did not have a modern strategic UAV capable of flying thousands of kilometers from the control point.

Only two years later, in 2001 in Afghanistan, in addition to the Predator UAV, a strategic reconnaissance UAV Global Hawk has appeared, together they were able to keep under constant control almost all the dangerous territory. Despite the fact that only eight

Predator UAVs and three Global Hawk UAVs took part in the preparation and conduct of ‘Operation Enduring Freedom’ (35 Predator UAVs took part in the preparation and ‘Operation of Eagle Eye’ in Yugoslavia), a wide range of tasks emphasized the special importance of strategic UAVs. Among the main tasks were the following: reconnaissance of air defense equipment in Afghanistan, studying the level of its combat readiness and combat rules; receiving data on the results of missile and bomb strikes and identifying new targets; obtaining information on the location and activities of military groups; tracking of stationary and mobile military facilities; identifying targets for missile launches; transmission of intelligence information in real time to control points; guidance of Air Force tactical aircraft and Navy deck aircraft to targets in real time; interaction with manned reconnaissance aircraft.

It was typical for Afghanistan to use of the Predator UAV for reconnaissance, but also testing the possibility of its use in the version of a reconnaissance and strike drone. The reason for this was quite valid. The Predator UAV actually began flying over Afghanistan in the summer of 2000. During the seventh flight on September 27, the crew has found a tall man in white clothes, surrounded by short people who behaved like guards. This man, according to the Americans’ data, was bin Laden (later analysis of available videos showed that in fact he was discovered for the first rime a month earlier). Although bin Laden has declared war to the United States, it could not be eliminated. With using the Predator UAV, it was only possible to detect it, but it was not possible to destroy it. This was the basis for the armament of the unmanned vehicle and its transformation into a reconnaissance and strike version of the MQ-1B Predator by arming it with missiles.

Among three stages of UAV use in Afghanistan, only the first (in preparation for 'Operation Enduring Freedom') and the second (active phase of the operation from October 7, 2001 to December 6, 2001) Predator UAVs have been used to perform reconnaissance missions. The third stage used mainly the reconnaissance and strike version of the MQ-1B Predator.

Overall, the use of the Predator reconnaissance UAV in Afghanistan is considered as successful. At the same time, their capabilities were not fully used. Thus, according to Colonel Thomas Bright, Deputy Chief of Operations of the US Central Command, despite the fact that 8 Predator UAVs were involved in 'Operation Enduring Freedom' in Afghanistan, the capabilities of ground control stations provided simultaneous stay in the air only one or three devices at any given time. In his opinion, to ensure effective combat operations, it was necessary to have five or six UAVs in the air at the same time.

Another shortcoming, according to experts' opinion, was the lack of trained personnel. It turned out that the number of UAVs could be higher, but they did not have enough pilots in the crew. As experience from the war has shown, the lack of personnel in Afghanistan was about 50%. As a result, only half of the aircraft have been deployed over Afghanistan and were able to be used with enough pilots. The problem of providing by pilots has become a constant situation that required a radical solution in terms of motivation: financial support, career growth, encouragement, and moral and psychological condition. This is confirmed by the results of research conducted by American expert David Mindell and published in the public domain in 2015.

Afghanistan became the first region of application of the American UAV Global Hawk. It has a corresponding external resemblance to the Predator UAV: V-shaped tail and enlarged nose of the fuselage. At the same time, Global Hawk, which had much larger dimensions and weight, was a purely high-altitude strategic reconnaissance, operating at high altitudes - up to almost 20 km. Given the takeoff weight of the UAV, Global Hawk is equipped with a powerful turbofan engine. Unlike many drones, this aircraft was able to perform maneuvers immediately after takeoff and actively gain altitude. At an altitude of 18288-19812 m, it can stand up to 42 hours.

Realizing the potential of the drone, it was considered irrational and ineffective to track the activity of small groups of terrorists or other small mobile objects. Therefore, the main purpose of the drone was to monitor strategically important reconnaissance objects and to provide continuous round-the-clock surveillance of large areas. The main difference, compare with the strategic manned reconnaissance aircraft, was that the Global Hawk UAV could fly on three times longer distance and consume much less fuel per flight hour. In 2001 this drone has made a record flight across the Pacific Ocean.

The use of the Global Hawk UAV in Afghanistan was limited by few flights to work out technical issues of combat use and interaction with ground forces.

The Global Hawk UAV is considered to be the first unmanned aerial vehicle designed to operate in new high-risk environments. In the early 1990s, the strategic drone had to solve the same tasks as the U-2 manned reconnaissance aircraft, but with lower cost.

The main difficulties in the application of Global Hawk, as it was later established, were the organization of management of these devices. The Global Hawk UAV had to have three satellite lines to support Afghanistan's typical combat operations. The first one had to be used by a control point in Europe to control UAV flights and receive data. Secondly, the received data obtained were transmitted to the United States for use in the relevant authority of analysis and planning of hostilities. The third line was needed to send instructions from the United States to the European control center about the continued use of onboard reconnaissance equipment for the UAV. Some elements of the UAV control system could be located in different parts of the world, in contrast to similar elements of the Predator UAV, most of them were located in Afghanistan or near it.

One of the main lessons of the conflict in Afghanistan is that while the United States' intelligence-gathering capabilities have been excellent, it has not been enough to keep all the hotspots under control.

At the same time, the prospects for the use of strategic UAVs in Afghanistan began to be significantly affected by the financial component, which could lead to the denial of their use. An example of this statement was the situation with the Global Hawk UAV. Thus based on the experience of using UAVs in Afghanistan, there is a need to improve its individual tactical and technical characteristics. It was necessary to install additional sensors on the UAV and significantly complicate the onboard equipment, which led to increase in its total value. As a result of such refinements, the price of UAVs has approached the level that Americans have paid for bombers in the past. In 1997 during the development period the cost of one Global Hawk UAV was 16.4 million USD USA, then in 2001 the Global Hawk UAV with optoelectronic and infrared cameras, as well as the new radar, already cost about 28.2 million USD. The larger RQ-4B Global Hawk which could carry much more powerful sensors, including radio reconnaissance systems and advanced RS, cost an estimated 43.1 million USD, not including the cost of RS. Currently, the cost of the Global Hawk UAV is over $ 100 million USD, and the hour of its flight more than 30 thousand USD.

Thus, it can be stated that strategic UAVs began to become unavailable in terms of finance, as their price has gained almost the same as manned aircraft had. In addition, as a result of further price increases, UAVs have begun to adapt to the various existing communication networks and information exchange. As a result of significant financial costs, the military may eventually abandon such UAVs. This is a confirmation of the opinion that the issue of financial ‘attractiveness’ of UAVs should be one of the main ones.

The next step in testing the relevance of strategic reconnaissance UAVs was ‘Operation Iraqi Freedom’ in 2003. The use of Predator and Global Hawk UAVs in operations has allowed reconnaissance to be conducted on the whole territory of Iraq. Among the top priorities were the collection of data regarding the location of control points, air defenses mean, units and parts of the Iraqi armed forces, potential facilities for the production and storage of weapons for mass destruction, OTM ‘Scud’, and possible shelter places for Saddam Hussein.

Predator UAVs, both in the Balkans and Afghanistan, have been collecting intelligence in Iraq to destroy specific targets. At the same time, the use of the Global Hawk strategic UAV had its own peculiarities. During the flight at high altitudes for 38 hours UAV inspected large areas, conducted reconnaissance of high-resolution point targets, and provided real-time information transmission. One Global Hawk UAV has been involved in reconnaissance operations in Iraq, which forced the Americans to take the most careful measures to save a single vehicle. Therefore, during the conducting observation flights over Iraq, the timing of UAV flights was coordinated over time with the actions of tactical fighters that suppressed the Iraqi air defense system, ensuring the safety of UAV flights. And in order to make the most efficient and effective use of the results of the UAV’s flight, real-time reconnaissance data from it came to the attack planes that destroyed the detected objects.

The beginning of the launch of this vehicle cannot be called successful because of the issues with the channels of intelligence transmission. For example, in late March 2003 a Global Hawk UAV has been lifted launched the air to monitor 30 potential targets for the Baghdad bombing. However, due to complications in the process of data processing and transmission, reconnaissance was obtained with a delay, which affected the timing of the task.

At the same time, the UAV's value as a strategic spy, has been confirmed later in 'Operation Iraqi Freedom'. Despite the fact that the Global Hawk UAV accounted for only 3% of all US reconnaissance flights and 5% of high-altitude flights, the UAV collected 55% of all operational data on the location of Iraqi air defense positions and took more than 4,500 images of Iraqi military facilities. During the Global Hawk UAV flights, operators discovered at least 13 anti-aircraft missile positions, 50 launchers, 300 containers and 70 missile transporters. In addition, images of 300 tanks were transferred, which accounted for 38% of all known at the time armored fleet in Iraq. For comparison, the US Air Force's U-2 strategic reconnaissance aircraft, which accounted for 80% of all aerial photographs taken during the 1999 NATO coalition operation in Kosovo, was used in Iraq in 2003 only for its ability to conduct radio and multispectral species intelligence.

The need for permanent control over large areas has led to the continued use of Global Hawk strategic UAVs in Iraq after 'Operation Freedom of Iraq'. However, their number has been increased. Thus, if during the operation the only Global Hawk UAV was used exclusively in the interests of the Air Force reconnaissance, in 2005 two Global Hawk UAVs were received for use in the interests of the US Navy.

A significant disadvantage of the UAV was its inability to detect dangerous weather conditions and evade maneuver.

During the Iraq campaign in 2003, the number of losses of strategic UAVs (Predator) amounted to 25 aircraft, most of them happened not from the actions of the enemy, but from the mistakes of operators and due to failure of equipment.

The ongoing Syrian conflict has continued the history of regular use and loss of Predator and Global Hawk drones to carry out reconnaissance missions in the country and russian bases. During 2015, the United State lost 10 destroyed and seriously damaged Predator UAVs (one of them was shot down and the rest disabled or lost for non-combat reasons). There is information about the possible loss of one Global Hawk UAV near the coast of Syria, shot down by a russian S-300 surface-to-air missile launched from a russian base.

The use of the RQ-170 Sentinel strategic drone, which made its first flight in 2007 and has been used in Afghanistan since that year, is not ruled out by the United States in the interests of conducting air reconnaissance in Syria. The unmanned vehicle has been made using stealth technology.

Thus, due to the use of strategic reconnaissance UAVs in military conflicts of the late 20th - first decade of the 21st century it was possible to implement one of the main requirements for air reconnaissance - to ensure continuous surveillance of objects and large areas. Even a relatively small part of the tasks of strategic UAVs compared to other classes have shown that without the use of such UAVs in modern conflicts, it is not possible to rely on the accuracy, completeness and efficiency of reconnaissance.

6

APPLICATION OF UNMANNED AVIATION IN CIVIL AREAS

Among the main areas of airline services expansion using UAVs in the civil aviation sector are the following mentioned below.

UAVs have become the most popular in the agricultural sector. Here they are used for operational monitoring of the crops condition, creating an accurate map of the fields considering the terrain for further use in geographic information systems, to build routes of agricultural machinery. Modern crop monitoring technologies allow farmers to apply fertilizers and plant protection products to those areas where it is really needed. Aircraft can be involved in assessing the suitability of plants for reproduction and in collecting the necessary pollen, spores and dust. Drones will be needed to protect the crop from birds and other animals, to determine the current stage of ripening and, most importantly, for its overall assessment. If to review animal husbandry separately, then the use of UAVs is possible during the studying the patterns of animal migration, identifying sick individuals (including rabies). Drones will help to find animals in the open area, as well as assess whether the place is suitable for hunting grounds.

In forestry UAVs are used to classify and inventory forests, assess such important indicators as the average height of trees, their number, planting density. UAVs are also widely used to identify real and potential forest problems, among them we can highlight tree diseases and natural disasters, especially forest fires. The capabilities of drones provide insurance companies with a convenient way to assess damage to forestry in appropriate cases. UAVs can be used during reforestation after the mentioned events, including the development of a «digital layout» which is an interactive map that clearly shows the current state of the forest. Insurance companies have also become actively interested in unmanned aerial vehicles.

UAVs can remotely check the condition of technical facilities, equipment and fields, their inspection may be associated with a risk to the health and lives of employees.

In the oil and gas industry, UAVs can be used in such important aspects as assessing the state of the environment in drilling areas. This significantly reduces the cost of these research. Drones are also great for tracking oil and gas pipelines. Given the frequent problems with oil spills and natural gas emissions, the use of UAVs is relevant for fast response to these crises.

The same functions of UAVs are performed in mining-related industries. This includes quality control of the environment, especially water, in areas of mines, monitoring of gas emissions during hydraulic fracturing. Drones are already monitoring the current state of mines, as well as looking for new sources of minerals and precious metals.

UAVs are useful for infrastructure during the monitoring of railways condition, roads, and power lines, assessing their damage, detecting leaks from pipelines.

UAVs are also widely used in the assessment of urban land use. Other important uses of UAVs include search and rescue operations and science research (both on land and on water). In general, UAVs are very convenient and unpretentious in the process of operation, the directions of their application can be found in almost all areas of business, including those not mentioned above.

6.1. Disaster medicine

The rapid development of the nuclear and chemical engineering industries in the world against the background of the greenhouse effect on the planet Earth accompanied by a large number of emergencies of technogenic, natural and social nature, however, the number of wars and local armed conflicts does not tend to decrease. All the above in the life of modern humanity requires a significant, careful attention to the issues related to ensuring the safety of life, health and life of the population, saving economic potential and the environment. This is due to the increase in the number of natural and man-made disasters and the growing scale of losses from them. People affected by emergencies need express medical care. At the same time, it is often not about individuals, but ten or even hundreds of people. In these conditions, in foreign countries, the activities of specialists in emergency care and disaster medicine could not be imagined without the appropriate equipment of their units with innovative means of preventive medicine, diagnosis and treatment of patients that are medical drones. This is, first of all, the time of arrival to the patient (victim) in accordance with the resolution of the Cabinet of Ministers as of 21.11.2012 № 1119 «About tandards of arrival of emergency (ambulance) teams at patient's location». Standards of arrival of emergency (ambulance) crews to the patient's location on demand should take time in cities above 10 minutes, in settlements outside the city about 20 minutes from the moment of the request to the dispatcher of the emergency dispatch service in emergency medical disaster care center and medicine [7], which is significant affects performance and that can be overcome through aeromedical evacuation and medical UAVs.

In developed foreign countries, medical UAVs are aerodynamic containers that are used to transport medicines and medical devices, including primary and home care products and vaccines.

In order to develop innovative UAVs with the required accuracy and speed of drugs and medical devices delivery to a given place, in the developed countries of far and near abroad there are ongoing systematic research in this area. UAV piloting is carried out in manual or software mode during long-distance flights and accurate passage of a given route. In addition, they also have several key advantages, such as not requiring landing space like helicopters and manned aircraft and can be programmed to drop supplies from low altitudes. Positive qualities of UAVs for the most efficient delivery of medical supplies are their ability to recognize obstacles in their path avoiding clash with them and the ability to resist surly weather conditions where manned aircraft and helicopters will remain on the ground and perform several flights during the day. In addition, an important positive factor regarding the feasibility of their implementation is the impressive ability to fly over emergency areas, and without the participation of the crew is a key reason for their high demand.

Other important benefits include, for example, transportation of blood samples or diagnostic equipment, laboratory reagents and tests, medical devices and products, including primary and pre-medical care and vaccines in remote and small hospitals and clinics, as well as key medical and surgical instruments, including portable ultrasound equipment and the provision of emergency medical support. This innovative technology provides with advantages such as prompt delivery of medical products, including antidotes or vaccines, for disease-prone residents of regions or areas of emergency care, providing medicines to victims and sick in hard-to-reach and remote places at home or on ships at sea. Moreover, the provision of defibrillators to patients suffering from cardiac arrest, and the transportation of organs required for transplantation are important purposes for the use of medical UAVs.

The market for medical drones in 2018 amounted to $ 40 million, according to foreign experts the global market for medical UAVs could reach almost $ 948 million by 2027.

6.2. Aviation measuring systems

An example of such a system is a simulation test complex for radar stations (RS) of space surveillance and missile attack warning systems [X]. This system is usually performed on the basis of two off-road vehicles, one - ground control point (GCP), the second - to transport UAVs with a launcher, and is able to provide autonomous operation in landfills in winter and summer time.

As a payload, UAVs are equipped with special equipment units that provide receiving of radar probing signals, their re-radiation, as well as transmission of data parameters through the UAV telemetry channel to the GCP for registration and further analysis. The UAV coordinate determination system together with the ground equipment of the GCP allows the registration of the flight trajectory with an accuracy of not more than 1 m in space with the calculation of the UAV location at any time in the radar coordinate system. In the future the comparison of the reference trajectory of the UAV that obtained by measurements from the radar is used to calculate the corrections for the adjustment of the RS. The adjustment process is performed by UAV flight at a distance of 10 to 60 km and altitudes from 50 to 3000 m from the radar station, at the same time the necessary flight trajectory is provided, for example, flying along the axis of the of the diagram beam or flying over the radius to comparison the energy of the partial diagrams of the multi-beam antenna array.

Such complex is not difficult to operate and allows to reduce the cost of RS testing compared to the use of manned aircraft for the same purpose.

6.3. Environmental monitoring

Aviation measurement systems are also effective when used for environmental monitoring. The current state of solving the problems of environmental monitoring in the world for various reasons could not be considered as satisfactory. The issues of environmental research cover a wide range of issues, each of them is characterized by relevant features and specifics. The control of the environment of energy objects, first of all NPP and TPP, has received the greatest development in solving of mentioned problems, especially in hard-to-reach places and in conditions of man-made danger. Nowadays the theoretical and methodological foundations for the design and practical use of mobile information and measurement systems for monitoring the environmental characteristics of energy facilities remain not enough developed. At the same time, radiation accidents at Three Mile Island (USA), Chernobyl (Ukraine) and Fukushima-1 (Japan) showed special relevance and the need for operational remote monitoring of external damage and radiation in the initial period of the accident. This opportunity came with the beginning of unmanned aerial vehicles using. Table 6.1 shows the comparative characteristics of the main types of environmental control systems in energy facilities which are widely used in world practice and showed the prospects of using information and measurement systems to control environmental characteristics based on UAC to solve actual problems.

Table 6.1

Functional characteristics of the main types of environmental control systems

Functions System type	Multifunctional	Multi-parameter	Possibility of tests (s-soil, w-water, a-air)	Metrological characteristics	Visualization	Control	Ecological safety	Price
Stationary laboratories	+	+	+	+	-	-	-	-
Mobile laboratories	+	+	+	+	+	-	-	-
UAC based systems	-	+ -	-	+ -	+	+	+	+

Creating a mobile remote-control system based on the UAC the following provides opportunities: to use the principles of creation a new class of environmental control systems; to develop modern hardware and software tools for remote performing of measurements and control of characteristics; environmental parameters; to ensure the efficiency and mobility of the application of the system based on UAC in different geographical areas of industrial enterprises, energy facilities, including inaccessible, mountainous, forested areas; to create and propose a new class of mobile control systems based on UAC for practical use, which provides opportunities for the implementation of modern control and measurement technologies in an automated mode, operation of systems in hard-to-reach places and under man-made conditions, including radiation, hazards, multifunctionality (adaptation) of appointment by changing the modules of sensor subsystems, conducting dynamic measurements in 3D coordinates; use the remote method of research, while ensuring the safety of

	Unmanned aerial measuring systems		
By method of measuring signals formation	Active		Passive
By method of data collection	Integral type		Differential type
By method of data transmission	Real time		With data storage devices
By the number of measuring parameters	One-parameter		Multi-parameter
By the duration of the life cycle	Disposable using		Reusable
By the number of UAVs operating simultaneously	With one UAV		With several UAVs
By the number of spatial coordinates	One-coordinate	Two-coordinate	Three-coordinate
According to the UAV control mode	Programmable		Operator controlled

Figure 6.1. Classification of unmanned aerial measuring systems based on UAC

researchers - operators in emergencies of energy facilities (accidents, disasters and others); to provide assessment of environmental characteristics in the areas of NPP and TPP according to measurement data. The classification of unmanned aerial measuring systems is offered (fig. 6.1).

This classification allows to justify the choice of implementation of environmental monitoring and control systems based on their purpose at the stages of development of technical tasks and design, as well as to identify a new class of control systems and take into account the peculiarities of its operation and practical use in various areas.

7

METHODS OF COUNTERING UNMANNED AVIATION

In recent years, UAVs have become increasingly widespread. As it was mentioned above, UAVs have long established themselves as reliable and effective means of conducting air reconnaissance, striking targets and performing some other tasks. According to experts' estimations, in the United States over the past 15 years more than 30 thousand UAVs of various classes and types, most of which are used by the military and special services, have been produced. Drones have been used extensively in all recent armed conflicts, as well as in other areas.

The successful detection and defeat of targets that have been repeatedly performed by UAVs in Iraq or Afghanistan, clearly demonstrates the development of such robotic aircraft. Moreover, such successes of UAVs are often the reason for the pluckiest predictions: it is sometimes claimed that UAVs will be able to completely replace manned aircraft and some other types of military equipment in the future. Even today, American experts conclude that remote-controlled aircraft of the US Air Force Predator and Reaper UAVs have become a public embodiment of the ‘robot war’.

However, according to the logic of the weapons and military equipment development, the drone can not be fundamentally all-powerful and invulnerable. The urgent need to effectively counter hostile or obstructing enemy UAVs in peacetime and wartime has necessitated the search for and development of a variety of ways to protect, destroy or capture drones. It is proposed to define this complex direction as the concept of ‘PDC’ (as Protection, Destruction, Capture) which evere country should have, especially given the spread of various forms and methods of terrorist acts.

7.1. Defense

Defense of ground objects from technical means of air reconnaissance, which are installed on UAVs, is a set of organizational and technical measures taken to exclude or difficulty in obtaining the data on reconnaissance objects with help of technical reconnaissance device (TRD), using reconnaissance or reconnaissance-strike drones.

As the experience of armed conflicts with the use of UAVs shows, all the variety of tasks to protect objects was reduced to three typical tasks: hiding of protected objects or their components from detection using (TRD); exclusion (or difficulty) in recognizing of hidden objects (or their components) using TRD; creation of false objects (imitation), similar to the real ones, hidden from detection using TRD. During the fighting the following known approaches to the protection of objects have been used: passive and active concealment.

Passive concealment excludes or significantly complicates the identification and detection of intelligence objects by eliminating or weakening their unmasking features. It is carried out by performing organizational and technical measures. Organizational measures include territorial, spatial, time, energy and frequency restrictions on the use and modes of operation of facilities (their components) that are hidden; use of camouflage (shielding) properties of terrain and local objects, hydrological and hydroacoustic conditions, meteorological conditions and time of day, which limit the possibilities of TRD application; exclusion of cases of keeping and storage of weapons and military equipment in open areas; creating special schemes for the transportation of weapons and military equipment; timely notification of objects of protection the appearance and actions of UAVs in the area of hidden objects.

The technical measures of passive concealment should include: technical solutions that reduce the contrast of objects in different physical fields relatively to the relevant background; technical solutions to reduce the level of various radiations and acoustic noise of hidden objects; use of camouflage absorbing and reflecting (scattering) the cover, artificial masks, awning, screens, absorbing nozzles, shielding structures; painting concealing objects in tones that correspond to the terrain and seasons; creation of aerosol, water, bubble and explosive curtains. Active concealment occurs due to the use of means of creating active and passive interference in various physical fields (electromagnetic, acoustic, seismic, hydroacoustic, radiation, etc.) and the false environment (imitation).

Operational and tactical camouflage by Iraqi forces has become a factor that negatively affected the results of aerospace reconnaissance systems and assets by multinational forces in Operation Desert Storm against Iraq (1991).

The camouflage included the use of a large number of different models of tanks, planes, fake airfields and starting (firing) positions. Iraq has effectively used both fake man-made military facilities and new means made with the formed fiberglass, and new means such as inflatable models of tanks, planes, launchers and infantry fighting vehicles. These false artificial military objects had a corresponding silhouette (shape), as well as similar radar and thermal unmasking features, which, taken together, allowed to reliably simulate real combat equipment and successfully mislead the enemy. Numerous fake radio networks have been set up, as well as camouflage nets, dozens of hectares were purchased in advance by Iraq.

The reconnaissance mission to search for Iraq's ground-to-ground tactical missiles Scud-B proved to be the most difficult for the multinational reconnaissance aircraft. The Scud-B stationary launchers were destroyed almost during the first day of the air operation, the search for locations for mobile missile systems became quite problematic. During the first two weeks, about 30% of all Allied combat flights, including UAVs, were used to solve the task of finding Iraqi OTM 'Scud-B'. However, all mobile systems could not be affected, despite the fact that during one hour before launch, they were in the open in a stationary position (installation of a liquid-propellant missile in a vertical position, untwisting of gyroscopes of inertial guidance system and rocket launch are performed within an hour after the mobile complex reaches the starting position. After launching the missile, the OTM launcher can be quickly relocated to another area). Moreover, it was known that Iraqi OTM complexes were based in only two areas in a relatively small area. Only a small number of them have been detected in the initial stages of preparation for launch, which made it possible to target attack aircraft. Some of the flights had the wrong targets, which distracted significant forces of reconnaissance and strike aircraft. After all, among the 43 operating Iraqi Scud-B mobile complexes, only 8 were found and fired from the air, but the results were not confirmed by photos. The command of the multinational force has openly admitted that the fight against the active Iraqi Scud-B missile systems has been ended without any results. Inconspicuous air missiles, which periodically changed their location, have not been managed to 'calm down' until the end of the war.

In 1980-1988, the Spanish construction company Grexa built 150 underground hangars in Iraq, which would be enough to hide half of the Iraqi Air Force planes from aerospace reconnaissance aircraft. These hangars were able to withstand air bombardment. They were built based on British projects, so the aircraft of a multinational force was not able to destroy them.

Iraqis' use of camouflage properties of the area, various structures (tunnels, bridges, overpasses, etc.), service camouflage coatings, the creation of a system of erroneous positions and trenches, and the imitation of hostilities have made it difficult to obtain intelligence by multinational intelligence forces.

For example, Iraqi forces have managed to disguise the location of air defense equipment not only from high-resolution US reconnaissance spacecraft, but also from multinational reconnaissance aircraft, whose command has admitted later that 50% of air strikes were on misguided targets. A similar result took place with inflatable models of tanks.

Iraq's widespread use of man-made facilities and the simulation of the operation of targets after firing on them significantly reduced the effectiveness of damage of airfields, air defense positions and complexes, as well as other important facilities. This allowed the Iraqi side to mislead the combined central command about the real scale of the losses and become the reason for the low effectiveness of the first air strikes. The command of the multinational force had to review plans and approaches for the next fire strikes and hostilities, to postpone the air-ground operation to liberate Kuwait.

Due to the well thought out and high quality camouflage of many objects, a significant number of MNF aircraft strikes have been carried out on false targets (models of aircraft, RS, OTM CP, false AS, CC, etc.). Good organization of the restoration work should also be noted: many facilities were rebuilt by engineering units during the dark hours of the day, they camouflaged it in a way to continue to appear affected from the air or space.

Space and air reconnaissance have been widely used by US troops in the war against Iraq and generally showed high effectiveness. At the same time, there were many cases when, as a result of high-quality camouflage measures in Iraqi army units, primarily the construction of faulty objects, the probability of finding true (up to 0.2) objects was sharply reduced and, as a result, strikes have been made on simulated objects.

Calculations show that in order to reliably cover groups of troops, the number of defective objects in relation to the real ones should be 50-75%, which requires the involvement of a significant amount of forces, resources and time to perform relevant work. In this case, to divert self-guidance munitions from important objects, you need to simulate 1-2 false targets per 1 real object, which will reduce the probability of damage to the latter to 0.3-0.4.

It should be highlighted that qualitative camouflage carried out by the Iraqis, despite the limited camouflage capacity of the TOW, even deserved praise from the chairman of the Committee of Chiefs of Staff of the United States, General K. Powell.

The preservation of the Yugoslav army during Operation Allied Force of NATO forces against Yugoslavia (1999) was facilitated by operational and tactical camouflage measures taken in advance throughout the country. Their sense was not only in the use of existing means of camouflage, but also in the use, following the example of Iraq, of a huge number of fake objects created from vinyl film. Inflatable copies of armored vehicles, tanks, aircraft, anti-aircraft systems and even bridges were made in a record short time. They were kept in strict secrecy in various places away from settlements and military units. This allowed the Yugoslavs to save much of their military equipment from enemy attacks. The condition of Yugoslav troops and the amount of military equipment withdrawn from Kosovo were a clear demonstration of the results of effective

Yugoslav camouflage.

In order to reduce the effectiveness of the use of weapons by the United States and NATO countries, the Yugoslav Armed Forces have conducted a set of organizational and technical measures within the framework of operational camouflage. They were aimed at misleading the enemy about the composition, location, condition of groups, planning future actions to increase the survivability of troops (forces) and achieve the suddenness of their combat use. The main tasks of camouflage were the following: to ensure the secrecy of the headquarters, troops and military facilities; misleading the enemy.

Ensuring the secrecy of the armed forces was carried out by carrying out a set of measures aimed at preventing or eliminating the leakage of information, loss of state and military secrets, elimination or weakening of unmasking signs of dislocations and all types of military activities.

The camouflage of troops and objects was also carried out with the use of natural materials, environmental properties, and the movement of troops only at night.

The Air Force masked aerodromes, relocated aircraft to alternate aerodromes, arranged false parking places using aircraft models, sheltered aircraft in mountainous and forested folds of the area near highways used as airstrips. In a number of cases, NATO Allied tactical aircraft have not been able to carry out targeted bombing during the repeated strikes due to smoke caused by fires and also created by special smoke bombs.

Experience with the use of false man-made weapons in the local war between the US & British coalition forces against Iraq (2003) has shown that the effectiveness of the E-8C JSTARS and U-2S reconnaissance aircraft has decreased, especially for mobile purposes, due to the widespread use by the Iraqi armed forces of the natural conditions of TOW and artificial shelters, as well as means of camouflage and disorientation. In this regard, special attention was paid to the use of reconnaissance and striking UAVs, although this step was also not effective enough. The American news agency Associated Press (2013) has managed to find in Mali a document intended for Islamist militants with instructions on protection from drones, which was left by retreating al-Qaeda militants in the Islamic Maghreb. This handbook, which has appeared on the Islamic Forum, describes 22 measures to protect against UAV. They include: placing of mirrors that reflect sunlight on the car or the roof of the building; constant movement of headquarters; creating the visibility of the assembly with the help of dolls and statues to mislead the enemy; hiding under trees with a thick crown, which is considered the best shelter from aviation; hiding in places where the sunbeams does not fall. All these tips were actively applied in practice by Islamists in Mali.

During the war in Syria, militants from ISIS-controlled territory masked oil tankers to simple trucks to transport oil to Turkey.

russian S-300 anti-aircraft missile systems were secretly delivered to Syria. They were unloaded from a large landing craft at the port of Tartus using an aerosol method of protection against US air reconnaissance, which regularly took place using a strategic UAV Global Hawk and a manned aircraft of electronic reconnaissance and RW EP-3E Aries II. A clay-sand mixture was used for the external camouflage of russian military equipment. ISIS militants in Raqqa actively used the method of camouflage to reduce the effectiveness of reconnaissance UAVs, the essence of which was to change the forms: cloths of appropriate color were stretched between the houses, which greatly reduced the ability of drones to detect targets.

The Turkish military used an inflatable model of the Leopard tank during the fighting against the Kurds in Syria, which the Kurdish fighters took to be a real tank and 'successfully' used the Iranian ATGM system Toophan-1 against it, in fact repeating the erroneous and quite expensive missile action of the Americans in Iraq in 1991.

7.2. Destruction

Only the positive impressions about the use of UAVs in military affairs, which happened recently, can be considered premature. It is one thing when the capabilities provided for UAVs are only available to their troops, it is another thing when they are in the enemy's arsenal in different versions: reconnaissance, reconnaissance-strike, strike, RW, etc. Today, thousands of military and double-purpose UAVs are ready to take part in armed conflicts. This is becoming very dangerous, given the fact that more than 85% of this number of drones are light small aircraft. How should we confront not one, not two, but several drones, if many of them are so small that they cannot even be seen by radar? This should be considered one of the most important issues of modern military science.

Methods of destruction of UAVs are formed based on knowledge of its construction (glider, engine), various devices and equipment installed on, control channels and transmission of intelligence information, etc.

A simple and well-known way of getting rid of an enemy UAV is considered to be its direct physical destruction. Any aircraft can be shot down if the conditions are appropriate. The problematic issue in this case remains the timely detection of the drone and a successful attack with its physical destruction. Different types of weapons can be used for this. For example, small light UAVs can be shot down with simple small arms, and to defeat heavy drones you need to use anti-aircraft missile systems, as happened in local wars and armed conflicts of the second half of the 20th century- the first decade of the 21st century.

For example, according to available data, 12 Pioneer UAVs were destroyed by air defense during the fighting in Iraq (1991). During the First War in Chechnya (1994-1996), two Bee-1T UAVs were shot down by militants who were able to organize heavy barricade fire with small arms and anti-aircraft guns along the flight route of the drones. During the Yugoslav war (1999), 11 NATO UAVs were shot down. At the same time, a significant degree of vulnerability of drones came from ground air defense means (according to various data, up to 60% of all lost UAVs were shot down by anti-aircraft artillery fire and individual air defense means such as ‘Arrow-1M’). During the Second Iraq War (2003), 1 Pioneer UAV and 2 Hunter UAVs were shot down. During the Abkhazian-Georgian conflict

(2007-2008) two of Hermes-450 UAVs were shot down at an altitude of 7,000 meters by air defense, and the remaining 5 Hermes-450s were shot down by Buk AAMS. During the Syrian conflict (since 2011), one Predator UAV was shot down by Syrian air defenses. It was the possible loss of one Global Hawk UAV near the coast of Syria, which had been shot down by a russian S-300 surface-to-air missile launched from a russian base. In 2017 alone, 16 drones approaching russian bases in Syria have been destroyed by air defenses. On the night of January 5-6, 2018, militants attacked russian bases in Syria with a swarm of drones including 13 strike UAVs, 7 of them have been destroyed by Pantsir-S1 missile and artillery systems, and the rest of the RW specialists have managed to take control. At least three russian drones have been shot down in Syria. However, it should be noted that the above data on the destruction of UAVs are not considered complete due to the fact that such information is limited in open sources.

The reality of today is that UAV technology has become available, and UAVs have begun to be included in the armaments programs of many countries around the world. At the same time, to destroy them, it is proposed to have effective systems, tools and methods of destruction. Military experts began to understand the difference between how easy it is to launch their vehicles at the enemy and how difficult it is to avoid alien drones into their territory, but also to counter them.

An attack on a UAV is possible with the use of any weapon, provided it is detected and identified in a timely manner. It is known that the main means of detection in modern air defense systems are radar stations. They are able to detect aircraft and helicopters at a distance of several tens of kilometers, depending on the characteristics of the target and the characteristics of the terrain. In a number of cases, UAVs, especially light ones, are a difficult target to detect using existing RS. These devices have a small effective area of reflection (EAR), so their detection becomes quite a challenge. In particular, the maximum detection range is reduced, and efficiency is lost. Heavy UAVs, such as the American remote-controlled Predator, Reaper or Global Hawk are quite large, which helps to detect them with existing air defense.

As any material object, an unmanned vehicle has unmasking features that make it visible into the surrounding space, making it visible to observation. The level of visibility is determined by the value of its signatures in the radio frequency, infrared and visible ranges, as well as acoustic signatures. Modern light drones have low signatures (0.1 m^2 - 0.01 m^2): UAVs are made of composite materials and plastic with a special color, as well as a special combination of layers. Their small petrol and even more so electric motors radiate little heat and work almost silently.

UAVs are little reflected when hit by a radar beam: their radio frequency signature EAR does not exceed 0.1 m^2, which is very small and creates difficulties in detecting an active surveillance RS. Scientific and technological progress in small-scale radar have already solved such problems. With the detection of UAVs with EAR 0.1 m^2, such radars are no longer difficult, but there was a more complex problem as the identification of the target and its separation from flying birds, obstacles and other reflected signals that locators usually filter. However, modern UAVs have low flight speeds, which also negatively affects the mode of selection of moving targets due to low Doppler signature.

The solution of such problems is considered together with creating locators that have a variable in the cycle of detection of disparate ability. Such radars are able to detect and identify flying objects with a small radar signature and moving on non-linear, difficult to predict, almost random trajectories.

The new generation locators use a bird identification algorithm.

One of the key technologies for such RS with an active phased array antenna is the technology of multi-beam identification methods with the accumulation of information to increase the detection capabilities of the drone via Doppler shift. RS with new technologies is able to provide analysis of the signature and kinematics of UAVs, and for more accurate targeting and target identification, they work together with optoelectronic means of detection. Using the data of the unique radio radiation of the drone, which can be recorded by means of radio reconnaissance is also effective. LTAR and VIGILANT FALCON radars from SRC (USA), HARRIER from De Tect (USA), SQUIRE from Thales (France), HAMMR from Northrop Grumman (USA) work in a similar way.

The inclusion in the UAV of the radio electronic equipment required for the performance of tasks (reconnaissance, strike, retransmission, etc.) leads to its unmasking for air defense systems and RTR means.

The American company Snake River Shooting Products has proposed to fight drones using special charges that can shoot down

UAVs during the flight. Probably, if you use an anti-aircraft gun installation with a special ammunition, which can be filled with metal bullets (weight is 1 g and the number of 400-500 pieces) and a ‘smart’ programmable detonator, then when the ammunition is detonated at the point of meeting with the UAV, the balls are able to create an area (cloud) of effective damage and make it a sieve. There is a similar well-known principle of building a shrapnel projectile, which was actively used in the wars against the enemy’s manpower.

An example of such ammunition is a 35-mm anti-aircraft projectile KETF KETF (Kinetic Energy Time Fuse) with detonator of technology AHEAD (Advanced Hit Efficiency and Destruction); 40-mm projectile PMD 330 with the number of striking elements 407 and weighing 1.24g; projectile PTFP (Programmable Time Fuse Pre-Fragmented) – more than a hundred striking elements of cylindrical shape made of wolfram, stabilized by rotation to improve the structure of the cloud of debris for more effective destruction of the target.

Melee combat vehicle LD2000 CIWS (China) equipped with a naval seven-barreled 30-mm Gatling gun, as well as radar and optoelectronic tracking system. At a range of 2.5 km it can destroy drones of fairly large size.

Among the ammunition of the combat module with caliber 57 mm AU-220M (RF), which can be installed on the armored personnel carrier, there are high-explosive fragmentation projectiles of remote detonation, which allow it to successfully fight small UAVs of quadcopter type. In the russian army since 2016, drones are already considered the main air target in the tactical chain.

In the USSR in the 1990s, a MiG-101 attack aircraft was developed, the preliminary design has been protected by the Mikoyan Design Bureau. Due to the relevant circumstances, it remained on paper and in models. Its flight characteristics, airborne locator and round-the-clock optoelectronic station, 30-gun were selected based on the tasks of fighting with UAV. It could also carry unguided aviation jets, which were planned to be equipped with detonators with a temporary mechanism to detonate them near the UAV. This would ensure the destruction of the device by a cloud of fragments. In the context of the destruction or damage of modern UAVs, we can mention another Soviet development. In the 1980s, the Sanguine automotive laser system, designed to disable enemy's optoelectronic systems, was tested. According to available data, the Sanguine complex, built on the basis of the anti-aircraft automotive gun Shilka, could disable optoelectronic systems at a distance of 10 km. At distances of 8-10 km, the destruction of light-sensitive elements of the target equipment was ensured. Thus, the Sanguine complex could well be used against modern light and medium-sized UAVs, 'blinding' or destroying their optoelectronic surveillance systems.

Specialists from South Korea have suggested using a sound wave to shoot down drones. They determined the resonant frequencies for gyroscopes. Here should be selected the appropriate resonant frequency, the gyroscope will resonate and start giving indicators, which, as confirmed by experiments, lead to a UAV accident.

The physical destruction of drones, as a fairly affordable method, can be considered the implementation of the idea of using radio-controlled aircraft models (their cost is insignificant), to implement a well-known technique as air ram.

Given the limitations in the use of a number of UAVs types based on wind speed, the working idea may be able to create a swirling air flow using, for example, anti-aircraft artillery with special ammunition.

A well-established and well-known method of UAV control is the suppression of the GPS channel by means of RW, or failure, which leads to disorientation of the flight and its possible loss due to an accident in the event of a collision with obstacles.

The GPS satellite navigation system in combination with the inertial guidance system is used both to control the flight of the UAV and to determine the exact geographical coordinates of ground objects (targets). At the time of filming the UAV it is necessary to know its location with maximum accuracy, which is provided by the installation of a GPS receiver. The receiver can either constantly measure the current coordinates of the UAV, or turn on periodically, adjusting the operation of the inertial navigation system.

Awareness about the coordinates is necessary to return the drone back to base. For point bombing and air-to-ground missiles, the current coordinates of the UAVs related to the targets selected for destruction also need to be determined with high accuracy.

Deactivation of the GPS system receiver by the influence of radio interference organized by the enemy allows to effectively counteract the use of UAVs. In 1997 at the International Air Show in

Zhukovsky (russia), a russian company demonstrated the first transmitter of electronic interference systems GPS and GLONASS, which disrupted the work of their receivers. As a result, they lost the ability to measure the coordinates of the objects where it was installed. This muffler transmitter caused a sensation in the West. With these ‘mufflers’ it is possible to make a cloud on the way of UAV flights, barrage ammunition, cruise missiles, high-precision bombs, etc.

American experts were the first who evaluated all the dangers of the novelty for their military equipment. The Pentagon purchased several dozen such ‘mufflers’ and tested them on samples of its military equipment; its operation was based on the GPS system. It turned out that high-precision weapons (cruise missiles, guided bombs with JDAM system, etc.) of the United States and other NATO countries under the influence of obstacles, stop to be high-precision. The most important conclusion was immediately drawn: if a country wants to protect itself from high-precision weapons, it is necessary to organize a continuous electromagnetic field of interference over its entire territory with the help of ‘mufflers’. In this case, the correction of the flight of high-precision weapons using the GPS system will be impossible.

Following the Americans, other countries began to buy ‘mufflers’. Combat tests of these vehicles took place in the spring of 2003 in Iraq, when at the very beginning of the war with the help of high-precision weapons failed to hit important targets. On the fifth day of the campaign, a big international scandal happened with accusations against russia. For the next five days, only after the

Americans had tentatively identified the location of the ‘mufflers’, they have leveled to the ground by carpet bombing the whole areas together with ‘mufflers’, which has immediately changed the situation.

Everything that happened has shown the world how with the help of cheap device it could be possible to actually reduce to zero the effectiveness of various military equipment that uses a satellite navigation system. Nowadays similar ‘mufflers’ are already in service with the armies of several countries. Spread of GPS ‘mufflers’ has created a problem for the United States, as it has a non-nuclear strategic doctrine based on high-precision weapons that cost hundreds of billions of dollars.

The destruction of the UAV, as noted, is associated with a number of difficulties in identifying and hitting the target. Therefore, an alternative to destruction is often proposed, there is the suppression of electronic drone systems. Some modern UAVs have the ability to autonomously perform certain tasks, but almost all such equipment is controlled by the operator, and commands are transmitted by radio. Thus, the suppression of the control channel of the REW can at least hinder the task.

To successfully suppress the work of an enemy UAV, it is necessary to set the frequencies at which it is controlled, and then ‘damage’ them with obstacles. In addition, the loss of communication with the operator will make it impossible to transmit intelligence information, such as video from the digital camera of the drone. The further fate of the UAV, that left without any control, depends on the intercepting party. First of all, it can be destroyed, and the destruction of such a target will not be considered a difficult task.

In case of a loss of communication channel with the operator, some UAVs have the appropriate mode of operation. With loss of signal from remote control, automation turns the UAV in a specified area where it is able to perform landing. In this case, the control system ignores all signals, and movement to the specified area is carried out using satellite navigation. Using the GPS or GLONASS system, the aircraft can determine its own position in space, direction and distance to the operator or aerodrome and return to it. To prevent the 'evacuation' of the drone, RW means must suppress not only the control channel, but also the signals of the navigation system. As a result of the successful 'mufflers' of all these signals, the enemy is likely to lose the equipment that fell into the area of the RW.

To detect small, slow and low flying air targets, the company Israel Aerospace Industries (IAI) ELTA adapted its three-coordinate radars, namely models ELM-2026D, ELM-2026B ELM-2026BF of close radius (10 km), middle (15 km) and long-run (20 km) radius of actions, integrating special UAV detection and tracking algorithms into them, as well as combining them with optoelectronic sensors for visual identification of objects. In order to disrupt the operation of enemy UAVs, ELTA company has developed interference systems that can be used together with detection and identification sensors or as a separate system of continuous operation. 'Muffler' disrupts the flight of the drone and can force it to either return to the starting point ('return home' function) or shut down the engine with a subsequent emergency landing.

The belarusian design bureau ‘Radar’ has developed an ‘electronic rifle’ (complex ‘Thunderstorm-R’), which can operate in two modes, which differ in the nature of interference. There is a possible simple ‘muffler’ of certain ranges or suppress the signals of satellite navigation systems. In the first mode, the operator can set the suppression in the ranges of 2.4-2.485 GHz or 5.76-5.88 GHz. This mode is designed to suppress the radio control channels of UAVs. The second mode allows to mute the operating frequencies of satellite navigation systems GPS, GLONASS, GALILEO and BeiDou.

The DroneRanger system, developed by Van Cleve and Associates, is designed to detect UAVs of all sizes, from micro to large drones. Micro-UAVs are usually defined within a radius of 2-4 km. DroneRanger includes a circular scanning radar and a positioning system that integrates daytime and thermal imaging digital cameras and radio frequency mufflers. Radar detects drones, obstacle makers ‘muffle’ radio frequencies that are used for their remote control, and block the frequency ranges of GSNS satellites that allow drones to fly on autopilot. ‘Frequency muffle’ can be realized with the help of directional or omnidirectional antennas, as well as a combination of near and far radio coverage. The frequency ranges and output power of the muting system are regulated depending on the task performed, the level of protection and geographical location. ‘Muffling’ can be performed automatically when the UAV is detected or manually.

In order to disrupt the on-board sensors of the drone and then disable it, there may be a deliberate disruption of communication with the drone, as hackers usually do using the latest technology. At the same time, the UAV's data transmission and control channels are 'clogged' and it becomes 'blind', which leads to loss of control and, accordingly, an accident.

American experts have invented a way to destroy UAVs, the essence of which is to disrupt communication between the drone and those who control it on the ground. When the system is put into operation, it produces an electromagnetic beam at a distance of up to 50 meters, which is automatically tuned to the most frequently used frequencies. As a result of such actions, communication is disrupted and the drone stops to receive the operator's commands in order to further disable it.

Another very real way to destroy a UAV can be the effect of powerful ultrahigh frequency radiation (UFR), i.e., a session similar to being in a microwave oven is arranged for the drone: UFR – impact fires 'sensitive' electronics, turning the miracle of technology into a pile of waste. Following this path, one of the russian corporations has created a UFR gun capable of neutralizing the electronics of drones at a distance of more than 10 km.

The Boeing company has introduced the Compact Laser Weapons System. Like any other energy weapon, this system focuses a beam of laser light on a target, trying to burn a hole in it or cause a UAV to catch fire. Based on existing information, this system is quite capable of operating quite effectively within its tactical range.

According to media reports, Chinese engineers are moving in a similar direction, building a laser system that detects UAVs at altitudes of up to 500 meters and destroys them from a distance of up to 2 kilometers. According to the developers, the system works quite effectively, shooting down drones flying at speeds up to 180 km / h.

In Germany, for example, its own laser system has already been developed and capable of shooting down UAVs at distances up to 5 km. In the United States, Lockheed Martin (ALADIN hybrid laser system) develops laser systems. However, the main problem of laser anti-drone systems is that the maximum power of lasers is limited not only by the current level of laser technology, but also the capabilities of power systems.

When powerful lasers didn’t exist, low-power lasers were used, the beam got the UAV heated to the desired thermal signature, and the UAV became a target for Stinger-type MANPADS with a homing thermal head, leaving only pieces of the drone. With the advent of powerful solid-state lasers, such an original logistics chain has been abandoned: now they are learning to shoot down UAVs directly and immediately.

As the analysis shows, scientific and technological progress is not ‘standing on the same place’, which, in turn, contributes to the active development of various means of destruction (decommissioning) of drones for military purposes, a number of which can only be guessed at the secrecy of this type of development.

7.3. Capture

Experts from around the world have successfully tested a method of capturing (intercepting) UAV control in flight using the technology of ‘hacking’ the drone control system using GPS and subsequent reprogramming, as a result of which the device begins to receive radio signals from satellites and hackers.

UAV control systems are usually complementary to RW or stand-alone. Among the main ways to ‘hack’ the UAV are the following: ‘hacking’ an encrypted channel or substituting authorization data and obtaining access to drone control as a result; exploiting software vulnerabilities, including buffer overflows; use of interfaces and data channels of the original software for ‘stretching’ of third-party code.

According to open sources, in 2011 Iran used the technology of spoofing attacks on the UAV navigation system and landed an American secret drone RQ-170 Sentinel at its airfield. Devices of this type are equipped with modern devices not only for collecting various intelligence data: obtaining high-resolution digital images, radar images of the area, measurements of radiation background, air samples, etc., but also to overcome the electronic countermeasures. Within two minutes after the start of such an attack, the UAV stops flying the previous way and immediately receives ‘new’ coordinates. According to one version, the Iranian military with the help of the russian electronic warfare system 1L222 ‘Autobase’ has muted the control channel RQ-170. After losing the signal, the drone went into automatic mode and, according to the program, headed to the US Air Force base in Afghanistan on GPS signals. At the time, upgraded GPS spoofers, portable radio transmitters with 1227.6 MHz and 1575.42 MHz frequencies, were probably used to capture Iran (these are the frequencies that all military drone receivers use in the military; the latter are often equipped with radio coding modules).

The Pentagon has denied the Iranian version of the UAV interception. According to the US military, the equipment failed, but the device miraculously did not fall or crash. However, in the summer of 2012 it became more difficult to deny the version of Iran, as American experts have confirmed its credibility.

As it turned out, a few years before the loss of RQ-170, the US military, anticipating similar events, had announced a competition to create a system capable of ‘replacing’ GPS signals. This method of electronic warfare is called ‘spoofing’. In July 2012, the University of Texas, led by Todd Humphreys, announced the creation of its own version of the GPS spoofer. The essence of the present invention is simple: the device generates and sends radio signals of a special configuration corresponding to the signals of the satellites of the GPS system. As a result of such ‘substitution’, the satellite navigator incorrectly determines its location, which can be used for various purposes.

Today, for example, the russian complex REB ‘Shipovnik-AERO’ has the necessary characteristics for ‘hacking’ UAV radio channels, that capable of to perform: electronic reconnaissance for the presence of radio control channels for enemy UAVs, analysis of these radio channels (including extraction of data package with control commands and feedback telemetry information), full-fledged spoofing attacks on enemy UAVs using the GPS radio navigation suppression channel for all types of consumers. A large number of different types of antenna installations allows the most accurate directional sources of UAV control radio channels in the range from 25 to 2500 MHz. To suppress the radio control channels of the Shipovnik-AERO UAVs, it has 4 ranges of radiation from electronic countermeasures and correction: 0.025 - 0.08 GHz, 0.4 - 0.5 GHz, 0.8 - 0.925 GHz, and 2.4 - 2.485 GHz.

Specialists of OJSC ‘CB Radar’ of the Republic of belarus have developed a station for electronic warfare with UAVs ‘Thunderstorm-C’, the advantages of which are the following: detecting the appearance of UAVs within the range of the station and tracking the movement of UAVs; a wide range of radio reconnaissance and suppression frequencies, which corresponds to all possible operating ranges of UAV equipment; detection and suppression of UAV control channels from the ground control point and data transmission channels from the UAV to the ground control point; effective suppression of UAV navigation, spoofing navigation (replacement of navigation data by false ones), as well as the introduction of UAVs from the planned route or forced emergency landing.

At the same time, more technically advanced and, accordingly, more expensive UAV models when using RW systems against them are able to continue driving under the control of the operator using video images of the underlying surface or a complex system of onboard sensors and magnetometer (compass) to get out of massive obstacles. However, the use of a video camera and an on-board computer that processes video images for orientation in the field does not provide quality navigation in difficult weather conditions and at night.

Based on the above material, it becomes quite clear that a hostile or obstructing UAV can either be destroyed, or interfere with its task, or capture, making it his winning trophy, as well as skillfully defend against it. Of course, all such actions are associated with certain difficulties of one nature or another. In particular, most of the considered methods of counteracting the use of UAVs require modern equipment, appropriate means of surveillance and detection, interception systems (complexes) and anti-aircraft weapons. The issues of detecting UAVs in the dark and conducting a successful attack remain quite problematic.

Increasing the probability of UAV counteraction tasks will depend, first of all, on the characteristics of UAVs that need to be countered. One way or another, it is clear that countermeasures to drones exist and can be used if necessary. It should be expected that in the future they will be only improved, adapting to innovations in the development of UAVs as the duel between air defense and aviation continues in a new dimension.

8

CURRENT CONDITION OF UNMANNED AVIATION

The need to create UAVs arose in conditions of high losses of manpower and equipment, which are typical for modern wars. After the end of the Second World War and until the end of the 1990s, UAVs were designed and used for reconnaissance. They had installations with more advanced equipment capable to transmit high-quality images, new technologies of the time were used for their launch and flight, they were modernized to increase the flight altitude, as well as more invisible to enemy AD.

Scientific and technological progress in the late 90's - early 2000's have influenced UAV as well. Together with the development of new technologies for the transmission and processing of information, the emergence of a new element base, their production began to fall in price, and their functionality to improve in the following areas [24]:

- increasing the flight range, like increasing the efficiency of the engine, as well as reducing its acoustic noise (the emergence of UAVs with electric motors), increasing the energy consumption of batteries;

- improvement of navigation, control (communication) systems;
- improvement of the glider to reduce weight, size, effective scattering area (ESA);
- improvement of fire means, which are installed on UAVs (in the early 2000s, UAVs began to install guided missiles);
- improvement of non-fire means (means of radioelectronic warfare (RW)) installed on UAVs;
- improvement of reconnaissance (radio, optoelectronic, infrared);
- improvement of photo and video surveillance systems.

As a result of the corresponding development, the concept of UAV use has changed. Thus, unmanned strike aircraft began to play an important role during armed conflicts.

Taking into account the directions of development of modern technologies it is possible to predict that the directions of further development of UAVs will be the improvement of their avionics, technical characteristics, communication systems, duration and range. Considerable attention in the creation of new UAVs is paid to autonomy, resistance to the RW control system, improving the algorithm of image processing and a video surveillance system. Improving the technical characteristics will allow the use of UAVs in groups, while the management of the actions of these groups will be carried out not only through the work of operators, but also with the use of ‘‘artificial intelligence’’. It is also necessary to further improve the interaction of unmanned systems with other types of

WME (special operations forces, manned aircraft). Applying appropriate approaches to the creation and use of unmanned strike aircraft will significantly complicate the fight against it by air defense forces and means.

8.1. Foreign countries

An analysis of the experience of military conflicts that have taken place and continue in recent decades shows that modern wars are radically different from the usual stereotypes of the wars of the fourth (World War II) and fifth (second half of the 20th century, nuclear weapons) generations. They've got a new sence and a new meaning. Sixth-generation wars are characterized by the active use of high-precision robotic weapons, which are equivalent and sometimes exceed the power of nuclear weapons in destructive power. Armed struggle in such wars has moved to outer space, which is becoming the main theater of operations [19].

In modern conditions, the armed struggle is multifaceted, in contrast to past wars of the fourth generation, where its character was determined mainly by the horizontal component, and the vertical (air) coordinate was ancillary in the absence of the space component in general (fig.8.1). Active combat operations in modern conditions are conducted by operational groups of troops (forces) simultaneously in airspace, on land and at sea without spatial limitations.

The first such example is the war of multinational forces against Iraq in the Persian Gulf in 1991 [87].

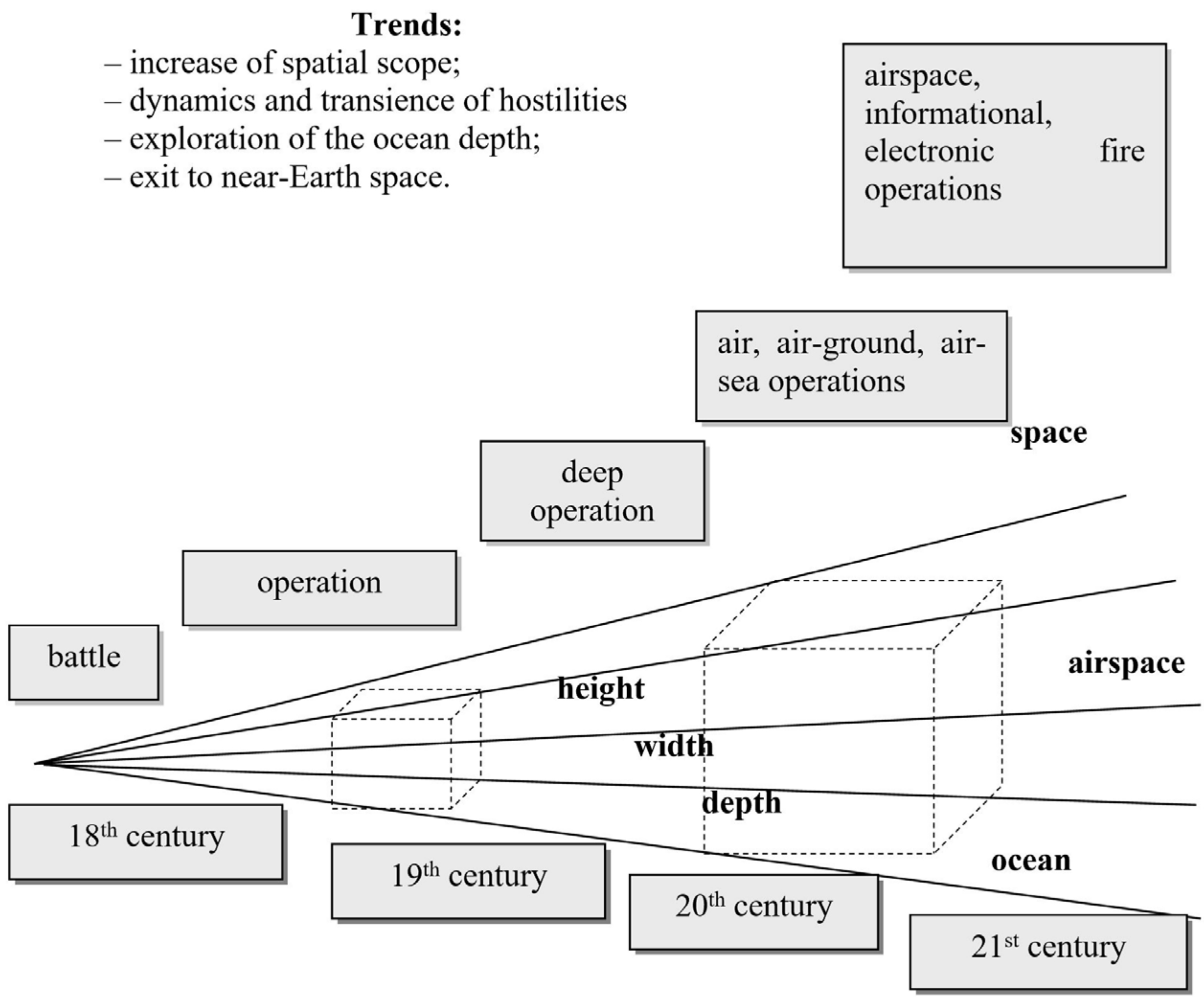

Figure 8.1. Evolution of basic spatio-temporal indicators and ways of armed struggle

Along with the expansion of the spatial scope of hostilities, an essential feature of modern armed conflicts and local wars is the change in the temporal indicators of armed struggle, due to its high dynamism and transience because of the use of new models of weapons and military equipment [85].

Expansion of spatial indicators of armed struggle, the rapid growth of the role of the information factor and action in space, as well as the widespread use of guided weapons leads to a trend towards globalization of armed struggle management in general and a gradual transition to the scheme: from controlled weapons to controlled armed struggle [12].

The most typical feature of modern armed struggle should be considered the interconnected process of reconnaissance, data transmission, command and control of troops and weapons, fire (electronic) destruction of the enemy on a scale close to real time. The experience of modern operations shows the growing interest of the world's leading countries in conducting all types of reconnaissance. Reconnaissance has become global in the wars of the sixth generation, due to the purposeful creation and application of new highly effective means of intelligence that allow it to identify any targets at any distance in a different environment [168].

The results of the preparation and conduct of "Operation Desert Storm" by Multinational Forces (1991) against Iraq [91], by NATO's united forces of "Operation Allied Force" (1999) in Yugoslavia [7], by coalition forces led by the United States

- the counter-terrorist operation in Afghanistan (2001) [27], "Operation Iraqi Freedom" (2003) in the Persian Gulf area [22], by coalition forces led by the United States and led by the russian

Federation "special operation" in Ukraine (since 2022) became clear confirmation of the shift in the direction of aerospace reconnaissance. During the period of operations (combat operations), a significant part of the intelligence information about the enemy's ground objects was obtained with the use of aerospace reconnaissance means [4].

In the current combat situation, reconnaissance UAVs have become more efficient and effective than manned reconnaissance aircraft, solved the problem of tactical and operational-tactical air reconnaissance and RW, targeting, conducting and adjusting of fire, combat control and communication, meteorological, radiation, chemical and biological reconnaissance without risk to personnel in the interests of the command of various armed forces levels. This reduces the time to bring the received data to the appropriate level of management. UAVs can operate both in the direct vicinity of the front edge of the combat area, and over the entire territory of the enemy [13].

The results of military conflicts can be confidently stated, that unmanned aerial vehicles have already become an authorized element of the American intelligence triad together with space reconnaissance and manned aerial reconnaissance, as well as an important part of the fleet of leading countries and NATO countries [182].

UAVs have proven their direct advantages over manned reconnaissance aircraft. They do not have a pilot, which does not require his rescue if the reconnaissance plane is shot down. For example, two combat helicopters and several tens of Marines were involved in rescuing an RF-16 fighter jet that was shot down during a reconnaissance flight and ejected over Bosnia during a peacekeeping operation. If an UAV had been used for reconnaissance, both the loss of the RF-16 fighter jet and the significant costs of rescuing the pilot could have been avoided.

UAVs are capable of conducting reconnaissance of enemy’s objects in areas unavailable for E-8C, RC-135 and U-2R reconnaissance drones operating at a great distance from these objects. This is due to the fact that the terrain creates invisibility zones for aerial reconnaissance of manned reconnaissance aircraft, which may contain objects of striking: increasing range and the presence of mountainous terrain leads to an increase in the effect of shading targets. An example is the Balkan TOW, where 50% of the territory, which was subject to air reconnaissance, fell into invisibility areas [268]. Reconnaissance UAVs, together with surveillance and reconnaissance of such areas, as well as search for the area of visibility observed by the TRD of manned reconnaissance aircraft (from 50 to 250 km depending on the type of air reconnaissance vehicle), provide multi-angle and long-term observation of enemy objects, being behind the line of combat [273].

Another advantage of UAVs is their small size, which positively contributes to the successful implementation of military tasks in conditions of active resistance to enemy air defenses. UAVs are equipped with more diverse means of reconnaissance than manned reconnaissance aircraft, among which the main role is played by optoelectronic and radar stations, the results of which are used to obtain images of ground objects. TRD, which are equipped with UAVs, are performed in a compact, miniature version [193].

The undoubted advantages of reconnaissance UAVs have ensured their further development around the world. Given the growing requirements of modern warfare and the still-insufficient effectiveness of reconnaissance UAVs, as the experience of local wars has shown, in recent years, the Command of the Armed Forces of NATO countries has stimulated work on clarifying the main tasks and requirements for UAVs, research of directions and ways of their combat application, and also development of devices of new generation [40].

Many experimental samples were created to assess the effectiveness of combat use and confirm the possibility of technical implementation of the proposed reconnaissance UAV projects. The results of research and combat use of UAVs show that the main factors in improving their combat capabilities are increase in flight duration, small-sized equipment of modular type, real-time data transfer, reduction of visibility in a wide range of wavelengths and resistance to the action of RW [222]. The invulnerability of modern UAVs in combat missions is achieved by equipping with the means to ensure survivability (false targets, setting up electronic interference, etc.) or by creating devices, the design reduces their visibility for means of detecting enemy air defenses. According to the criteria of “cost /efficiency’’, the first method, based on US military experts’ opinion, gives the best results [54].

It should also be noted that another way to protect UAVs at the present stage of their use is to conduct reconnaissance at altitudes, where the drone becomes invulnerable to most means of destruction launched from the ground, as well as from subsonic missiles launched by the enemy from aircraft [219].

Ways to ensure the survivability of UAVs include their equipment with reconnaissance hardware, that allows in some cases to obtain the necessary data without entering the area of the enemy’s air defenses [84].

Considering that the UAV’s performance of reconnaissance tasks related to enemy objects is probable in the conditions of active action of air defense and RW means, there is a need to reduce their visibility for enemy radar. In this regard, the development of the Dark Star UAV was carried out by the Americans using “stealth” technology to ensure high survivability due to the relatively small EAR. Global Hawk UAV has a higher altitude to reduce the impact of air defense, small signatures (unmasking signs), including radar, optoelectronic equipment and a radar station with a synthesized aperture, which allows it to perform reconnaissance tasks from great heights. Reduction, for example, EAR drone Mirach 20E is achieved by making it from a composite material. Reduction of infrared radiation of the Horizon UAV system is provided by a covering of its fuselage by the special paint capable of absorbing heat [9].

The transition to deep reconnaissance with the use of UAVs requires new methods of pre-targeting with programming their flights and search modes. These methods are based on the accumulation and use of large databases on enemy territory, especially cartography. They are used for analytical assessment of areas of probable target location, based on the results where UAV flight routes are selected to the specified areas of reconnaissance [10].

The value of the duration of patrolling in the depths of enemy airspace is due to the fact that the presence of this property makes the UAV not so much a means of detection as a means of operational monitoring and support of important mobile of enemy’s targets [228].

According to US Defense Ministry officials, the importance of high-altitude long-range UAVs was recognized in 1994 according to the results of research and war games, the purpose was to obtain answers to two questions: what combination of reconnaissance equipment, communications systems and high-precision guided weapons will be needed in the future? What each of these elements can add in increasing combat effectiveness [191]?

It should be noted that the leading role in the development of long-range UAVs designed for reconnaissance and combat missions belongs to the United States and Israel [180].

The revolutionary breakthrough in the area of unmanned aerial vehicles is not limited to the emergence of long stay in the air by reconnaissance UAVs. In recent years, a new promising area has emerged - mini- and micro-UAVs [40].

Experts and analysts of US military operations in Afghanistan and Iraq mentioned that analysis of the experience and effectiveness of various means, as well as the weapons systems of the US ground forces and special forces in the fight against the Taliban terrorist gangs in Afghanistan, indicate the increasing role and importance of miniature UAVs as Man-portable Unmanned Reconnaissance Air Drones (Mini-uav). These systems have proven their effectiveness in solving the tasks of tactical military intelligence in the interests of combat units on the battlefield, especially in mountainous and very rugged terrain, when it is very important for troops to see everything that is happening at any given moment in front of their front and in the immediate surroundings - literally behind the nearest hills [162].

A portable UAV with a small wingspan can be launched by a single soldier-operator. Flight control and information retrieval is carried out using portable equipment in the form of a conventional handheld case. An example of such a mini-UAV is the American Raven, whose wing span does not exceed 1.34 m [150].

Interest in small UAVs is growing worldwide, especially in Europe. The greatest interest in the technology of such UAVs is observed in France, where work on the creation of various mini- and micro-UAVs is gaining momentum. Analysts estimate that in Europe, the need for mini-devices - mainly for testing, evaluation and development of new technologies - is estimated at hundreds in the coming years, and the market for such weapons systems is becoming more profitable and attractive.

The idea of creating a micro-UAV as a means of reconnaissance of military units belongs to the specialists of the Massachusetts Institute of Technology. It is believed that such a tool with the size of a bird is particularly effective in combat operations in the city, and in addition to monitoring the situation can be used for targeting, detection of elements of chemical and biological weapons [175].

The following general requirements are applied to micro-UAVs: length 6-20cm, takeoff mass 10-100g, payload weight 1-1g, flight time 20-60min, speed 30-65 km/h, flight range 1-10 km. Some of the technological elements needed to create such devices already exist, but most of them need to be developed, refined or improved. The main problem of microplane construction is energy: how to pack enough power in a tiny amount on board to solve all the problems?

The most perfect for micro-UAVs are reconnaissance. There is already miniature equipment for optoelectronic reconnaissance of visible (mass 1 g) and infrared (mass 10 g) wavelength ranges, radio engineering, acoustic and biochemical reconnaissance [176].

An example of the creation of the first micro-UAVs is the device Wasp-III. It is manufactured by AeroVironment to manage advanced research and development of the US Department of Defense. The UAV is radio-controlled and is a flying wing with a span of 73 cm and a total weight of 450 g.

The active development of various options for reconnaissance UAVs confirms the conclusion that their role is growing as the most promising means of air reconnaissance in the near future for many countries. This is also due to the cost-effectiveness of UAVs because of their cheaper cost compared to manned reconnaissance aircraft, simplification of combat training, reducing the composition of forces and shifting the emphasis on war, that can be carried out without long-term preparation of infrastructure and prior deployment of forces and resources.

The UAV reconnaissance function is being implemented today in parallel with the solution of the issue of creating reconnaissance and strike UAVs in order to meet the growing need for these weapons systems both now and in the future.

Along with the transition to the sixth generation of wars, there are still numerous low-intensity military conflicts. The current battlefield is being transformed due to the fact that direct confrontation between enemy troops within a certain TOW is happening not so frequently, for example, the long Arab Israeli armed confrontation, the civil war in Syria, the war in southeastern Ukraine etc. According to military experts, it is a complex and miscellaneous space where it is not always clear who is a participant in hostilities and who is not. Low-intensity military conflicts are typical for actions of militants (insurgents, terrorists), guerrilla actions by armed groups, which periodically hide among non-combatants. In these circumstances, a factor of particular importance is the timely receiving of information that the enemy considers unavailable. The use of UAVs with TRD operating in low light conditions and at night allows to detect and recognize the actions of even small groups, which has been successfully demonstrated by Israel for a long time [82].

Such conflicts are characterized by the manipulation of public opinion, when there are difficulties in obtaining a real picture of the hostilities process. Thus, both sides of the armed conflict can place responsibility for tragedies and crimes on the enemy's side, as well as knowingly arrange incidents, for example, with TV reporting and showing footage of innocent non-combatants who were victims of air or artillery strikes, a powerful means of influencing world public opinion. This was demonstrated during the Abkhazian-Georgian conflict (2008) and during the war in Ukraine (since 2014). The use of mini-UAVs and micro-UAVs, or strategic Hawk-type UAVs with TRD for hidden surveillance can reveal the real picture.

The modern market of military drones is growing rapidly. Analytical resource Global Market Insights has published its forecast for this industry. In 2016 the market for military UAVs was about USD 5 billion, by 2024 it will increase to USD 13 billion. 65% of the market's profits come from the sale of «copters», the cheapness, compactness, maneuverability and ability to hang over targets (objects), makes these devices ideal for aerial surveillance. 67% of the market are UAVs that can be operated out of line of sight. Technical progress is also helping to increase the demand for long-range and high-capacity drones capable of carrying out long-range missions [5].

One of the factors in the rapid growth of the market is the demand from countries such as China and India, which are trying to keep up with Western countries in the use of military drones. China takes 50% of the drone market in Asia and is rapidly developing its own production of drones [36].

Among the leaders in the production and use of military drones three countries are firmly established: the United States, Israel and China. France is notable in the market too. Actively working to establish their own industry in russia, Turkey, Iran, and India, especially in the direction of launching a strike UAV [23].

Earlier, another American analytical company Orbis Research, which regularly publishes research from different markets, including the military, released a report «World market for military drones 2017-2027.» According to Orbis Research, the market volume will grow to USD 15.2 billion by 2027. According to a similar earlier published report by the Dutch consulting firm ASD, the market turnover for military UAVs will grow to USD 13.7 billion by 2022. Thus, the forecasts of companies almost match [264].

According to the forecast, the biggest increase will be in the demand for strike drones - their market share will exceed 40%, the share of high-altitude long-range UAVs will reach 25%, and the share of medium-altitude long-range UAVs may be more than 17%.

In terms of geography, the share of North America in the global market for military drones will be more than 34%, the Asia-Pacific region - almost 32%, Europe - 24%.

The markets of China, India are expected to flourish in Asia, as well as in Australia, ussia, Great Britain and in Europe. In ten years, the world could spend more than USD 133 billion on military UAVs which is the best confirmation of the next transition of the world to the so-called wars of «robots» and «TV wars», which is another threatening challenge to the existence of peace on our planet.

The United States, which took a course to create the armed forces of the future capable of waging remote or contactless warfare, remains the largest player in the global drone market, accounting for more than 40% of the market. Unmanned aerial vehicles are becoming more widespread in the United States.

High attention to increasing the number and planning of large-scale use of military UAVs are conditioned by number of factors as the following: implementation of network-centric war concept; the possibility of replacing manned aircraft in solving a number of combat and security and providing tasks; prevention of losses among the flight crew; significant decrease in the cost and complexity of the manufacture and operation of unmanned aerial vehicles compared to manned. The mentioned advantages will allow it to keep the leading position of the United States in the development and application of new models of aircraft, increase the combat capabilities of aviation units, and continue to maintain the advantage of the US Air Force in the air.

Conceptual foundations for the development of UAVs as part of a system of robotic systems created in the interests of the Pentagon, are presented in the «Plan of Integrated Development of Robotic Systems of the US Department of Defense», as well as in the «Comprehensive Plan for the Development of Unmanned Systems for 2013-2038», however it does not provide information on so-called «black» programs, such as the new low-visibility supersonic UAV from Northrop Grumman for the US Air Force.

According to the «Comprehensive Plan for the Development of Unmanned Systems for 2013-2038» of the US Department of Defense for mid-2013, there were counted 10,964 UAVs in the register: in group I (up to 9.0 kg): 7332 Raven UAVs, 990 Wasp UAVs and 1137 Puma UAVs, all from AeroVironment; 306 T-Hawk UAV from Honeywell; in group II (9.0-25 kg): 206 UAVs ScanEagle from Boeing / Insitu; in group III (25-600 kg): 499 UAVs Shadow, 18 UAV complexes Expeditionary UAS of Special Operations Forces and 20 UAVs Stua of Marine Corps; in Group IV (over 600 kg, below 5,500 meters): 237 Predator UAVs from General Atomics, 44 Hunter UAVs and 28 Scout UAVs from Northrop Grumman; in Group V (over 600 kg, above 5,500 meters): 112 Reaper UAVs from General Atomics and 35 Global Hawk UAVs from Northrop Grumman.

One of the first documents of the US Air Force, which sets out in detail the list and content of major measures related to the mass equipping of the Air Force with long-term UAVs, was the «US Air Force Unmanned Aerial Plan for 2009-2047.» The official views described in these documents indicate the growing role of UAVs in solving the problems of armed struggle. In recent years, the intensity of UAV use in US military operations has increased many times over. In particular, during the US Air Force operations in Afghanistan (2011-2016), the share of UAVs has been increased from 5 to 61%, and during the operation of the US Armed Forces and their allies «Steadfast Determination» against ISIS in Syria and Iraq from August 2014 to June 2016. UAV Predator and Reaper (originally called Predator B) have performed more than 9 thousand combat flights, using about 3.5 thousand units of high-precision weapons at almost 2 thousand objects [154].

The efficiency of UAV use has formed a tendency to increase their number. Thus, in recent decades, for example, the number of UAVs of long flight duration has increased significantly and exceeded 400 units, and the amount of funding for the purchase of these samples has increased many times. According to the plans in the medium term, their number will increase by almost 100 units, which will allow, if necessary, to carry out simultaneous round-the-clock patrol of such UAVs on 60 routes in different regions of the world.

At the same time, in the development of UAVs, the US Air Force Command faces a number of problems, the main of them is the lack of qualified personnel, and especially pilots of remotely piloted long-range UAVs. In order to compensate for the lack of specialists in the Air Force, measures are being taken to attract UAV pilots to the number of flight crew specialists who are in reserve and declared unfit for flight work. Large-scale work is underway to increase the motivation of personnel to learn and serve as pilots and operators of detection means [252].

Conceptual views on the use of UAVs reflect the importance of developing theoretical provisions, as well as continuing research & development funding to determine the role and place of UAVs in wars and armed conflicts of the future, justifying their optimal range and number in the US Armed Forces [41].

High attention is paid to clarifying existing and justifying new approaches to the use of UAVs. Given the current condition and key areas of development of UAVs, as well as the content of actions in which it is planned to use UAVs in the future, they will be involved both individually and in groups. Despite the fact that currently the single form of use of UAVs is the main, at the same time, the group is becoming more widespread [136].

Currently, the US Armed Forces have UAVs of various types, range and duration, such as: Predator [132], Reaper, Global Hawk, Avenger, Sentinel, Pegasus, X-47B, Hunter, Gray Eagle, Raven, Dragon Eye, Fire Scout, Wasp, Puma and others [151].

Potential buyers of US UAC include NATO members, Saudi Arabia, other Gulf states, Japan and South Korea, as well as probably India, Singapore, Australia and countries which signed an agreement on the control regime for missile technology. It is also noted that with purchasing military equipment, the buyer country has to ensure that the equipment is not transferred to third parties, used to monitor local populations, and will be used exclusively in the framework of operations authorized by the world community.

Israel, along with the United States, is a leading country in the development area, production and use of various types of unmanned systems. During the four decades, Israel has been a world leader in UAV development, especially due to the success of IAI / Malat, which began producing UAVs in 1974. Israeli drones have flown more than 1.1 million hours in more than 50 countries. According to the Stockholm Institute for Peace Research, Israel is responsible for 41% of drones sold worldwide in the first decade of the 21st century [220].

Currently, dozens of countries around the world use drones from Israeli manufacturers. In general, taking the level of development of the scientific, technological and production base of Israel, it can be argued that in the near future this country will remain a leader in the creation of UAVs. Its military-industrial complex is able to meet the needs of national armed forces and special forces in UAVs for various purposes, as well as provide a wide range of these tools to potential customers from other countries [95].

In Israel, the development, production and export of unmanned systems are performed by ten companies, which created a total of more than seventy types of aircraft. According to the Center for Analysis of the World Arms Trade, in the period from 2010 to 2017, the country took first place in the ranking of suppliers of new high-altitude and medium-altitude UAVs with long flight duration - mainly the family of Heron and Hermes (240 units about USD 4 billion) [199].

Israel also takes first place in the ranking of manufacturers of new tactical UAVs and second after the United States in the ranking of supplies of mini-UAVs and micro-UAVs [229].

In 2010-2013, 152 devices that cost about USD 2.37 billion were sold abroad and for the period of 2014-2017 the portfolio of orders already amounted to 88 UAVs worth USD 1.559 billion.

The Heron-TP UAV is in the service of the Israeli National Air Force. The main feature of the device in the version of Heron-TP is to increase the range and duration of the flight, which allows it to reach the territory of Iran. Heron-TP is the largest UAV in the world. The wingspan of the device is 26 m. The payload in different versions can reach 1000 kg. The main purpose of the device is reconnaissance, but the device is able to perform strike tasks. The device can be in the air for up to 45 hours. Foreign countries are showing interest in Israeli development. The first European customer was France, a contract was signed with France for more than USD 500 million.

The unmanned systems Harpy (anti-radar) and Heron should be noted, they belong to the class of combat disposable UAVs. Israel is considered a leader in R&D, production and development of tactics of combat use of this class of vehicles [30].

IAI (Israel Aerospace Industries) has also developed a multi-purpose UAV Super Heron, capable of performing reconnaissance missions and combat missions to destroy targets of various types. The drone is able to spend 24-48 hours in the air depending on the load. The wingspan is 17 meters. The maximum takeoff weight of the aircraft reaches 1.45 tons. The increased power of the engine allows the UAV to rise to a height of more than 10 km, and its maximum speed reaches approximately 240 km / h [61].

Heron Tpor or Eitan with a turboprop engine (4.65 tons) received a baptism by fire during the Israeli Air Force strike on a convoy carrying Iranian weapons through Sudan in 2009. It competes with the American UAV Reaper in the number of orders from major European countries. Other IAI products include the Searcher III UAV, which is in service with 14 countries, including Spain and Singapore, which have used it in Afghanistan [29].

Experts from another major developer and manufacturer of UAVs Elbit Systems - over the past decade, created a family of UAVs with a long flight duration of different classes of Hermes. It includes devices with different takeoff masses: Hermes-90, Hermes-180, Hermes-450, Hermes-900 and Hermes-1500. UAVs of this family are designed as multi-purpose platforms with the ability to accommodate a variety of onboard electronic equipment. Depending on the installed equipment, such UAVs are able to solve the tasks of species, radio and radio - technical reconnaissance, RW and be used as a repeater. Modifications of Hermes-450 and Hermes-900 can carry controlled aircraft means of destruction [210].

Elbit's smaller UAVs with electric motors include the Skylark ILE. It is an UAV at the level of an Israeli army battalion, which is also in service with more than 20 armies and French special forces. The Skylark II, launched from a machine, was selected as a brigade-level drone [220].

The leader of the Aeronautics family is the Aerostar UAV, which was purchased by 15 customers and flew a total of more than 130 thousand flight hours. The Orbiter drones series of this company is armed with 20 armies and consists of the Orbiter-I, Orbiter-II (used by the Israeli Air and Navy Forces, ordered by Finland) and Orbiter-III [29].

BlueBird Aero Systems company has developed a hand-held MicroBU UAV, a SpyLite UAV used by the Israeli army and others (including the Chilean army) and a WanderB UAV taking off from the runways. In 2013, the company introduced the 24-kg ThunderB with a flight duration of 20 hours [139].

Israel sells drones in 58 countries [38].

China is actively developing the area of UAVs. China's military and political leadership pays special attention to the creation and development of the UAC, which will significantly increase the capabilities of the national armed forces. Mass robotics meets the basic principles of construction and modernization of the armed forces such as "mechanization" meaning the increasing the number of new weapons systems; "Optimization" - improving the organizational structure in order to increase the effectiveness of combat use; "Informatization" equipping troops with advanced means of intelligence, communication and management with their further integration into a single information space on the TOW [108].

Chinese specialists are copying foreign, the best UAV models, and the command is carefully investigating the experience of using UAVs in various armed conflicts and counter-terrorist operations [141].

The large number of experimental UAVs and UACs cannot be considered a coincidence. It should be assumed that in the near future the subject of UAVs in China will develop rapidly, and in the next decade this country may become a leader (after the United States and Israel) in the area of such tools. The main focus of China's unmanned systems will be to neutralize US efforts envisaged by the American concept “air-naval operation’.

Until 2010, the basis of China’s unmanned aircraft was systems with tactical reconnaissance UAVs. They provided performance of air reconnaissance. In recent years, China has sharply increased investment in the development of military unmanned systems.

Representative samples of more than 30 types of UAVs in service with the Chinese Armed Forces are: Chang Kong-1, BZK-005, ASN-104 i -105, ASN-206 i 207, W-30 i -50, PW -1 i ASN-15, I-Z, Z-2, -3 i -5, M22. In addition, it is armed with a multi-purpose complex, handed over in 1994 by Israel, which includes a single-use UAV Harpy [32].

Since the early 2000s, the priority has been to create high-tech models of systems from UAVs of various types. At the same time, special attention is paid to high and medium-altitude UAVs with a long flight duration.

The main goal in the area of creating UAVs in China is to develop concepts for the use of UAVs in the interests of strategic missile forces, the Air and Navy Forces, as well as the organization of interspecies cooperation. Most attention is paid to solving such tasks as: information support of the armed forces; obstruction of the use of the enemy’s forces and means; reducing the accuracy of enemy strikes; conducting RW; relay of communication and control signals.

The key directions of UAC development and their application in the country are determined by the General Staff and the General Directorate of Armaments and Military Equipment, which are subordinated to the Central Military Council of China. The main directions of UAV development in China, as well as in other leading foreign countries, are equipping them with guided aircraft, providing group use of UAVs and their common use with manned aircraft.

Despite the technological lag behind the United States and Israel in the field of unmanned systems, Chinese experts over the past 10-15 years have made significant progress in this direction [39].

Among the latest developments of the UAV ASN-229A, which is the largest device in the line of drones designed to replace the ASN-104 and -105, which are in service. The device is designed for conducting aerial reconnaissance, RW and correction of artillery fire. A tactical multi-purpose UAV of medium range SN-3 is being developed, designed for conducting aerial reconnaissance, RW, correction of artillery fire, and can also be used as a repeater of communication signals and data transmission.

Tests of high-altitude UAV CH-T4 on solar panels have been conducted in China. The drone with a wingspan of 45 m spent 15 hours at an altitude of about 20 kilometers. The UAV in working condition will be able to fly at altitudes up to 30 km at a speed of 200 km / h. It is assumed that the Chinese drone will be able to stay in the air for several months or even years, according to the Chinese opinion. Recharging batteries from solar panels located on huge wings takes place in daylight, the energy supply should be enough for the CH-T4 UAV to continue flying at night. According to the designers' information, during the flying at maximum altitude, the scope of "review" of the drone is about a million square kilometers. Drones of this type are informally called "atmospheric satellites". Despite all their technical characteristics and cheapness, the effectiveness of their use is highly dependent on weather conditions for energy production and quality monitoring of marine spaces and facilities. However, the use of CH-T4 UAVs to detect US Navy ships in the ocean is a “hot topic”, especially since such a drone will be only part of a large Pacific monitoring system being built by the Chinese.

The multi-role UAV WJ-600 is based on the S-602 anti-ship missile, designed to solve a wide range of tasks: conducting air reconnaissance, hitting time-critical targets, conducting RW and relaying communication signals. The device can also be used as an air target.

A promising example is the Wing-Loong UAV, which looks like an American Predator UAV. Strategic reconnaissance UAV Chengdu Xianglong constructively replicates the American Global Hawk.

The Chinese Army Command intends to use long-range reconnaissance and multi-role UAVs to detect and destroy the enemy outside the national territory. It is planned to deploy a network of UAC bases along the land border to use them on a permanent basis to monitor and ensure defense capabilities in the surrounding areas. This is largely due to China’s BeiDou space radio navigation system, which signals are used to detect the UAVs location, and progress in satellite communications systems that retransmit signals from drones.

Chinese specialists involved in the development of combat UAVs intend to introduce a ground or deck-based vehicle by 2025.

Despite the fact that **France** has a well-developed aviation industry and UAVs are developed by more than a dozen companies, the country's armed forces reach a small number of nationally developed devices. UAVs created by French developers are not different and are criticized for this by both domestic and foreign customers [98].

The French Armed Forces used UAVs to perform combat missions in different countries around the world. Thus, during the Gulf War (1990-1991) the MART device was used, in Bosnia (1996-1997) it was CL-289, and then Cresserel (1998-1999). In Kosovo, the CL-289, Cresserel, Sperwer and Tracker drones were used at various times (from 1999 to 2008). UAVs CL-289 and Cresserel were also deployed in Macedonia (1999), Pointer in Haiti (2004), Sperwer in Lebanon (2006-2007), CL-289 in the Republic of Chad (2008-2009) and Harfang in Libya (2011). In 2008-2015, Harfang, Sperwer and Tracker UAVs were used in Afghanistan. In 2013, the French Armed Forces actively used Reaper and Harfang UAVs in Mali according to the plan of Operation Serval, and since 2014 in the Sahara-Sahel region of Africa during Operation Barkhane [37].

The Armed Forces of France have the following UAVs: Reaper and Harfang in the Air Force; Sperwer and mini-UAV Tracker in the ground forces.

The French Armed Forces operate the Reaper UAV without weapons, only for air reconnaissance. Main reconnaissance equipment is the following: AN / DAS-1 optoelectronic system and AN / APY-8 "Lynx" radar station. By 2023, the French Air Force planned to have 12-16 Reaper UAVs and eight ground control stations. Acquisition in the United States of medium-altitude long-duration UAV Reaper will significantly increase the capabilities of the French Armed Forces to conduct aerial reconnaissance.

At present, the French Armed Forces make extensive use of UAVs, which have proven themselves well during armed conflicts. They are mainly joint developments of several companies Related to different nationalities.

The Sperwer UAV is the most famous French drone, which from 2000 to 2010 was in service in Canada, Denmark, Greece, the Netherlands and Sweden. The drone will be decommissioned after 2020 with the adoption in 2018 of the Patroller UAV, the flight duration of which is 20 hours and which has an ability to real-time surveillance and reconnaissance system that can be integrated with other digital means of combat. The drone is expected to be used by command units to support ground operations, assist in the defense of advanced combat units and gather intelligence [97].

Tactical reconnaissance UAV Tracker, known in France as DRAC (Drone de Renseignement Au Contact), is planned to be replaced by UAV Spy'Ranger from 2023.

France has been overseeing the international Dassault nEUROn program in the direction of creating a strike drone since 2004, which also involves Sweden, Greece, Spain, Switzerland and Italy.

Prospects for expanding the capabilities of the French Air Force in conducting air reconnaissance are associated with the creation of the European medium-altitude reconnaissance UAV RPAS (Remotely Piloted Aircraft System), which is being developed jointly with Germany, Italy and Spain [149].

UAVs that are being developed to replace existing UAVs and can be used by the French Armed Forces in the period 2025-2035 are being created by international consortia. It is assumed that they will surpass the existing UAVs in their flight characteristics and in this period will cover the needs of the French Armed Forces in this type of aircraft.

russia has intensified its work in the area of UAVs [265]. According to American experts, since 2011 the number of UAVs in the russian armed forces has increased ten times to more than two thousand units. Progress began in 2011-2012. In 2014, russia spent about USD 9 billion on unmanned military systems only. Thanks to its efforts, russia was able to be into the top five countries with the most advanced UAV technology, even though it began to develop this area quite late [69]. However, it fails to overtake not only the leader, the United States, but even Iran [102].

The russian army is equipped with UAC with such UAVs as: Orlan-10, Eleron-3 (various modifications), Forpost (produced under license as Israeli Searcher Mk I), Zastava, Granat (various modifications), ZALA (various modifications) and etc.[278].

The russian Air Force will soon have a heavy strike drone. The device of this kind will be the first in the history of russian aviation. The new UAV is called Altius-O and designed for long duration flights. Its weight exceeds 7 tons. russian experts believe that the new drone will become the answer to the American Global Hawk.

russia has also completed the development of a heavy strike UAV Hunter, which in terms of artificial intelligence [92] is a prototype of the sixth-generation fighter. The UAV was developed using technology to reduce radar visibility, has an aerodynamic scheme “flying wing”, and its takeoff weight reaches 20 tons. According to available information, the drone will be able to develop a speed of about 1000 km / h.

Corsair and Katran UAVs are considered promising developments [187].

russia’s armed forces have gained experience in the combat use of UAVs in the war in Syria. At the end of 2015, when russia’s military operation in Syria began in September, there were already 1,720 drones in service [60]. During 2016, the troops received another 105 UACs with 260 drones. As of spring 2016, a group of 70 russian drones, numbering about 30 complexes, has been deployed in Syria. In December 2016, it was reported that three more UACs had been overthrown to monitor the situation with the compliance of the truce reached at that time between government forces and the opposition. russia’s use of reconnaissance UAVs in Syria is considered successful. At the same time, the operation showed a critical shortcoming - the lack of strike drones in russia, despite the fact that over the past 13 years, state funding has been provided for five programs to create heavy strike drones with guided weapons, however none of these projects have been adopted.

Work is dynamically conducted to create UAVs in **Turkey**. Thanks to domestic UAVs, Turkey is one of the few countries that have succeeded in this area. On the one hand, Turkey produces products that are strategically important and competitive, and on the other hand, it is moving forward with confident steps. By pursuing an independent policy in this area, the country also makes a significant contribution to the economy through the sale of such products [255].

The production of domestic drones is the story of how Turkey has gained its independence and contributed to economic development. The first drones to be used by the Turkish Armed Forces in the 1990s were the Israeli Heron UAV and the US Gnat UAV. Following this, Turkey began production of domestic UAVs. The Turkish Armed Forces are armed with Anka UAVs (various modifications) and Bayraktar (various modifications), which are entirely manufactured in Turkey. There are also other UAVs which are tactical, reconnaissance, for example: TAI Baykuş, Gözcü, Keklik, Martı, Şimşek, Vestel Karaye and others [254].

In November 2016, Turkey became the sixth country in the world which has developed and adopted strike drones. Prior to that, the countries armed with such systems were the United States, China, Iran, Pakistan and Israel. The need for Turkey to develop national strike drones arose in 2012 after the US Congress blocked the sale to this country of Predator and Reaper strike drones. The first strike drone entering Turkey was a modified Bayraktar TB2 reconnaissance aircraft with MAM-L air-to-surface missiles, which was used in Operation Olive Branch against Kurdish People's Self-Defense Forces (YPG) and was actively used in Syria and YPG. during russia's war with Ukraine in 2022 [256].

During seven years, Turkey has managed to create its own strike UAV. The drone has a completely Turkish electronic stuffing, control systems, missile system, all this used to be bought abroad. One of the reasons for forcing the creation of its components is the information security of UAC and the inability of foreign manufacturers to influence in any way the work of UAVs, software installed components, not to mention dependence on foreign supplies of components.

The ThinkTech think center at Turkey's defense company STM has performed an investigation that reviewed the Turkish Armed Forces' needs for drones, including kamikaze drones, used in reconnaissance and pre-reconnaissance to further destroy the enemy.

Turkey is developing a new strike UAV Akinci, which was put into service in 2020 and became the third strike drone developed in Turkey. The technologies obtained in the development of the Akinci UAV will open the way for Turkey in the area of combat drones, starting in 2027 [103].

According to The National Interest, **Iran** is taking fourth place in terms of its potential in the area of UAV development, which has clearly "jumped above the head", despite relatively small investments. In the area of experience in the use of drones, the country is second only to the United States and Israel [248]. The Iranian Armed Forces are equipped with UAVs as Fotros, Shahed 129, Mohajer (various modifications), Ababil (various modifications), Hesa Karrar, Sarir, Toophan-2, Ra'ad-85 and others [200].

Qods Aeronautics Industries (QAI) company is considered to be the main developer of UAVs in Iran, although a number of UAVs for training operators and target drones were manufactured by Iran Aircraft Manufacturing (Hesa) which is a part of the Iran Aerospace Industries Organization (IAIO).

Iran has launched serial production of the Mohajer-6 strike drone, equipped with high-precision “smart” bombs, capable of long flights, which allows it to perform reconnaissance, surveillance, as well as provide support in combat operations. The Mohajer-6 UAV is the first Mohajer UAV capable of carrying guided weapons. Another modification of this Mohajer-4 series has already been used by the Iranian military during the conflicts in Syria and Iraq. In addition, according to unofficial data, these devices were supplied by Iran to the “Hezbollah” group.

Iranian UAVs make extensive use of technical innovations in trophy Israeli and American UAVs [173]. For example, the new Iranian project, introduced in 2013 named Yasir, resembles a ScanEagle with dual tail spars and an inverted V-shaped tail.

Shahed Aviation Industries Research Center has developed the Iranian military tactical UAV Shahed 129 in 2012 using the latest US military engineering technology. This drone is able to detect not only the hidden movement of a potential enemy, but also perform tasks related to patrolling a particular region, and the UAV can be in flight for up to 24 hours, which ensures high efficiency of its use. Among other things, the Shahed 129 UAV is also positioned as a full-fledged weapon, in particular, the drone can carry bomb and missile loads, providing combat against ground, air and sea targets.

The first use of the Shahed 129 UAV was made in Syria in 2014, making a flight to investigate the area and identify the locations of radical rebels. The military test was quite successful, so in 2015 the Iranian manufacturer received orders to supply this equipment to other countries.

Iran has introduced an UAV based on the Sentinel UAV, which got to the Iranian side. After the appropriate time (2014), Iranian designers have made a new drone, which 40% replicates its prototype. This UAV is smaller in size than the Sentinel UAV, has a jet engine and is capable of carrying four bombs of type 342.

India is a confident member of the club of countries that have actively taken a course on the use of UAVs. The country has been developing its own drones for more than a decade, primarily based on the needs of its military which has already begun using UAVs in reconnaissance operations, border protection, naval patrols and high-precision strikes. The Indian Armed Forces plan to significantly increase the fleet of UAVs in the coming years to conduct reconnaissance and patrol.

To meet the growing needs of the armed forces, the Indian government is investing millions of dollars in domestic and foreign UACs, mostly from Israel, receiving at least 108 Searcher and 68 Heron UAVs, as well as Harpy and Harop. The Searcher II UAV has been manufactured in India under license since 2006. At the end of 2013, the Indian government approved the purchase of 15 more Heron UAVs worth USD 195 million.

India is going to buy Predator combat UAVs, which can be equipped with Hellfire missiles with a laser homing head. They are planned to be located along the borders with Pakistan and China in the area of disputed fields to ensure the identification of various targets, including means of nuclear, biological and chemical attack.

Ever since India began developing UAVs, the country has gained great success in developing small and medium-sized UAVs. In order to meet the growing demand of the Indian Armed Forces, research organizations and enterprises such as Aeronautical Development Establishment (ADE), National Aerospace Laboratories (NAL), Hindustan Aeronautics Limited (HAL) and Bharat Electronics Limited (BEL) are developing UAVs for conducting reconnaissance, gathering information, targeting and aiming weapons.

Developments in India mostly include micro-UAVs, mini-UAVs, tactical UAVs, and MALE (medium-altitude long-endurance) drones. Most projects start from scratch, and integration is facilitated by foreign companies [174].

Using the latest technical developments and highly qualified personnel, Indian scientists have been able to develop fully domestic UAVs with autonomous control. Ease of operation, adaptability to work in adverse conditions, functional flexibility and reduced operating costs - all these advantages make UAVs a better choice compared to manned systems.

In 2017, CSIR-NAL company developed the Suchan multifunctional UAV. A drone with a shortened takeoff and landing is capable of tracking stationary objects, and it is expected that it will “learn” to accompany moving objects. Suchan UAVs provide the military with an alternative to portable UAVs developed in the United States, Israel and Europe. However, this drone has the possibility to improve in terms of performance and capabilities compared to its capabilities, such as Raven and Skylark drones, which have a much longer flight duration and can accommodate a wider range of sensors.

The main developer of drones in India is the Defense Research and Development Organization (DRDO). In its developments there are a number of UAVs tested in real operation, among them are: demonstration mini-UAV Kapothaka; air launch target Ulka; tactical UAC Nishant; Lakshya UAV target; mini-UAV Imperial Eagle; quadcopter Netra and UAV rustom of MALE class.

DRDO is working on projects to improve existing ones and is developing other drones, such as rustom-2, Panchi and Lakshya-2. The possibility of developing promising projects rustom-H, AURA (strike drone entirely Indian-designed) and Abhyas are also being considered.

The rustom-2 drone, developed by DRDO, now designated the Tactical Air-Borne Platform for Surveillance-Beyond Horizon 201 (TAPAS-BH 201), made its first flight in November 2016.

DRDO also intends to continue to develop state-of-the-art UACs with technology of the future for the Indian Armed Forces. Promising DRDO programs include the Autonomous Unmanned Research Aircraft (AURA) experimental platform, the UCAV strike drone, and other multifunctional solar-powered UAVs.

The aim of the AURA project is to develop a tactical inconspicuous UAV capable of carrying laser weapons. The aircraft with a gross weight of 1.5 tons must fly at a maximum altitude of over 9,000 m and a range of up to 300 km. The program was launched in 2009 and has stopped and resumed several times.

Hindustan Aeronautics Limited (HAL) company in cooperation with DRDO is developing a tactical UAV Gagan which will have a range of 250 km and a working altitude of about 6 thousand meters.

India is one of the few countries seeking to develop domestic

UACs, including tactical, MALE and HALE. At the same time, the country has an urgent need for advanced platforms of these classes, especially for tactical drones and MALE complexes.

According to Drone Wars UK information, **the UK** government has already spent billions of pounds on the purchase, development and research of unmanned aerial vehicles.

The drones adopted by the British Army include the following UAVs: Reaper, Desert Hawk, Hermes 450, Black Hornet, T-Hawk and others [142].

The Ministry of Defense of the United Kingdom has officially announced the adoption of new strike drones such as the Protector. Under the designation Protector, the British Armed Forces will receive a Certifiable Predator B RPA drone, which is a modification of the Reaper strike UAV. The British military plans to purchase 16 such drones, but is considering increasing the order to 20 units.

Reconnaissance UAVs WK450 Watchkeeper, developed on the basis of Israeli Hermes 450, have also been adopted. The issue of adopting Zephyr 8 UAV, which can be in the air for up to three months, is being considered. Over the next two years, the country’s armed forces are planned to be replenished with three such aircrafts.

It was planned to create a long-stay UAV under the Scavenger program in 2018. In accordance with the requirements of the Ministry of Defense of the United Kingdom, the UAC was designed to support six deployed operational units and should have about 20 UAVs. It may take 30 devices to keep the system running for 15 years. It is estimated that the program costs around £ 2 billion, including funding for the development, demonstration, production, operation of the UAC and the payment of maintenance staff.

The United Kingdom [231] and France are jointly developing new combat UAVs, which are planned to be adopted in the early 2030s. As part of the French and British Air Forces, they will partially replace the Dassault Rafale and Eurofighter Typhoon fighters, respectively. It is planned to spend about two million euros on the development of a new combat drone. According to previous plans, the development of a new combat UAV will use the experience gained by France in the creation of the nEUROn and the United Kingdom under the Taranis project. Tests of the new French-British drone are scheduled for 2025. As part of the project, the parties also intend to conduct research on the interaction of manned and unmanned aerial vehicles in the air in solving common tasks.

The above review of countries that are leaders in the development of UAVs, does not limit the list of countries that develop UAVs or purchase UAC in other countries. This club, as it was partially covered earlier, already includes dozens of countries: Austria, Italy, Germany, Sweden, Canada, Norway, Czech Republic, Spain, Poland, South Africa, Australia, belarus, Ukraine, Kazakhstan, Azerbaijan, Armenia, Georgia , UAE, etc.

According to The National Interest, in 10 years the list of leaders in the field of UAC development may change. If the United States, Israel and China are likely to remain in their current positions, Iran and russia could cede their positions to other countries.

In particular, Iran may simply lack industrial potential, and russia may be undermined by economic problems and the need to reform all its armed forces. The main contenders for the leading positions of the publication are India, Brazil and a number of EU countries, such as France.

8.2. Ukrainian developments

Ukraine inherited the obsolete reconnaissance UAC BP-3 Reys from the Tu-143 UAV and UAC VR-2 Swift from the Tu-141 UAV, the resource of which has almost expired.

At the same time, Ukraine tried to track changes in the «unmanned fashion» [34,68-70,275,276,80,286]. This was noted in the monograph of Doctor of Military Sciences, Professor S. Mosov «Unmanned reconnaissance aircraft of the world: history of creation, combat experience, current status, prospects for development», published in 2008 [152]. At that time, domestic developers as Research Institute of Physical Modeling (Berkut-1, Sapsan), KB Vzlet (Remez-3, Albatross-4k, Yastrub), Ukrainian Aviation Company UAVia (R-100, R-400), The state enterprise “Plant №410 of Civil Aviation” (Monolith), Chuguiv Aircraft Repair Plant (Strepet), etc., have offered several different options only for UAV gliders [147].

The lack of domestic production of technical surveillance and reconnaissance means for UAVs made it impossible to move from the creation of gliders to the creation of full-fledged reconnaissance UAVs and UACs, which could be offered to both domestic and foreign consumers [159].

With significant potential, Ukraine lags behind many countries in the development and creation of unmanned aerial vehicles [117]. Naturally, in this situation, without cooperation with other countries, the development and serial production of UAC was postponed for quite some time [116].

At the same time, the Ministry of Defense of Ukraine made some attempts to provide the UAC army in 2008. The military department began to study the capabilities of the Israeli UAC Bird Eye worth USD 1.3 million. One of these UACs was purchased for testing, but Bird Eye never joined the army.

The urgency of developing UAVs, primarily for the Armed Forces of Ukraine [119], was conditioned by the world experience of military conflicts, which was first noted by the team of military scientists from the National Defense Academy of Ukraine and Zhytomyr Military Institute of Radio Electronics S.P. Korolyov in the monograph “Aerospace Intelligence in Local Wars of Today: Experience, Problems and Trends” (2002) [20], which was published in the open press and designed not only for professionals but also for a wide audience of readers.

With the beginning of the counter-terrorist operation in the south-eastern region of Ukraine, which began in April 2014 (from the end of April 2018 - the Joint Forces operation), the need of UAVs for the Armed Forces of Ukraine, first reconnaissance and then striking, has become inevitable [160].

Reconnaissance UAC BP-3 Reys and UAC BP-2 Swift were obsolete. First, the drones were launched from bulky wheeled platforms, given their size and weight, and secondly, the results of air reconnaissance were recorded on aerial film. After completing the task, the Soviet drone returned to the planned landing site, then the aerial photographic film was removed from the UAV and delivered for chemical photographic processing and decoding. The relevance of received data decreased, as during this time the situation at the front could change significantly. The fighting has shown that the military needs modern drones capable of transmitting information in real time, followed by processing the information received in real time or close to it [130, 156].

With the beginning of the war at the front in different periods it was used about 30 types of various, most of the homemade, UAVs, collected by volunteers for reconnaissance and fire adjustment [31].

In 2015, the National Guard of Ukraine adopted the tactical reconnaissance UAV Fury [17, 72], developed by the Kyiv RPE “Athlon Avia” on the basis of commercial RVJET. In 2016, five unmanned kits were delivered to the Armed Forces of Ukraine (the first drones were handed over in 2014). These deliveries continued in 2017 within the framework of the State Defense Order [241].

In 2015 Bulgarian tactical reconnaissance UAVs KS-1, developed by BULCOMERSKS, were purchased. As part of US military assistance in 2016, 72 Raven tactical reconnaissance UAVs were delivered to Ukraine. In addition, 87 Chinese Skywalker X8 reconnaissance UAVs were purchased in the same year.

In 2017 the Armed Forces of Ukraine adopted the tactical reconnaissance UAV Fly Eye, developed by the Polish company WB Electronics S.A. [240, 218]. Since the beginning of 2015, it has been produced (in fact, large-scale assembly is carried out) at the facilities of the Chernihiv Radio Equipment Plant (CheZaRa). Not so long ago, another example of this Polish manufacturer, a small-scale Warmate strike drone from the kamikaze drone class, entered the Armed Forces of Ukraine as part of the Sokil reconnaissance and strike complex. The Chernihiv Radio Equipment Plant assembles unmanned aerial vehicles from Polish components under a Polish license [195].

The UAC Observer-S, developed by Def C and designed to perform air reconnaissance tasks in combat conditions, detect and determine the coordinates of military equipment, location of troops, fortified enemy positions for targeting, fire adjustment, is allowed for operation in the Armed Forces of Ukraine for a special period [16].

According to the 2018 agreement, Turkey will supply Ukraine with operational and tactical Bayraktar TB2 UAVs manufactured is by Baykar Makina company. These drones can carry guided anti-tank missiles and aerial bombs. The cost of one UAC is USD 69 million. In the future, the possibility of licensed production of Bayraktar TB2 UAVs at the facilities of the well-known “Antonov” Aircraft Plant is being considered [257].

The Ukrainian company “POLITEK Aero” has developed tactical reconnaissance UAV Spectator-M which manufactured by the Kyiv-based Joint Stock Company Meridian n. S.P.Korolyov. The first sets were handed over to the Armed Forces of Ukraine at the end of 2015. The second batch with revisions was received in 2016. Since 2017, the drone has been put into service by the State Border Guard Service of Ukraine [167, 30].

The Ukrainian military multifunctional tactical UAV Leleka-100, developed by DeViro is in a state of experimental operation.

Another Ukrainian development was the tactical reconnaissance UAV PD-1, capable of performing tasks in the conditions of enemy RW systems. The first flight took place in 2015 [258].

The prototype of the new tactical UAV Gorlytsia was developed by specialists of the leading aviation enterprise “The Antonov Design Bureau”, which is a part of “Ukroboronprom”. According to its characteristics, the drone is able to stay in flight for 7 hours, work at an altitude of 5 thousand meters, and the range of its flight exceeds a thousand kilometers. The “Gorlitsa” UAV is capable of performing various functions, including conducting air reconnaissance, providing fire coordination, as well as enemy fire damage using air-to-ground missiles [259].

The company «Defense Electronic Technologies» also from the Ukroboronprom has created a tactical strike UAV from a series of kamikaze drones RAM-UAV, which was tested in Donbass [198].

The Sparrow tactical reconnaissance UAV, developed by SPYTEK Research and Production Enterprise (Ukroboronprom), which can be in the air for up to three hours, has successfully passed departmental tests and is to be put into trial operation in the Armed Forces of Ukraine. The company also conducts tests of the ANSER drone with a long stay in the air (from 6 to 12 hours) [206].

The Ukrainian developers of UAV include: design bureau “Vzlyot” Ltd. “Scientific and industrial systems” (Berkut-A6, A-2 Sinytsya, A-3 Remez); Research and production center of UAV “Virazh” NAU (M-7D “Sky Patrol’, M-6-3 Zhaivir, M-10 Eye 2); RPE Ltd. ‘‘Ukrtechno-Atom” (Kazhan-2); Research and Production Company “Matrix of Technologies” (Katana, Commander, Eye);

Spai Tech company (Columba); Smic Aerospace company (Microvisor SM 7), etc. [194, 237].

On January 17, 2018, the National Security and Defense Council of Ukraine reviewed and approved the “The main Indicators of the State Defense Order for 2018-2020’, and on January 29, 2018, the President of Ukraine has issued a decree putting this decision into effect. According to this document, providing the army with UAVs is an important priority. For this purpose, the General Staff of the Ukrainian Armed Forces has already decided to add 500 UAVs to the list of needs of the Ukrainian army [227].

9

PROSPECTS FOR THE DEVELOPMENT OF UNMANNED AVIATION

Further changes in the development of armed battle indicate that in the long run, humanity will move into the era of wars of the seventh generation. The main features of the armed struggle in these wars may be the transfer of major efforts to outer space (Fig. 9.1), the widespread use of space reconnaissance, navigation and strike systems; the emergence of robotic military equipment, increasing the role of intelligence in creating the latest means of armed battle, the gradual expulsion of man from the battlefield; increasing the scale of information, information-psychological and electronic warfare not only in the ground and air, but also in the airspace; the use of weapons based on new physical principles, the emergence of intellectual, informational and other non-lethal weapons [143].

In the wars of the seventh generation, lay of not only strategy but also operational art and tactics will be changed. These wars will have a wide spatial scope, there will be no clearly defined main and other directions of action, strikes will be inflicted at the same time from all possible directions of the TOW throughout the enemy’s territory with almost no restrictions [145].

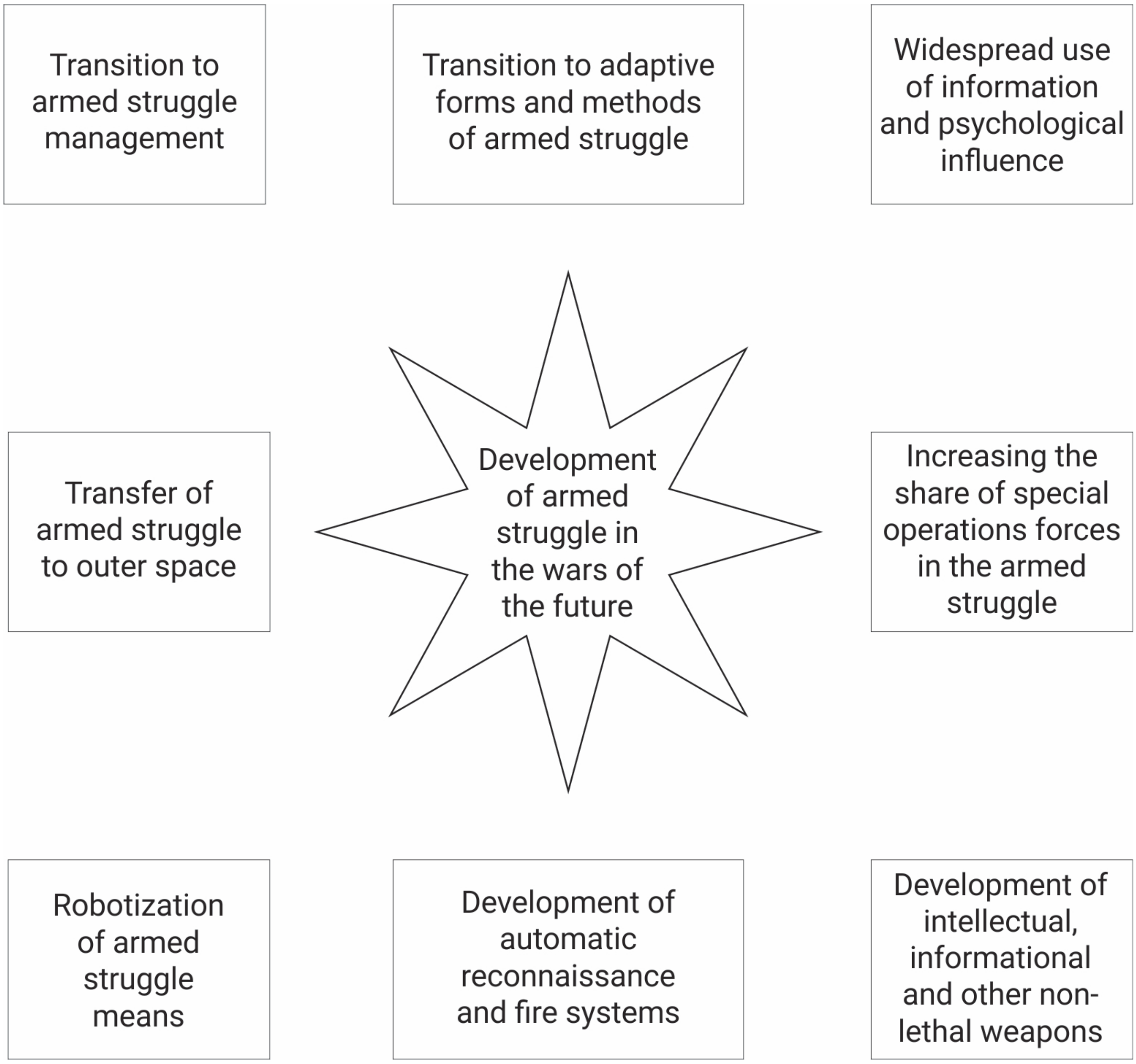

Fig.9.1. Direction of further development of armed battle in the wars of the future

The goal of the war will not be the physical destruction of the enemy, but his “internal crushing”. Military and information efforts will be directed at such goals as undermining the moral environment of the enemy’s population and the consistent destruction of the cultural environment of his residence. An important point will be the identification and the right identification of enemy's "strategic centers of weight" [185].

Ground forces in such a war may not be formed in advance, so concepts such as "front", "rear", "front line" are likely will lose their traditional essence. They will be replaced by the new concepts of "object – goal" and "object - not goal". New ideas as "need to be impressed" and "do not need to be impressed" will be introduced. Naturally, these changes will affect the entire organizational and staffing structure, various types and kinds of troops of the armed forces [253].

War can be performed simultaneously throughout the all territories of country. The dependence of combat units on logistics will be insignificant. The management of forces and means will ultimately be reduced to three main principles: "to explore", "to make a decision" and "to destroy". The concepts of tactics and strategy will be mixed as the objects of political infrastructure and the whole society of the enemy will become combat targets. The concepts of defense and offensive will become rudimentary. Defense will be considered the most effective saving of combat capabilities by tactical unit.

Military operations will be highly maneuverable. Huge information overloads will bring big difficulties for commanders' actions, which will complicate operational and strategic goal-setting.

Occupation of the enemy's territory will be optional to win. It can be achieved as a result of a strategic air and space offensive operation, an electronic warfare operation and a victory in the information confrontation.

Preparation for the wars of the future, due to the adoption of fundamentally new means of armed battle, and on this basis - a radical change in the forms and methods of using troops (forces), which will lead to the transformation of topogeodesic and navigation support into a fundamentally new type of support – geoinformational. This is due to the fact that geographic information systems are means of combining of topogeodesic and navigational information with the capabilities of modern information technology and raise to a fundamentally new level of providing troops with information about the area. Therefore, on the basis of geographic information systems, automated systems for obtaining information about the area using unique small and reliable electronic computers will be created, and new schemes for transmitting information using spacecraft and small terminals, which can provide not only mobile controls but also combat units, including even individual servicemen, will be formed.

A characteristic feature inherent for the future use of space systems and means will be the creation and active involvement of space strike weapons capable of hitting ground (sea), air and space targets in real time, globally using high-precision weapons based on new physical principles.

An important aspect of the seventh generation wars will be the widespread use of new technologies. According to Western military experts, a situation may be technologically possible when several soldiers will be able to have the same combat effectiveness as a modern mechanized brigade.

Robotics, remote control systems, new communications and artificial intelligence will radically change the tactics of warfare. Widespread use of weapons based on new physical principles, which further development is associated with the creation of laser [179], electromagnetic, kinetic, beam, acoustic and plasma weapons, will ensure the achievement of war goals even without the use of ground forces.

The first step was the war in Yugoslavia (1999), when NATO Allied Command has decided to use graphite bombs to disable overhead power lines, transformer stations and other elements of the capital's energy supply system in order to coerce the leadership of this country to stop further resistance. Controlled weapon systems in the near future will be able to choose the optimal flight trajectory, to come the target from the perspective of the most effective defeat, track its maneuvers, select the necessary target from a set of possible objects, to solve problems specific to so-called systems of artificial intelligence, without human participation in a situation of uncertainty of "decision-making".

Seventh-generation wars in the age of high technology will carry the danger of nuclear destruction. A party with nuclear arms may find itself in a situation where it will not be able to conduct normal hostilities. Moreover, the breaking or destruction of the industrial potential, political and social infrastructure of society at any stage of the war can lead to an escalation of the conflict and its transformation into a nuclear.

The wars of the seventh generation will be characterized by the growing scale of information-psychological and electronic warfare not only in the physical but also in the virtual space. The so-called

"World Wide Web" (the computer information Internet network) is increasingly becoming a new electronic environment for human civilization.

In the future, according to experts from the world's leading countries, the information war at the level of the armed forces will gradually go beyond the type of support and become a type of military action. Information weapon will be system-destroying, as the result will be able to disable combat targets, economic and social systems. The emergence of "intelligent" information weapons, its new models based on nano- and biotechnology is expected. Thus, the three traditional spheres of warfare: ground, sea and airspace will be supplemented by a new (fourth) sphere as informational, where the forces of information warfare will operate. The development of information weapons will lead to the fact that in the future there may be information wars which will be conducted in the information space mainly by information means and ensure the achievement of strategic, political, economic and other goals without the use of existing means of destruction.

Radical changes in the area of electronic warfare will lead to changes in the ideology of its conduct in the wars of the future and the creation of new forms of electronic warfare, such as radioelectronic and radioelectronic-fire strike, radio electronic operation and more. The spread of radioelectronic warfare in the information space will turn it into an active component of information warfare. Along with the traditional components of electronic suppression - radio, opto-electronic and hydroacoustic suppression, new components such as electromagnetic and software-computer suppression will appear and begin to dominate.

A special role in the wars of the future will be played by a perfect reconnaissance system, which must promptly provide the military-political leadership and the armed forces with the necessary information with maximum completeness, accuracy and reliability.

In the next 15-20 years, the world’s leading countries will create the latest intelligence systems and tools and will be able to implement technologies of contactless wars [150].

Reconnoitring retrieval systems and data transmission facilities will be located, as a rule, in near-Earth space. The field of intelligence will cover not only enemy’s troops (forces), but also software, computer networks, telecommunications and radio navigation systems, energetics, transport, media and other areas, but its main efforts will be concentrated in outer space.

Increasing the amount of intelligence information about the enemy will require the use of new methods of processing and interpretation using elements of “artificial intelligence”. Space reconnaissance systems of the future will be able to obtain images of the terrain with a resolution of up to several centimeters in different areas of the electromagnetic spectrum. The further development of reconnaissance and strike combat systems, associated with the targeting to sea-based and air-based cruise missiles, will in fact reduce the specific (image-forming) means of space reconnaissance to the rank of components of strategic offensive weapons.

A special place in the system of aerospace reconnaissance in the seventh generation of wars will be given to UAVs. A revolutionary breakthrough in the area of unmanned aerial vehicles will lead to their further active use by many countries around the world to perform various tasks both in wartime and in peacetime. The development of reconnaissance means in the direction of minimizing their size will allow, for example, to create micro-UAVs with the size of a small bird (or even smaller!) and a range of up to ten kilometers. Ideally, such a “plane” will be able to fly for a long time over the enemy’s positions, being virtually invisible that is especially important in conducting possible hostilities in the city [232].

The first two decades of the 21st century have been marked by the massive development of unmanned aerial vehicles for various purposes. According to the foreign press, the total number of UAVs has increased significantly and already counts tens of thousands units. In the nearest future the main focus will be given to reconnaissance and multi-purpose small UAVs with long flight duration [286].

Interest in UAVs has grown significantly since their successful use in a number of military conflicts in recent decades. Thus, during the hostilities in Syria (since 2014), Georgia (2008), Afghanistan (2001), Iraq (2003), and the ongoing Arab-Israeli armed confrontation, the growing role of UAVs has been convincingly demonstrated as effective means of air reconnaissance and surveillance. This the need for long-range drones, such as the Global Hawk UAV has been confirmed. The main operational value of such UAVs, based on American experts opinion, is that they can operate from remote locations far enough from reconnaissance areas, such as Diego Garcia island or from the bases of Southeast Asia. The size of these UAVs allows them to install not only systems designed to obtain species information, but also electronic reconnaissance systems with satellite communications provided to them and ensure the transmission of all information received to ground analysis centers.

The possibility to use large UAVs for electronic reconnaissance is especially important in mountainous areas, as the higher altitude allows you to monitor the operation of such electronic means, which signals from low altitudes is impossible to intercept.

It should be noted that the US Armed Forces is actively investigating various options for the long-term use of reconnaissance UAVs. For example, the possibility of using small drones for reconnaissance before combat use of large and vulnerable to enemy air defenses manned strike platforms (eg, Apache helicopters) is being considered.

Regarding the actions of ground forces, US military experts are exploring the use of UAVs for reconnaissance of advanced FCS (Future Combat System) tanks by determining in advance the location of enemy tanks, artillery positions and guided missiles. This will allow to strike these objects in advance from closed positions, even before making eye contact with them.

US experts of aviation applied technologies believe that in the future reusable UAVs could be created, which will be launched from air carriers and saved after a combat mission by picking up in the air.

According to US plans, more than 30% of air force strikes designed to strike at remote ground targets, must be unmanned. These remotely controlled or autonomous combat UAVs, designed by American strategists, are capable to perform in the deep rear of the enemy flight tasks related to the detection and subsequent destruction of well-protected targets, which is too risky for attack aircraft [111].

According to some American experts, by 2025 almost 90% of all combat aircraft may become unmanned. In 2019, the Pentagon has requested much more drones than in 2018. The budget for the purchase of drones is planned to be increased by 27%. Of course, this is not just about drones, but also about reconnaissance drones, including naval and submarine, as well as means of combating enemy drones. The military plans to spend USD 9.39 billion on these needs, one billion of this will go to systems and ammunition to defeat enemy drones.

In the United States, work on the creation of new reconnaissance, reconnaissance - strike UAVs is being conducted in two directions: adaptation of existing vehicles to solve new problems; development of new concepts, the implementation of which does not require significant costs. The mentioned works are conducted by Boeing, Lockheed Martin and General Atomics.

The Boeing’s efforts are aimed at developing the concept of ultra-long-endurance UAV (ULEUAV), the main idea is to constructively combine long-range wings with a span of about 30 m with eco friendly hydrogen fuel cells - power sources for electric power plants.

Advanced Concept Development Division of Lockheed Martin company is considering the possibility of creating an inexpensive F-35 JSF striking drone. The main purpose of such a UAV will be to suppress radio electronic means located in the depths of the enemy, using high-power microwave weapons (High Power Microwave - HPM). Directed microwave weapons uses high-power electromagnetic pulses that can disable electronic components of radar stations, as well as distort or destroy the computers memory that control long-range air defense systems. In the long run, these weapons are considered a key point in future weapons systems designed to strike on objects of development and storage of chemical and bacteriological weapons. The list of promising developments of Lockheed Martin Corporation also includes the following points: inconspicuous UAV with increased range and wingspan up to 30 m; reusable UAVs launched from ships and submarines; a set of micro-UAVs with geometric sizes of about 20 cm; UAV which is inconspicuous and has a high speed at the initial stage of the flight, and when entering the area of reconnaissance changes the configuration, which allows to patrol in this area at low speed.

Lockheed Martin specialists estimate that interest in and demand for miniature drones has risen sharply since the events of September 11, 2001. According to the management of Aero Vironment estimations, the troops are not only able to quickly see everything that happens in front of them with the help of portable UAVs, they are able to effectively fill the reconnaissance and information “gap” in the immediate environment.

Defense Advanced Research Projects Agency (DARPA) of USA funds programs to study and create micro-UAVs that will not exceed the size of a hand palm [225].

These programs are intermediate on the way to the creation in the near future of “robobugs”, which are micro UAVs in the shape of robots - “bugs”, equipped with numerous sensors and capable of performing hidden surveillance and reconnaissance. Such robots bring special interest in the limited conditions of the city. According to the developers’ idea, they should get into homes and offices. The French organization of aerospace research and development Onera is active in this direction.

Another promising area is the creation of a family of mini-UAVs, “hovering“ in the air, and miniature drones that can “hang” during the flight over the object of reconnaissance or surveillance.

In parallel with the development of reconnaissance drones, a number of well-known companies in the world are actively working to create reconnaissance- striking, striking and other UAV types.

According to experts from the Malat department of the Israeli company IAI, in 15-20 years the most developed air forces will use UAVs capable of combating both ground and air targets. Such drones will be bigger than the current UAVs, will be able to perform combat missions in any weather conditions and will be equipped with advanced artificial intelligence systems.

According to expert forecasts, due to growing regional threats, territorial disputes and the implementation of plans to modernize the armed forces, the demand for UAVs will grow every year. The most active users will be the United States and Western Europe. The main production of UAVs will continue to be concentrated in the United States, but the total share of Western Europe will increase. The highest increase in demand for UAVs is expected in the Asian region, first of all due to existing territorial disputes, internal and existing external threats. In the Asia-Pacific region China will become one of the main leaders in developing its own UAVs. India will continue to implement national UAV programs.

The highest demand will be among medium-altitude long-range UAVs (MALE), designed for reconnaissance, surveillance and targeting (ISR). High demand is also expected for high-altitude long-range UAVs (HALE) and tactical UAVs (TUAV).

The trend of expenses reducing for defense will have a negative impact on a number of programs to develop new UAVs. For example, in 2010 the US has postponed a project of upgrade the Shadow UAV to RQ-7C. The decision to create a Talarion reconnaissance UAV as European one has already been reconsidered.

In the current conditions, in order to reduce R&D costs, a number of companies will continue to unite, creating multinational UAV development corporations that are able to enlist significant funds and new technologies to new projects.

It is possible that, despite the reduction of defense costs in many countries, sales in the UAV market will remain on high level. This will be due to the successful combat use of UAVs in operations in Iraq, Afghanistan and Syria.

The developers will be focused on the implementing of new technologies, especially such as invisibility. Demand for solar-powered UAVs will be higher, which will increase flight time and reduce maintenance costs.

New R&D programs in the UAV segment in the next decade will be aimed at solving such tasks as: reducing the size of UAVs while maintaining their operational capabilities; increasing the viewing angle of electron-optical / IR systems; ensuring the identification of disguised targets.

A new direction is the simultaneous use of a swarm of drones [121]. The first try was the simultaneous use of strike UAVs in Syria by terrorist groups against russian military bases in early 2018. It is expected that swarms of drones will be able not only to conduct reconnaissance, detect enemy radars and “open” air defense systems, but also “mute” signals and act as false targets. UAVs will be able to fly so slowly and low that in theory will not fall on enemy radars, and will be used as barraged ammunition.

DARPA agency has allocated USD 7.1 million to develop a swarm of drones capable of assisting the military in urban battles. Two teams will work on the task: one led by Raytheon BBN and the other led by Northrop Grumman. Theoretically, the swarm can consist of more than 250 machines, both air and ground. The developers will pay special attention to how the swarm operator will be able to control the drones, how and in what form it will receive information and give orders. Control systems by means of gestures, voice, movement of the head are considered. Special algorithms that would automatically force the swarm to perform certain tactical moves are in creation: for example, approaching from the flanks or creating a security perimeter. The ability of the operator to manage not only the whole swarm, but its subgroups is evaluated. In general, the researchers note that they do not have the technology to manage a large swarm and that so far, the main successes are more related to the work of the swarm indoors. In real life, everything will be much more difficult, especially in combat.

DARPA's nearst task in this direction is to create a swarm of 50 air and ground UAVs, which could detect and isolate the target in 15-30 minutes in the area of two city quarters. In June 2018, China Electronics Technology Group company has launched a swarm of 119 drones that showed the ability to act together. According to American analysts' opinion, China weighs the pros and cons of technology and may perceive swarms of cheap drones as an asymmetric response to the expensive few, but technically perfect, platforms of other countries' armed forces. At the same time, there is a danger that the technology of using a swarm of drones could fall into the hands of terrorists or Third World countries, which will be a threat to all other countries.

Analyzing the prospects for the use of UAV swarms during combat in the city, analysts identify three main areas of its application. The first is the reconnaissance of buildings. Before the attack, the building is surrounded by a swarm of drones, which inspect every window, door, hole, roof and look for the enemy. The information is passed to the operator and it becomes clear about the location of enemy forces, the need and time of fire support from the air and so on. The second direction is to create a smoke screen to hide the movement of attacking forces. Instead of bombs or cameras with sensors, drones can be equipped with smoke bombs and by applying in large quantities to expose a dense smoke cloud.

The third is the creation of a physical barrier to enemy fire. In the literal sense, a “wall” of drones in front of soldiers can, firstly, create conditions for hiding their exact location, and secondly, become an obstacle to bullets and fragments. Given the ability of the swarm to “heal itself”, it is possible to maintain such an obstacle in front of soldiers for some short time needed to attack, even if enemy fire destroys hundreds of drones from such a wall. Finally, a swarm of drones will be able to quickly determine who is in the crowd, in the building, on the street, who is a militant, and who is a civilian, who has a weapon and who does not. In theory, this could minimize losses among civilian during urban fighting.

The topic of the possible emergence of “killer robots” is considered popular [76]. However, scientists and entrepreneurs such as Stephen Hawking and Elon Musk warn that the autonomous decision to strike by robots, including air drones, could lead to unpredictable consequences and get out of human control. Big Western technology companies are making agreements that they will not help the military to develop artificial intelligence. The development of artificial intelligence and the created algorithms for automatic target selection, whether human or other object, will allow the machine to perform combat missions effectively, but the cost of even one error can be very high, as evidenced by recorded errors of operators using UAV Reaper.

Given the growing use of UAVs in the world’s armed forces, the following question is coming: how to ensure their safety in the conditions of the enemy’s radioelectronic warfare. There are not many options in this direction. The most obvious is to increase the autonomy of the flight and the mission, when the drone does not need to maintain a channel of communication with operators, constantly update their location and goal setting using the same GPS system. This option is considered difficult to implement, but scientists and experts are already actively working on it. Another option is to make communication channels inaccessible to the enemy. The third option is an aggressive response or pre-suppression of enemy RW signals and destruction of RW complexes before they disrupt drones. For this reason, in the United States in 10 years 14 obsolete RW EC-130H Compass Call aircraft operating in Iraq and Afghanistan will be replaced by 10 new ones, investing USD 2 billion in the program [126].

China is actively developing a program for deck drones and directly links the creation of new aircraft carriers to equipping them with UAVs [90]. This Chinese decision can be considered a response to a similar program taking place in the United States. Both countries are fighting for influence and control over waters in the Pacific. Reconnaissance and strike drones on the decks of aircraft carriers will significantly expand the capabilities of the military and allow to operate at long distances.

The American Loyal Wingman program, launched in 2015, the issue of providing pilots in the sky with reliable assistants in the form of drones as full-fledged unmanned combat aircraft is being decided. The point of the program is that the pilot and the computers of his aircraft should control all their subordinates UAVs in the air, not through operators on the ground. This is aimed at saving time and allows to respond quickly to the situation directly in flight, as well as to send unmanned aerial vehicles to dangerous tasks in the first place, without risking the lives of pilots [189].

Thus, it is possible to state with confidence that the global market for military UAVs is becoming more saturated, diverse and promising.

CONCLUSION

The experience of modern local wars and armed conflicts shows the growing tendency to distance people from direct participation on the battlefield. One of the directions for realization of this tendency, as it is covered in the monograph, is strengthening the role of unmanned aerial vehicles in solving the following various tasks: air reconnaissance, information retransmission, air strikes, etc.

The use of UAVs directly on the battlefield or for strategic air reconnaissance will not surprise anyone. The armed forces in any country want to see the following devices in their formation: technologically developed countries are actively developing and using UAVs, and less developed countries actively buying drones too from them and increasing their air unmanned fleet. The use of unmanned aerial vehicles can dramatically change the whole future of hostilities on the planet. For example, in the United States it is predicted that in this century in the US Air Force will take place situation where no man-pilot and all aircraft will be unmanned, and the F-35 will be the last aircraft to provide space for a man-pilot.

The military drone market is showing rapid growth. For comparison, in 2016 the market for military UAVs was about 5 billion USD, by 2024 it may increase to 13 billion USD. At the same time 67% of the market are drones that can be operated out of line of sight. Technical progress also contributes to the growing demand for long-range UAVs and significant payloads, which are able to quickly perform missions over long distances.

The global market for military UAVs is becoming more saturated, diverse and promising. The global drone race increases the pace, and together with it, a variety of issues related to countering drones is growing too.

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